Sweden-China Bridge

November 2022
Date of the webinar: 1 June 2022

EXPERIENCES OF BATTERY SWAPPING FOR ELECTRIC HEAVY TRUCKS FROM CHINA

Summary of the Sweden-China Bridge battery swapping EHTs webinar June 2022

An integrated system solution for recharging electric heavy vehicles, energy storage, energy balancing and new business model based on decomposition of vehicle, battery and charging.

Sweden-China Bridge
LOGISTIKIA ÖSTERGÖTLANDS LOGISTIKKLUSTER
vti
TRAFIKVERKET
China EV100 中国电动汽车百人会

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Report number: 2022-8

Webinar hosts: Professor Mike Danilovic, Project Leader Sweden-China Bridge in cooperation with Mr. Per Lindahl, Managing Director at Logistikia, Sweden, and Mr. Ma Fangli, Vice secretary general of EV100, China.

Project: Collaborative Academic Platform for the Electrification of Transportation Systems

Funded by: The Swedish Transport Administration (Trafikverket, TRV).

Date of the Webinar: 1 June 2022

ISBN: 978-91-987011-8-0

Publisher: Sweden-China Bridge

Edition: Only available in pdf for individual printing

HALMSTAD UNIVERSITY LUND UNIVERSITY TRAFIKVERKET vti JÖNKÖPING UNIVERSITY

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ABOUT THE SWEDEN-CHINA BRIDGE PROJECT

Exploratory approach

This project is exploratory in nature and includes a step-by-step approach to knowledge development in the Swedish and the Chinese context. The project spans different areas of knowledge in which we will highlight what technologies and systems are prioritized in China, Sweden and in Europe, what drivers and motives exists for them, what actors are involved in the transition to electrified, intelligent and integrated transport systems, and what conditions and business models look like to achieve this conversion to electrified and integrated transport systems in an intelligent and smart society.

The purposes of the Sweden-China Bridge Project

1. The project aims to establish and develop an academic knowledge-sharing and -transfer platform between Sweden and China for collaboration between universities and research institutes in the two countries, in order to contribute to increased understanding and information and knowledge sharing on the technical and commercial development of electrified vehicle systems, integrated transport system solutions, and energy supply

infrastructure as a fully integrated system of intelligent and smart cities.

2. From this perspective, the project will explore the development and implementation of relevant technology for the electrification of vehicles, such as fuel cells, bio energy, battery storage, combinations of energy systems for hybrid vehicles, energy supply for integrated electrified vehicles, integrated electric road technology, associated charging infrastructure, and static and dynamic technology.

3. We also intend to explore the management of renewable energy supply systems, from the production of renewable electricity to its distribution to consumers of electrified transport systems, which is needed to ensure that electrified vehicles and transport systems.

Expected value creation

1. To create insights into the current and future status of electrification of transportation systems in Sweden and in China from technical, social, societal and economic perspectives.

2. To learn and mutually develop insights into how new knowledge, technology, system-based solutions, logistics and transportation systems can be developed, commercialized and operated according to a life cycle perspective in both Sweden and China.

3. To create a long-term learning context in which Sweden and China exchange experience for the benefit of both countries and their industries.

4. To develop a deeper understanding of how Sweden and China are managing the large-scale electrification of the road network using different technologies, including electric charging, energy production (fuel cells, hybrid vehicles, battery storage and electric roads): what do the short- and long-term potentials look like? How are they using long-term industry policy instruments to develop technology and implement it in society? How are they outlining business models for the large-scale roll-out of electrified transportation systems?

Research team

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ACKNOWLEDGMENTS

The transformation of transport is moving ahead fast all over the world.

In our research on the electrification of transport in China and our communication with actors in China and Sweden, we have noted great interest in the differences and similarities between the two countries in this field. Given the variation between countries, solutions being developed and implemented must consider the specific needs and experiences of each country.

China took the lead in the electrification of transport as far back as 15 years ago, and the level of electrification has increased over time. Sweden has high ambitions in this area, and the targets for achievement are set high. Based on our research and our publications on battery swapping as one complementary mode to cable charging, many people in the truck industry and transport and logistics operations are interested to know more about battery swapping.

To support mutual learning between key actors in China and Sweden, we organized a webinar to facilitate experience sharing and professional dialogue on battery swapping. In total, we hosted more than 200 participants.

We are very grateful to EV100 for their positive attitude and willingness to collaborate with Sweden-China Bridge and to support the webinar as cohosts. Through the commitment of EV100 to share their experiences, we were enabled to identify the leading companies and key stakeholders in the industry covering the entire value chain for battery swapping.

We are very grateful to Mr. Jan Pettersson at the Swedish Transport Administration (TRV) for the support of our research project and his participation in this webinar, and to Dr. Jonas Jansson at VTI (Swedish National Road and Transport Research Institute). Our thanks also go to Arne Nåbo at the Swedish National Road and Transport Research Institute (VTI) for participation in the webinar and support for the arrangements, and to Mr. Per Lindahl and Logistikia, as a regional association for heavy truck and logistic operators in Sweden, for their support in arranging this international webinar.

Finally, we express our gratitude to all participants from the leading Chinese companies and associations for sharing their experiences, perspectives, and foresight: Mr. Yang Yixiu, Director of Carbon Trading Research Division, Green Electric Transportation Industry Innovation Center, SPIC (State Power Investment Corporation); Mr. Li Yujun, General Manager of Mobile Energy, GCL New Energy Holdings; Mr. Yu Xinrui, CTO, Aulton New Energy; Mr. Li Tao, General Manager of Specialty Vehicles Charging Solution, Star Charge; Mr. Li Liguo, Secretary General of the Battery Swapping EHT Promotion Alliance of China and Professor at Qing Hua University; Mr. Zhang Xing, Vice General Manager of Power Energy Technology, Sany Heavy Truck; Mr. Gao Yi, Vice President of Overseas Business, General Manager of Europe Business, Foton; and Mr. Wang Bo, Vice President, Beijing Highway & Railway Green Chain Multimodal Transportation Company.

As project leader, I am grateful to my research fellows and colleagues in this project, Dr. Jasmine Lihua Liu, and Professor Tomas Müllern, Tech. lic. Arne Nåbo, Dr. Philip Almestrand-Linné, and Ph.D. candidate Harrison John.

As co-author of this paper, I am grateful to Dr. Jasmine Lihua Liu for her collaboration, contributions, and commitment.

I thank you all from the bottom of my heart.

Professor Mike Danilovic,
on behalf of the entire research team.

INTRODUCTION TO BATTERY SWAPPING

The future is the transformation of yesterday

We are in the middle of a radical transformation from fossil-based energy to renewable energy, from combustion technology-based vehicles to electrical-based vehicles. Electric vehicles can operate using either rechargeable batteries or refuellable hydrogen energy. Today, battery-based solutions are the dominant technology, while hydrogen is just around the corner.

To achieve this radical transformation, we need new technologies in vehicles; to develop a new supply and distribution infrastructure for electricity, energy storage, and recharging vehicles; to develop hydrogen and refueling systems, and to create new renewable energy sourcing to ensure that the entire value chain is green. Thus, this transformation has significant consequences for the entire existing global and local value chain, including technology platforms - as we know them. Our dependence on fossil energy sources is high, and alternatives take time to develop, implement and utilize to the extent needed.

The EU has decided to ban the sale of fossil fuel vehicles by 2035, while Sweden has pledged to stop selling fossil fuel-based vehicles already by 2030. Thus, the time frame for the transformation is limited, and rapid changes must take place.

The industry needs to adapt

Although the decision to undertake this transformation is political, its implementation is based on industrial capabilities to develop suitable technologies and systems of solutions and to put them into practice favorably and profitably. Without profitable solutions, the industry will be hesitant to take on this transformation. Therefore, there inevitably needs to be a collaboration between politics and industry to make transformation possible.

The former Volkswagen CEO, Mr. Herbert Diess, said in his speech at the Financial Times Future of the Car summit in May 2022:

> *"Volkswagen is hesitating to go all the way in the electrification process due to two main reasons:*
>
> - *Although customer demand is there, the value chain is not in a place that can fully support Volkswagen's transformation.*
> - *The charging infrastructure is not in place and is not well developed to support the large-scale transformation to electric vehicles."*
>
> (Mr. Herbert Diess, Financial Times Future of the Car Summit, 9-12 May 2022)

This position of one of the leading automakers in the world is important to understand and address. When one of the largest Western vehicle manufacturers such as Volkswagen does not feel safe to expand into electrification due to a lack of development of a value chain for the green direction of transport and a lack of charging infrastructure, we need to take note and reflect on the content of this message.

The importance of charging infrastructure

The dominant technology for electric vehicles is a battery-based solution that requires recharging with electricity. The recharging can be done by static conductive charging via cable (the dominant contemporary solution today), or by dynamic inductive charging (still in the test and development stage) while driving on electric roads (still in the demonstration stage), or via swapping batteries which are stored and recharged in special swapping stations.

All technologies have pros and cons. No technology is perfect. There are several challenges associated with cable-based charging:

1. Long charging time. Charging time depends on charging current and battery capacity.
2. Overcharging due to high-speed and high-current charging, with degradation of the life span of the battery and risk of overheating and fire during charging.
3. Lack of scalability of charging infrastructure required to catch up with large numbers of electric vehicles, particularly important for heavy trucks.
4. Requires large physical space for charging piles, especially for heavy trucks.
5. Demands new infrastructure for electricity distribution from the grid to charging piles.
6. A large number of high-capacity charging piles along highways demands a huge transformation of electricity distribution capacity, grid system extensions, and electricity peak balancing solutions.
7. Lack of standardization of charging piles and vehicles.
8. Lack of standardization of payment systems and business models.
9. Requires energy balancing and temporary energy storage to balance the supply and demand of electricity.

Infrastructure availability in Europe

For some time, the EU and Sweden have chosen to focus on cable-based charging technology as the default for recharging electric vehicles. In 2021, the EU confirmed this strategy in the “Fit for 55” strategy. In the long term, hydrogen is seen as a complementary solution.

Although there has been strong growth in the deployment of charging infrastructure since 2014 (a +750% increase from a very low starting point), the total number of charging points available across the EU (less than 225,000) still falls far short of what is required. Fewer than 25,000 of those 225,000 points are suitable for fast charging (with a capacity of > 22 kW). Just one in nine charging points in the EU is a fast charger.

The European Automobile Manufacturers’ Association (ACEA) unites Europe’s 16 major car, truck, van, and bus makers, and is a voice of the European auto industry. They argue that based on European Commission calculations, a 50% reduction in vehicle CO_2 emissions by 2030 would require an additional 6 million public infrastructure points within the EU. In particular, the rapidly growing numbers of electric heavy trucks (EHTs) will require many high-capacity chargers. The ACEA states that there is a need to increase the charging infrastructure by 27 times to catch up with the increase in electric vehicles.

> *“… a completely unbalanced picture when it comes to the spread of charging points for electric cars across the European Union.”*
>
> (Source: ACEA, 2021)

In July 2022, the international company BCG (Boston Consultancy Group) published a paper arguing that Sweden needs about 3 million charging piles and 600 refueling hydrogen stations by 2050 to manage the ongoing electrification. Considering that Sweden has about 2,550 charging stations with 13,800 charging piles in 2021, it will be challenging task to reach 3 million charging piles by 2050. BCG also argues that considering the weight of heavy trucks and their long operational range, the only

probable solution is hydrogen technology, and thus 600 refueling stations are needed.

Both ACEA and BCG indicate a need for rapid and large-scale transformation of charging infrastructure to enable EVs' rapid growth, which is in line with Mr. Diess' statements. A key question is whether a single solution such as cable-based charging can be the universal solution or whether we might need complementary solutions.

Considering that the EU will stop selling fossil-based vehicles by 2035 and Sweden by 2030, the importance of building up charging infrastructure cannot be overstated. The lack of charging infrastructure is considered one of the most challenging issues to support the development and diffusion of EVs in Europe and Sweden.

To achieve this, we need to focus on collaboration between governments and industry and explore alternative technologies and solutions that can complement the cable-based charging infrastructure. Suppose we fail on the diffusion of charging infrastructure. In that case, we risk that electrification today will meet with the same failure as it did at the beginning of the 1900s when fossil fuel-based vehicles won out. At that time, a lack of charging infrastructure and a lack of electricity supply were two main reasons for the failure of electric vehicles.

BATTERY SWAPPING AS AN EMERGING COMPLEMENTARY TECHNOLOGY AND SYSTEM SOLUTION

In two of our reports on the electrification of transport in China, we have put particular focus on battery swapping technology originating from 1886 and modern Tesla cars. The international company Better Place developed automated swapping systems and collaborated in China's development and large-scale commercialization. After the Better Place demonstration projects, with 600 Renault vehicles adapted to battery swapping, the European development of alternative and complementary solutions to cable-based solutions halted. However, this development continued in China and several other countries.

As China is the world leader in EV development and the largest EV market, it has seen and experienced the consequences of large-scale cable charging infrastructure. Already 10 years ago, the city of Shenzhen, with 12 million inhabitants, started to transition to EVs. Today, the city has more than 22,000 taxis, 18,000 buses, and 68,000 logistics vehicles, all of which are electric, and all charged via cable charging, as this was the only available solution at the time.

Population density, cities' increasing size, and development speed have pushed China to develop complementary technologies and solutions for EVs, such as the exchange of batteries in special battery swapping stations. Empty batteries are stored, recharged, and function as energy storage, support energy balancing, and through slow charging,, sustain batteries' health and life span.

According to our estimation, China will have about 25,000 battery swapping stations by 2025 for passenger vehicles and more than 600 battery swapping stations for trucks.

In 2021, battery swapping technology became the Chinese national strategy for charging infrastructure to complement other technologies such as cable-based charging.

The business model is more important than technology

In our analysis of battery swapping solutions for passenger vehicles and heavy trucks, we have noted that technology is important. However, even more important is the related business model being developed by the Chinese actors might enable the commercialization of swapping technology on a large scale.

The swapping stations are fully automated and are capable of swapping one battery in three to five minutes.

The new business model for battery swapping stresses financial and business-wise decoupling and unbundling, i.e., separation of vehicle, battery, and charging. In practice, the vehicle owner:

a. buys the vehicle excluding the battery,

b. rents the battery of the size customer need, and

c. subscribes to the charging/swapping of batteries.

This way, the customer requires a lower investment cost for the vehicle, can choose the size of the battery needed, and can over time exchange the battery for a smaller or larger one depending on needs, and does not have to worry about the quality and life cycle of the battery.

Finally, the customer can choose a subscription to swap, pay per swap, or recharge via cable on their own.

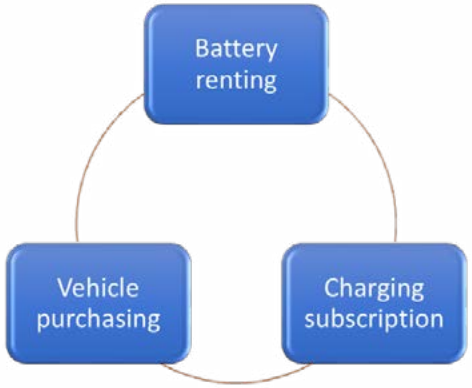


Figure 1: The new business model for battery swapping – The unbundling concept (own construct)

In 2022, the Chinese vehicle developer NIO established operations and sales of NIO cars and started to set up swapping stations in Norway. One swapping station is in place, with 21 more planned for Norway and an additional 10 in Sweden. Already about 92% of their Norwegian customers have chosen this new business model where the provision and charging of batteries are seen as service, decoupled from the purchase of the vehicle.

From the technology to the business of battery swapping

A new ecosystem needed to be developed to commercialize battery swapping-based solutions based on the new business model of separation, decoupling, or unbundling of vehicles, batteries, and charging. Additional motives for this were the necessity to have energy storage, energy balancing, and dual electricity flow to and from vehicles. Thus, the new ecosystem and the new business model involved a range of actors such as energy producers, electricity distributors, battery manufacturers, swapping station operators, swapping technology developers, and vehicle manufacturers.

Figure 2 illustrates the new ecosystem for battery swapping solutions. This ecosystem and business model are similar for both passenger vehicles and heavy trucks. The way of thinking that informs the design of the ecosystem and business model is based on the Chinese experience, context, stages, and development speed. The new ecosystem requires the emergence of an entirely new value chain that enables new actors to develop both technologies and business aspects in an integrated way.

Figure 2: Symbiotic relationships between the main players in the new battery swapping ecosystem. Dynamics of establishing battery-swapping in China. (Own construct).

Battery swapping takes off

The sale of electric heavy trucks (EHTs) has accelerated in China.

The total sales of EHTs in China amounted to less than 700 in 2018, and in 2021 rose to a significant figure of 10,513. This was an indication of the rapid growth of EHTs in China between 2018-2021.

It is estimated that by the end of 2021, the total sales of EHTs in China 2022 might reach 25,000-35,000 vehicles.

Year	Sales volume of NEHT
2018	Less than 700
2019	More than 5,034
2020	2,619
2021	10,513

In the period January – June 2021, battery swapping-based EHTs accounted for 17.99% of new energy heavy trucks, while pure EHTs represented 67.2%. Thus, in 2021 the battery swapping EHT had just begun to be fully commercialized.

The situation started to change more radically in 2022. In the first half of 2022, January – June, the proportion of battery swapping-based EHTs jumped to 48.29%, while cable charging-based EHTs accounted for 46% of new energy vehicles. This indicates that already in the first half of 2022, battery swapping-based EHTs are bypassing cable charging-based EHTs. The total number of battery swapping-based EHTs has increased by 15 times. The cluster of new energy vehicles includes hybrid solutions but not pure fossil fuel-based technology-based vehicles.

Based on these numbers, we have reason to believe that battery swapping-based EHTs will continue to increase and will become one of the key charging/recharging solutions complemented by cable charging-based EHTs.

Figure 3: SANY's first intelligent battery swapping station.
Source: https://carnewschina.com/2022/05/10/sany

Based on our analysis, we believe that these two charging solutions, battery swapping and cable charging, are complementary and will complement each other. There are scenarios where swappable solutions are more effective, such as high-intensity operations, where there are high energy requirements, heavy vehicles that must operate continuously, and where operations cannot allow for charging stops. At the same time, it is reasonable to believe that there are scenarios where cable charging is more efficient, such as short driving distances, inter-city transportation, and densely populated areas where it is difficult to establish swapping stations.

THE WEBINAR CONTEXT – EXPLORING THE ENTIRE VALUE CHAIN

The Sweden-China Bridge project arranged a webinar with leading actors in China to share experiences and knowledge on battery swapping for the benefit of Swedish actors. More than 200 people participated in the webinar. The event was organized with dual simultaneous interpreting. This report aims to outline the key experiences shared by Chinese actors.

The webinar is co-hosted by the leading Chinese association in the electrification of transport, the EV100, and major industrial representatives from along the value chain. The focus of the webinar is on heavy trucks. Our ambition was to cover the entire value chain, including energy production, electricity distribution, heavy truck manufacturers, swapping station technology providers, and operators of heavy trucks based on battery swapping technology.

The purpose of the webinar

The purpose of the webinar is to exchange and discuss experiences of battery swapping technology for electric heavy trucks (EHTs) from a system perspective. The aim is to connect Swedish actors in the electrification of transport with Chinese actors in order to exchange knowledge, experiences and learnings on battery swapping technology and business for EHTs, from electricity generation and transport and logistics to the reduction of carbon emissions.

Purpose of the webinar:

- Exchange and discuss experiences of battery swapping technology for electric heavy trucks (EHTs).
- Explore the value chain for efficient battery swapping operations from green energy production and distribution to usage in operations of EHTs.
- Explore technology being developed, business models being applied and experiences of battery swapping-based EHT operators..
- Explore the new business model for battery swapping based on decomposition of buying the vehicle, renting the battery and subscribing to charging and swapping.

Content of the webinar

Battery swapping has emerged as a solution and as a complementary infrastructure for charging electric vehicles.

Battery swapping enables vehicles to quickly recharge by exchanging batteries in 3-5 minutes. Battery swapping also enables energy balancing and energy storage, and opens for new business opportunities in buying and selling electricity. Thus, battery swapping creates value for electricity generation, distribution in the grid systems, buyers of green transport solutions, transport company operators and truck drivers.

In the webinar, participants developed a deeper understanding of how battery swapping works from the perspectives of key actors, putting battery swapping in large scale operations in China.

Sweden-China Bridge, a Swedish academic research project, estimates that by 2025 about 25,000 battery stations for passenger vehicles and more than 400 battery swapping stations for heavy trucks will be operational in China. Already in 2021 battery swapping become one of the two main charging infrastructure solutions for heavy trucks. In 2021, battery swapping became one of the two main charging infrastructure solutions for heavy trucks, and more than 30% of new sales of electric trucks were battery swapping based.

ORGANIZERS OF THE WEBINAR

Host: Sweden-China Bridge

Sponsors:

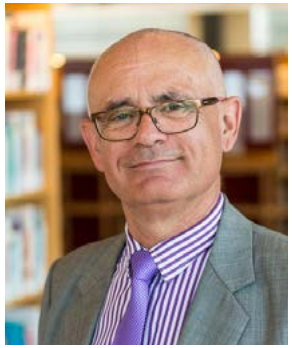
- Sweden-China Bridge • The Swedish Transport Administration (TRV)
- Swedish National Road and Transport Research Institute (VTI)
- Logistikia • EV100 • Shanghai DianJi University

LIST OF PARTICIPANTS & AGENDA OF THE WEBINAR

Speakers	Content
Mr. Jan Pettersson, TRV Director of the electrification program The Swedish Transport Administration	Opening the webinar and welcoming speech.
Mr. Zhang Yongwei Vice President and Secretary General of EV100	Opening the webinar and welcoming speech. EV100 is the leading association in China on the electrification of transport.
Mr. Jan Pettersson, TRV Director of the electrification program The Swedish Transport Administration	Sweden's national strategy for electrification of transportation and practice for electrification of transport
Dr. Jonas Jansson, Research Director, Swedish National Road and Transport Research Institute (VTI)	Exploring VTI's research on electrification of transport
Mr. Per Lindahl Director Logistikia	Exploring operators' perspectives on electrification of transport – demand and application scenarios for battery swapping EHTs in Sweden.
Professor Mike Danilovic, Halmstad & Lund University Project leader Sweden-China Bridge	Exploring application scenarios for battery swapping EHTs in Sweden and steps that are needed to support Swedish actors.

Mr. Yang Yixiu, Director of Carbon Trading Research Division, Green Electric Transportation Industry Innovation Center, SPIC (State Power Investment Corporation)	SPIC is a pioneer developer of battery swapping solution for EHTs in China. It is one of the leading energy producers providing an energy production perspective on battery swapping solutions.
Mr. Li Yujun, General Manager of Mobile Energy, GCL New Energy Holdings	GCL is a leading developer of battery swapping stations, systems, and energy storage and a distribution network supplier.
Mr. Yu Xinrui, CTO, Aulton New Energy	Aulton is a pioneer in battery swapping and the leading third-party actor in battery swapping system development.
Mr. Li Tao, General Manager of Specialty Vehicles Charging Solution, Star Charge	Star Charge is the top EV charging solution provider in China, now expanding to the battery swapping field. The company has participated in drafting all the Chinese domestic charging standards, as well as the IEC international standards as a Chinese representative.
Mr. Li Liguo, Secretary General of the Battery Swapping EHT Promotion Alliance of China and Professor of Qing Hua University	China's national policy for electrification of transport and development of battery swapping technology.
Mr. Zhang Xing, Vice General Manager of Power Energy Technology, Sany Heavy Truck	Sany is one of the top truck OEMs in China deploying battery swapping for EHTs.
Mr. Gao Yi, Vice President of Overseas Business and General Manager of Europe Business, Foton	Foton is one of the pioneers in battery swapping for EHTs and one of the top truck OEMs in China deploying battery swapping for EHTs.
Mr. Wang Bo, Vice President, Beijing Highway & Railway Green Chain Multimodal Transportation Company	Exploring the experiences of battery swapping EHT operators.

QUOTES FROM THE PARTICIPANTS



Mike Danilovic
Professor of Industrial Management, Project leader Sweden-China Bridge, Halmstad University & Lund University and Shanghai Dianji University

"Large-scale electrification of transportation is dependent on combinations of different complementary technologies. Battery swapping has been proven to be a very interesting solution that needs to be explored deeply and understood how it can help Swedish and European electrification. This webinar is a wonderful arena for experience sharing and joint knowledge creation that all of us need to develop the future solution for the electrification of transport. To achieve the global targets for green solutions we must collaborate, learn from each other, take bold actions and be brave to try new solutions. "

Arne Nåbo
Lic. Technology, EUR ING
Research Leader Electromobility, VTI

"Pollutions and climate change are global challenges. Thus we need to address these all together, globally. Thanks to the project Sweden-China bridge we have been able to gather scientists and practitioners from both countries to share knowledge on electrification of transport. I see battery swapping as a promising technology. It has great potential as an enabler for a fast and efficient way to electrify heavy duty vehicles, as it so well fits to the users' needs. My expectations on this seminar is that the participants will increase their knowledge on battery swapping and that it will lead to new business contacts."

Jan Pettersson
Director of the electrification program

The Swedish Transport Administration, (Trafikverket, TRV)

"Electrification of road transport is crucial to rapidly reduce the use of fossil fuels in the road transport system. The development of electrification solutions is now extensive and rapid, and it is of the utmost importance that Sweden monitors, follows, and also drives this development. Battery swapping is a very interesting technology that is developing rapidly and has a good chance of contributing to the transformation of the road transport system that is needed if Sweden is to achieve the climate target of zero net CO2 emissions by 2045."

Per Lindahl
Director Logistikia

"Electrification of road transport is crucial to rapidly reduce the use of fossil fuels in the road transport system. The development of electrification solutions is now extensive and rapid, and it is of the utmost importance that Sweden monitors, follows, and also drives this development. Battery swapping is a very interesting technology that is developing rapidly and has a good chance of contributing to the transformation of the road transport system that is needed if Sweden is to achieve the climate target of zero net CO2 emissions by 2045."

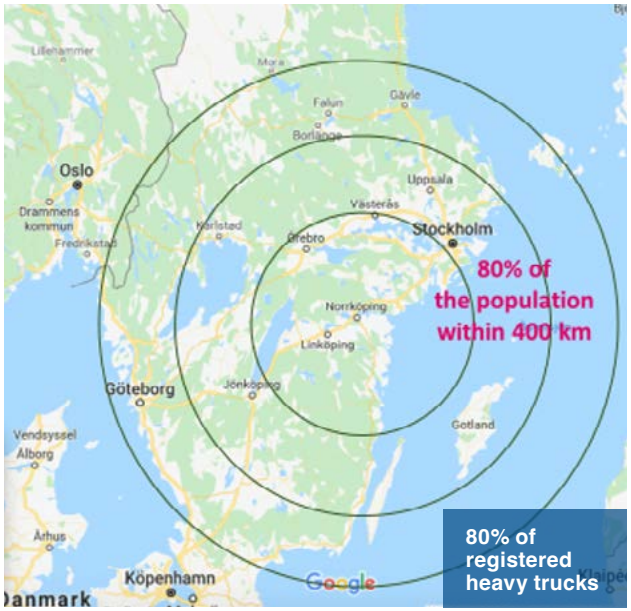
LOGISTIKIA - A LOGISTICS PERSPECTIVE ON ELECTRIFICATION OF TRANSPORTS

By Mr. Per Lindahl, Managing director Logistikia

Östergötland is a major logistics region

Sweden is one of the largest countries in Europe by size with a population of 10 million people and with logistics as an important industrial and societal function. Östergötland, and its two main cities Linköping and Norrköping, is a leading logistics region with a central demographic situation in Sweden and Scandinavia, only 200 km from the capital Stockholm. Östergötland constitutes a point of gravity in the southern region of Sweden (south of the town of Uppsala) where 80% of all heavy trucks in Sweden are registered.

The region has an excellent infrastructure, a long history of trade and industry and vast competence and knowledge emanating from companies and academia. Forestry, paper & pulp, trade, energy, steel, manufacturing industry, and agriculture are important business areas in the region. All are depending on efficient logistics across Sweden and internationally. The Port of Norrköping is a regional node for the growing trade on the Baltic Sea, handling 4,5 million tons in 2021. More than 3500 heavy trucks are registered in Östergötland which makes it the fourth largest region in Sweden.



Electrification is a challenge to logistics and transportation companies

Transportation and logistics are a low-margin business, extremely stretched, balancing filling rates, lead times, and time slots, with fleet utilization, optimizing routing design, fitting driver´s schedules with mandatory breaks, etc. Thus, the context is creating conditions that must be considered when transforming from old diesel trucks to modern electric trucks and related charging infrastructure. The performance of new electric trucks now entering the market is certainly impressive. But comparing a single electric truck with a diesel truck is misguiding when aiming to transform the entire transportation system.

The dominant solution based on cable charging not only introduces a new planning restriction in time, location, and operating distances, but also

increases the idle time for drivers and trucks. This new situation risks creating a complicated equation where operational and business logic must meet the new technical solutions and restrictions.

Introducing a few electric trucks (EHT), where customers are positive and excited, is not a problem. It rather creates opportunities for profiling and goodwill. But when a significant part of the fleet is to be electrified, it becomes more difficult. The most challenging is the charging of EHTs. Charging overnight at the depot, "filling up" at customer sites while collecting or delivering goods, or charging on the road when taking a break, will certainly be part of a solution. But it will not be sufficient from a systemic and efficient perspective. Today's global and integrated transportation system has evolved for over a century, building on the diesel engine and flexible, available fuel in abundance at low cost. To change this fast enough, we need to consider the fundamentals of the transportation system and how different components depend on and interact.

In this perspective the concept of battery swapping stands out as an important, complementary solution to cable charging, because it meets the needs of the business, keeping flexibility and minimizing the idle time for drivers and vehicles, which is fundamental for a truck operator's business margin. Battery swapping also enables a faster and more cost-efficient building of a sufficient charging infrastructure. Already today there might be a lead-time of a year or more, before a company may have an upgrade in electrical capacity for charging, a situation that may very well worsen as demand increases. This situation risks delaying electrification and creating more uncertainty for truck owners.

A battery swapping demonstrator in Östergötland

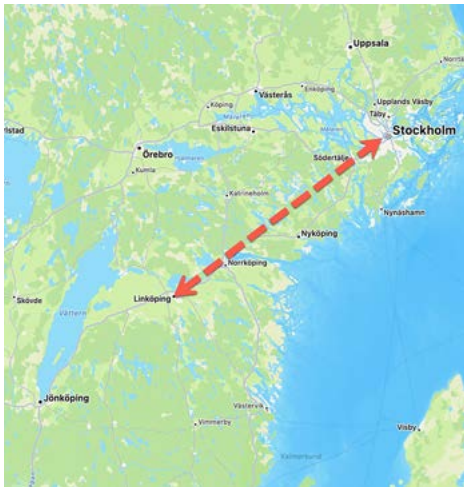
Logistikia is a cooperation platform aimed at logistics excellence in the region of Östergötland. Logistikia advocates and facilitates a development towards sustainable logistics, supporting businesses and exchange between academia and companies, authorities, and municipalities.

In the dialogue with transportation companies, we notice a deep concern about how cable-charged EHTs at any significance, can be feasible from a cost and operational perspective. When companies in the network were introduced to the concept of battery swapping, the understanding of the benefits was intuitive, and there was a large interest to test and evaluate the concept. Starting in this attention, Logistikia, Linköping University, Sweden-China Bridge, Halmstad University, and The Swedish National Road and Transport Research Institute (VTI), have outlined a demonstrator of battery swapping connecting Östergötland to the Stockholm region. 15 organizations have signed into this project. The consortium includes major parts of the logistics value chain and if the demonstrator can be put in operation, large companies are committed to operating the trucks and buying significant transport volumes. Hence, we are well prepared to establish, operate and evaluate a demonstrator in the region. The demonstrator will be rolled out in 2-3 steps, from where a full-scale implementation can continue, covering the south of Sweden with 40 battery swapping stations supporting at least 4000 trucks on daily basis. The first set-up will be based on daily traffic with Stockholm, where involved companies already today transport large volumes in both directions.

Our ambition is to set up this demonstrator in 2024 and to be the first battery swapping demonstrator site for heavy trucks in Europe. This way Logistikia and Östergötland can take the lead in the electrification of trucks in Europe. With a large platform for communication and the participation of Linköping and Halmstad universities, Sweden China Bridge, and VTI, the ability to evaluate, invite, and chair experience nationally and internationally is solid.

HEREBY WE ARE INVITING NEW PARTNERS TO COLLABORATE WITH US

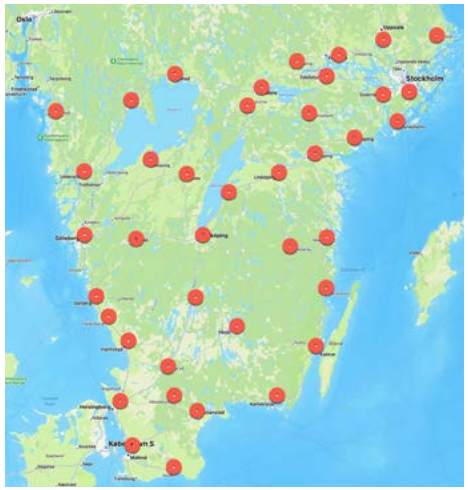
to establish and operate the first battery swapping demonstrator for heavy trucks in Europe.



Step 1
Demonstrator project with three battery swapping stations between Linköping/Norrköping and Stockholm.

Step 2
Expand to Jönköping as one of the key logistical hubs in Sweden with one additional battery swapping station.

Step 3
Cover the main highways in the south of Sweden and connects to Oslo.



Step 4
Expand across the south of Sweden. 40 battery-swapping stations could cover the southern part of Sweden with swapping stations to serve >4,000 trucks daily with battery swappings along the main roads in the south of Sweden.

REFLECTIONS ON THE CONTENT OF THE WEBINAR

There is no single technology that fits all
The current rapid development and diffusion of the electrification of transport are based on rechargeable batteries, while in the future there will be refillable hydrogen-based solutions as a complementary technology solution.

For battery recharging, cable-based solutions have emerged as the dominant technology. However, cable-based solutions have weaknesses such as high purchasing costs, relatively short operational distance on one charging, heavyweight, long charging times, degradation of batteries due to high currents, electricity demands and peak effects, sudden, unpredictable electricity demands, and the need for energy balancing and energy storage to balance the supply and demand side, besides development of a new electricity distribution system.

To manage these challenges, a new solution is being developed, deployed, and diffused in society. This battery swapping-based solution is based on new technology enabling the decoupling of vehicle and battery, external and cable charging, and a new associated business model where the customer buys the vehicle without the battery rents the required battery and subscribes to charging and swapping.

Battery swapping: an innovation?

It is not unusual that innovation happens on the part of newcomers who see opportunities that established key actors in the industry either do not see or do not understand how to turn into new solutions. This seems to be the case with battery swapping.

Often innovation involves a mix of old and new technologies. New business models are needed for solutions to become innovative to enable commercialization and diffusion. Technology itself is not enough until the latent value is exploited through business opportunities and real value creation. The transformation from fossil-based to electrical-based technologies for vehicles entails the radical transformation of technology.

When the battery swapping technology was first introduced, many established vehicle manufacturers did not accept it. Earlier experiences from Tesla and Better Place indicated that the solution was not fit for the early times of electric cars or was immature. But those early experiences formed the contemporary collective mindset of the failure of battery swapping solutions in the transport industry. However, times are changing, and new solutions are meeting today's needs and expectations.

China takes the lead in developing and commercializing battery swapping

The development of battery swapping requires a new ecosystem involving actors along the value chain of battery swapping technology and business actors.

What we see in the expansion of battery swapping in China is that the new battery swapping solutions were pushed by outsiders – people and companies that traditionally had not operated in the vehicle manufacturing industry. Thus, they were not entrenched in old technologies, solutions, or value chains.

- One major group of actors in the development of battery swapping solutions was energy producers that realized early on the impact of electrification of transport on the national grid system, energy supply, unbalanced situation of electricity supply, and peak demands. To manage the electricity supply side and support rapidly growing electrification, companies such as SPIC initiated the development of battery swapping solutions.

- Technology developers such as GCL, Aulton, and Star Charge realized that the new battery swapping-based solutions presented opportunities for them and rapidly grasped the challenge. Several technology companies were early pioneers of solutions as third-party technology providers.
- Focus on business operational scenarios. The initial focus of battery swapping solutions was identifying and targeting specific operational scenarios putting operators and customer demands and needs in focus. Thus, the main areas were the mining industry, construction industry, short-distance transport, specific vehicles such as tractors, dumpers, and mixers, and river operating vessels. Later, these specific scenarios were opened to include generic operations. Now, long-distance operations are in focus. Thus, gradual diffusion is taking place to include new operational conditions.

- The development of battery swapping focused on the system level of operation and the entire value chain of battery swapping. From the very beginning, the entire value chain was involved in the development of battery swapping solutions: energy producers, grid system operators, technology developers, battery manufacturers, newcomers such as vehicle manufacturers, etc. The involvement of operators and users was intensive from the start. Thus, the entire value chain emerged with early demonstration projects and was gradually scaled up to the commercialization of solutions. Most of the established heavy truck manufacturers were at some point engaged in this process.

- Industry, academia, and decision-making alliances were formed to support knowledge development and early demonstration projects based on specific business scenarios. Later, new projects were broadened to new application areas supported by actions by regulators, standardization actions, and defining battery swapping as a national technology strategy. Gradually, battery swapping solutions received wide recognition and acceptance.

- Those from outside the established vehicle manufacturing industry, such as Sany (entering the heavy truck industry in 2018) and Foton (founded in 1998 and already one of the largest manufacturers of commercial vehicles in China and the largest exporter of commercial vehicles, with extensive experience in the machinery industry), saw the electrification of transport as an opportunity and developed new vehicles that from the start were battery swapping-based. They have developed stationary stations and mobile swapping solutions.

- The third generation of battery swapping technology and stations was introduced in 2021. The speed at which solutions were developed, demonstration projects created, and commercialization implemented is based on what we call experimental design and development. Instead of long laboratory testing and careful verification periods, real life is used as a laboratory to develop and verify solutions, learn with operators and users, and further develop new solutions. Thus, we are already seeing the third

generation of battery swapping solutions for heavy trucks being put into operation. The new solutions can swap batteries in less than two minutes, and one battery swapping station of the third generation holds ten batteries and swaps 100 batteries per day.

- One important experience of battery swapping system solutions was focusing on the experiences and needs of operators and users and the commercial aspects of swapping. Without being commercially viable, the battery swapping route would not have been fully developed and would not have been scaled up to the national strategic level.

- From the user's perspective, the cable-charging solution indicates that the operational efficiency decreased by 28% due to charging time. The battery swapping mode decreases the investment cost to a similar level to that of diesel-based solutions, extends the lifespan of the battery by 20%, and improves operational efficiency.

Summary

From the annual data, since 2021, the sales of new-energy vehicles in the Chinese market have shown rapid growth. From 2018 to 2020, the annual sales volume of new-energy vehicles was about 1.2 million. In 2021, this figure increased by 156% year-on-year, reaching 3.266 million – 2 million more than in 2020.

According to statistics from China Automobile Association, in the first half of 2022, China's new-energy vehicle market completed 2.6 million retail sales, with a year-on-year increase of 120%. By the end of June 2022, the number of new-energy vehicles in China had reached 10.01 million, of which 8.104 million were pure electric vehicles, accounting for 81% of the total number of new-energy vehicles. It is worth mentioning that the huge growth in sales of new-energy vehicles is a result achieved against the background of a shrinking automobile market, which also means that new-energy vehicles are accelerating to replace traditional fuel vehicles in the Chinese market.

As a comparison of data, from January to June of 2022, the total sales volume of China's automobile market was 12.057 million, a year-on-year decrease of 6.6% . The sales volume of new-energy vehicles in China in 2022 is estimated to be more than five million.

According to data released by BYD, the cumulative sales volume of new-energy vehicles in 2022h1 is about 641,000, with a year-on-year increase of 314%. Meanwhile, Tesla recently released its Q2 production and delivery report. According to the report, Tesla delivered 564,000 electric vehicles worldwide in the first half of this year. According to the above data, BYD leads Tesla in sales by nearly 80,000 vehicles and becomes the world leader in electric vehicle sales.

It is estimated that the development of new-energy commercial vehicles will accelerate shortly in the commercial vehicle field. Mining, ports, steel plants, coal bases, urban logistics, engineering and environmental sanitation, and other scenarios will apply a large number of new-energy commercial vehicles. New-energy commercial vehicles will also be diffused further from megacities to second-tier cities in China.

Based on our observations, the development and commercial diffusion of battery swapping EHTs in China are speeding up. Key stakeholders are joining the field actively. Institutions and infrastructure supporting the battery swapping solution are been developed rapidly. It seems that 2022 is a turning point that marks the battery swapping EHTs entering the high-speed commercial growth stage and the year when battery swapping solutions is passing the threshold of becoming one major solution for electrification of heavy trucks in China.

As we can see from the numbers, electric heavy trucks are rapidly expanding in China. We also notice the fast-growing charging infrastructure based on battery swapping technology. Battery swapping does not get much attention in the west. However, it is seen as a strategically important complement to cable-based charging for passenger vehicles, heavy trucks, and special vehicles in China.

In our research on the electrification of transport in China, we have noticed that collaboration is one key aspect of technology development and diffusion of solutions, initially in demonstration sites and later in large-scale establishments. This collaboration is three-dimensional, vertical, horizontal, and lateral. The vertical refers to collaboration within the domain of different ministries on national, provincial, and local levels. The horizontal refers to collaboration among actors along the value chain, from material, and components to system suppliers. The lateral refers to collaboration across ministry levels and between key actors along different value chains. To achieve a high degree of electrification all are needed.

We observe in the Chinese context now that this collaboration is rapidly moving from isolated, single technology development and implementation to system-related multi-dimensional collaboration integrating different solutions in integrated complementary system solutions.

In China, as well as in the rest of the world, the charging infrastructure is crucial to support electrical vehicles to run. We have seen in China large-scale diffusion of cable-based charging and isolated sites with battery swapping, inductive charging, and solar roads.

Now, the focus of China is to move to large system-based integrated solutions in cities and along the highways. This ambitious cable-charging and battery swapping solutions are complementary and create a large-scale system solution. To achieve this acceleration of charging infrastructure several ministries are jointly working out action plans.

In China, as well as in the rest of the world, the charging infrastructure is crucial to support electrical vehicles to run. We have seen in China large-scale diffusion of cable-based charging and isolated sites with battery swapping, inductive charging, and solar roads.

REFLECTIONS ON BATTERY SWAPPING ACCELERATION -

"Joint Action Plan" for establishing large-scale charging infrastructure system solutions

On the 25th of August 2022, the Ministry of Transport, the State Energy Administration, the State Grid Corporation, and the China Southern Power Grid Corporation jointly issued The Action Plan for Accelerating the Construction of Charging Infrastructure Along the Highway, proposing to strive to provide basic charging services in the highway service areas in the country except for high altitude and cold areas by the end of 2022.

The Action Plan points out to explore and promote the application of new technologies and new equipment to improve the life-cycle efficiency of charging facilities; formulate and implement a phased plan, promote the construction of super-fast charging and high-power charging infrastructure in the highway service areas around the city clusters, and support the construction of battery swapping stations in the highway service areas by enterprises such as electric vehicle manufacturers and large-scale transportation companies. Strengthen the collection and release of service information of charging infrastructures, provide real-time information service for the public, and actively explore charging services based on appointments.

Following is the major content of The Action Plan

In principle, the charging infrastructure built in each service area or the parking space reserved with construction and installation conditions (for charging infrastructure) along the highway shall be no less than 10% of the parking space for passenger vehicles.

- **Financial support**
  Based on The Implementation Opinions of the National Development and Reform Commission and Other Departments on Further Improving the Service Capacity of Electric Vehicle Charging Infrastructure, financial support will be given to the construction of charging infrastructure along the highway, and the operation subsidy standard linked to the charging service quality will be explored to strengthen the subsidy of high-power charging and other demonstration facilities.

- **Optimize construction implementation procedures**
  Charging facilities are necessary public service facilities in the service area (station), and the land required is included in the scope of highway land. If it is necessary to increase land, the local government shall provide support according to the land use policy for the main works of the highway, simplify the handling procedures and organize the implementation as soon as possible. The layout and wiring of new charging facilities shall be well connected with the road site and facilities, and the layout design of driving routes and parking lots shall be optimized.

- **Strengthen the construction of supporting power grids**
  Power grid enterprises should increase investment in supporting power grid construction, reserve high-voltage, and high-power charging capacity, and meet the needs of charging facilities construction. For remote service areas (stations) where power grids have not been extended in place and do not meet the large capacity power supply conditions, priority should be given to using the distributed power supply and other methods to supply power nearby.

- **Suggestions on charging service**
  Local governments are encouraged to introduce relevant preferential measures to reduce the rent of charging infrastructure sites in stages, to create conditions for accelerating the construction of charging infrastructure. The charging service operators are encouraged to consider the balance between the reasonable income of the investment and operation entities and the user’s use economy, and charge reasonable service fees during the market incubation period.

Comments

The overall approach to developing charging infrastructure is that different technologies need to complement each other based on the specific societal, commercial, and consumer expectations in different parts of China. Thus, both cable charging and battery swapping will be established for passenger vehicles and heavy trucks. Now the focus is on establishing an open, public charging infrastructure along the highways enabling long-distance driving and commercial operations.

To achieve the targets of large-scale charging infrastructure establishment, different ministries and key stakeholders were involved in designing the joint plan and ensuring that the joint plan is communicated with related actors and implemented accordingly. This also shows clearly the extensive horizontal and lateral dialogue and collaboration between energy producers, grid system operators, technology developers, operators of charging infrastructure, and vehicle manufacturers.

The major learning from this illustration is the multi-dimensional (vertical, horizontal, and lateral) collaboration across traditional administrative and organizational silos and domains, joint collaborative efforts to achieve results, and an open system integrating approach to developing solutions.

Reference:

G20 battery swapping industry alliance
https://baijiahao.baidu.
com/s?id=1742120516137400860&wfr=spider&-
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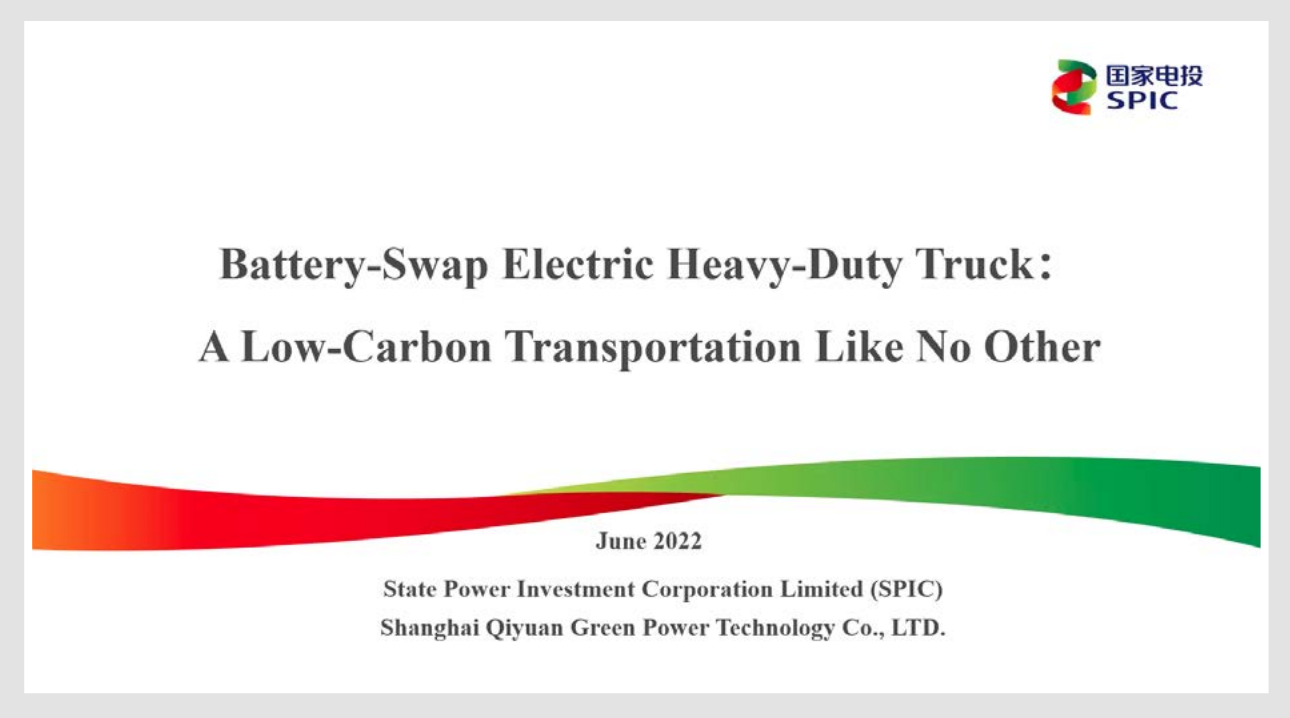
WEBINAR PARTICIPANT PRESENTATIONS

SPIC

Pioneer developer of battery swapping solution for EHTs in China. SPIC is one of the leading energy producers, providing an energy production perspective on battery swapping solutions.

Speaker

Mr. Yang Yixiu, Director of Carbon Trading Research Division,
Green Electric Transportation Industry Innovation Center



SPIC is one of China's five major power generation groups with a total capacity of 197GW, of which 62.52% is green energy. The company was ranked 293rd among the Fortune 500 in 2021. The battery swapping truck service is one of the company's six businesses.

Advantages of battery swapping mode

We have invested in the battery swapping mode because it can separate the vehicle from the battery. When our users buy trucks, they can choose to buy pure trucks without the need to buy batteries. Users can rent batteries and payment is billed by time and consumption of electricity. This can reduce purchasing costs by 50% and operating costs by 15 to 30%. In addition, it can improve the efficiency of energy replenishment because the time taken for battery swapping is only about five minutes.

At the same time, the responsibility for maintenance of the battery is no longer borne by the vehicle owner but by us. This provides users with greater convenience. The battery swapping mode can also become a cluster of operation platforms, which can help us better cooperate with the power grid for electric ancillary services. In addition, we also provide online payment and clearing services, mainly through cloud platform aggregation.

Solutions

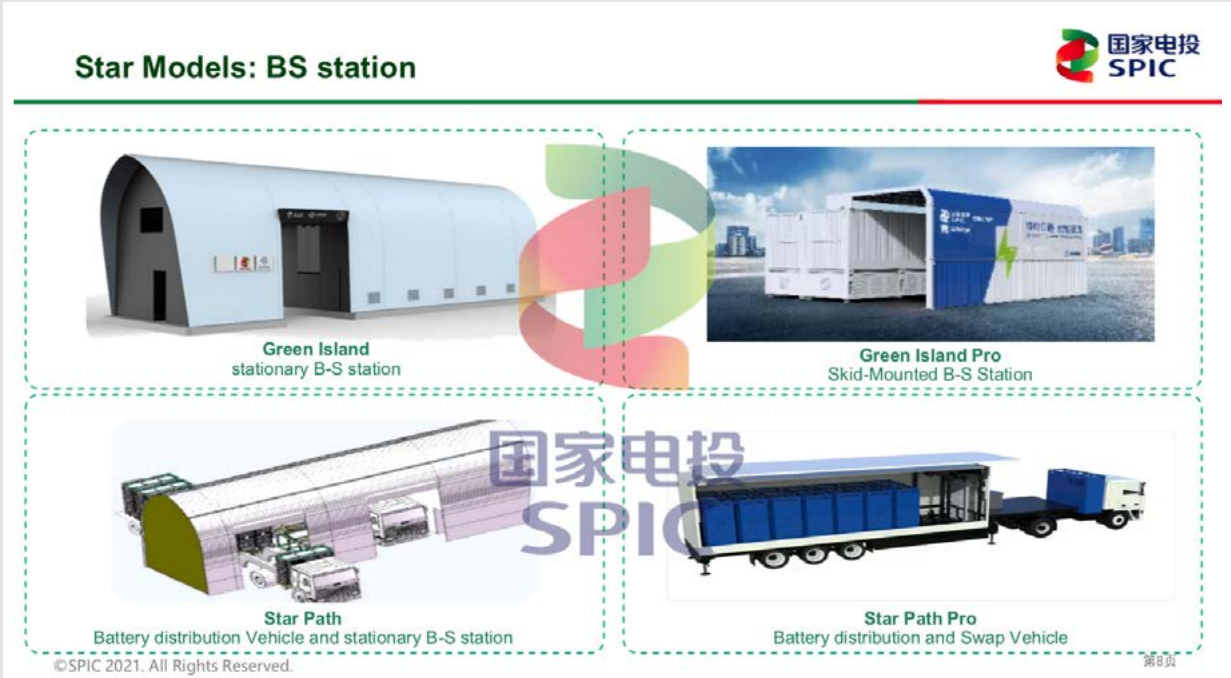
Our battery swapping station can support 160 different electric truck models, including heavy-duty port specialized tractors, heavy-duty tractors, heavy-duty dumpers, and heavy mining trucks.

We have stationary battery swapping stations and skid-mounted battery swapping stations, which can further reduce operating costs. There are also battery distribution and swap vehicles which can distribute and replace batteries.

In 2016, SPIC started running battery swapping heavy truck projects and became a pioneer in this field. We have supported more than 10,000 units of battery swapping heavy trucks in operation with an accumulated mileage of over 100 million km. Our battery asset service capacity has reached 934MWh, our nominal rated charging and consumption capacity has reached 872GWh per year, and we have 151 battery swapping stations in 31 provinces and cities in China.

Project cases

In Ningbo Meishan port, 40 battery swapping semi-trailers are supported by one static battery swapping station. In the Rizhao port, 30 battery swapping semi-trailers are supported by one static battery swapping station.



At the Huolingol south open-pit mine project, two battery swapping stations have been put in service to 21 battery swapping mining trucks with a maximum nominal rated payload of 120 tons. Heavy load downhill energy feedback reduces operating costs by 15-30%. Under heavy load uphill conditions, electric trucks possess a power advantage compared to traditional diesel trucks. The plan is that by 2023, 15 more battery swapping stations will be constructed to serve a fleet of 300 mining trucks. The world's first mining truck with a maximum nominal rated payload of 220 tons will be put into operation.

Experience sharing

1. Battery swapping mode can greatly reduce the cost of operations. We not only need to look at the difference in the cost of the truck itself, but also to consider the use cost, including the price difference between electricity and diesel fuel itself.

2. The government is increasing its pragmatic environmental protection planning, which provides significant support to some local governments, who can encourage the purchase of battery swapping heavy trucks.

3. Third, in terms of (battery swapping station) construction, we need to take into account the government's infrastructure planning, and the (station location) needs to have good access to the power grid to have a sufficient electricity supply and benefit from reduced electricity prices.

4. We hope that a relatively high-speed mobile internet connection can help us achieve real-time operational monitoring.

5. We need to realize multi-functional and full-function electric vehicles and an after-sales service network for the whole battery pack. We need to cooperate with local financial institutions to provide financial support for battery swapping heavy trucks, to truly promote the comprehensive development of the whole industry.

Suggestions

We believe that battery swapping heavy trucks can be developed well in Sweden. We suggest that in the early stages, focusing on centralized vehicle operation scenarios with long-term and stable transportation demand will be beneficial. In some areas, such as ports and coal mines, promoting battery swapping mode operations is very important and beneficial. In addition, we need to develop good after-sales service.

GCL

Leading developer of battery swapping stations, systems, and energy storage and distribution network supplier.

Speaker

Mr. Li Yujun, General Manager of Mobile Energy

Commercial vehicles are a means of transportation and production. Time is money for drivers, and relying solely on charging cannot meet the needs of the operation. Therefore, the demand for battery swapping is put forward by the users.

Stakeholders

There are several parties involved in battery swapping mode. First, goods transportation buyers are the core guarantee for the sustainability of the whole ecosystem. Second, there is the battery swapping service provider, followed by battery holders, land/electricity holders, drivers, and vehicle holders. To benefit all six parties, the question of how to balance and coordinate activities should be our core concern in the process of promoting the battery swapping project.

Business scope

GCL's battery swapping business covers four fields: trunk line, branch line, urban distribution, and passenger vehicles. How do deal with these different fields? Our idea, which is also agreed on the idea of the industry, is to standardize battery packs. For heavy trucks, light trucks, and battery packs, the technical route of single package standardization will be adopted. In the whole life cycle of battery swapping, the most important factor for energy storage is to include all kinds of battery packs after the standardization of battery packs.

We perceive that the technical route of battery swapping solutions for heavy trucks, light trucks, and passenger vehicles originate from the same source. The same technical solution for the three types of vehicles can be shared among them. This will provide a practical foundation for future full utilization of batteries in other scenarios, for instance, utilize as energy storage.

Industrial Ecology

|Gather various forces to build an intelligent, efficient and green energy service network ecosystem

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■ With cars as the energy carrier, batteries as the core resources, and ports as the infrastructure, we will build a green energy service network, gather various forces, and improve the overall operation efficiency of the industrial ecology.

Source of goods Provider
- Improve logistics efficiency

Vehicle owner
- Reduce vehicle purchase cost

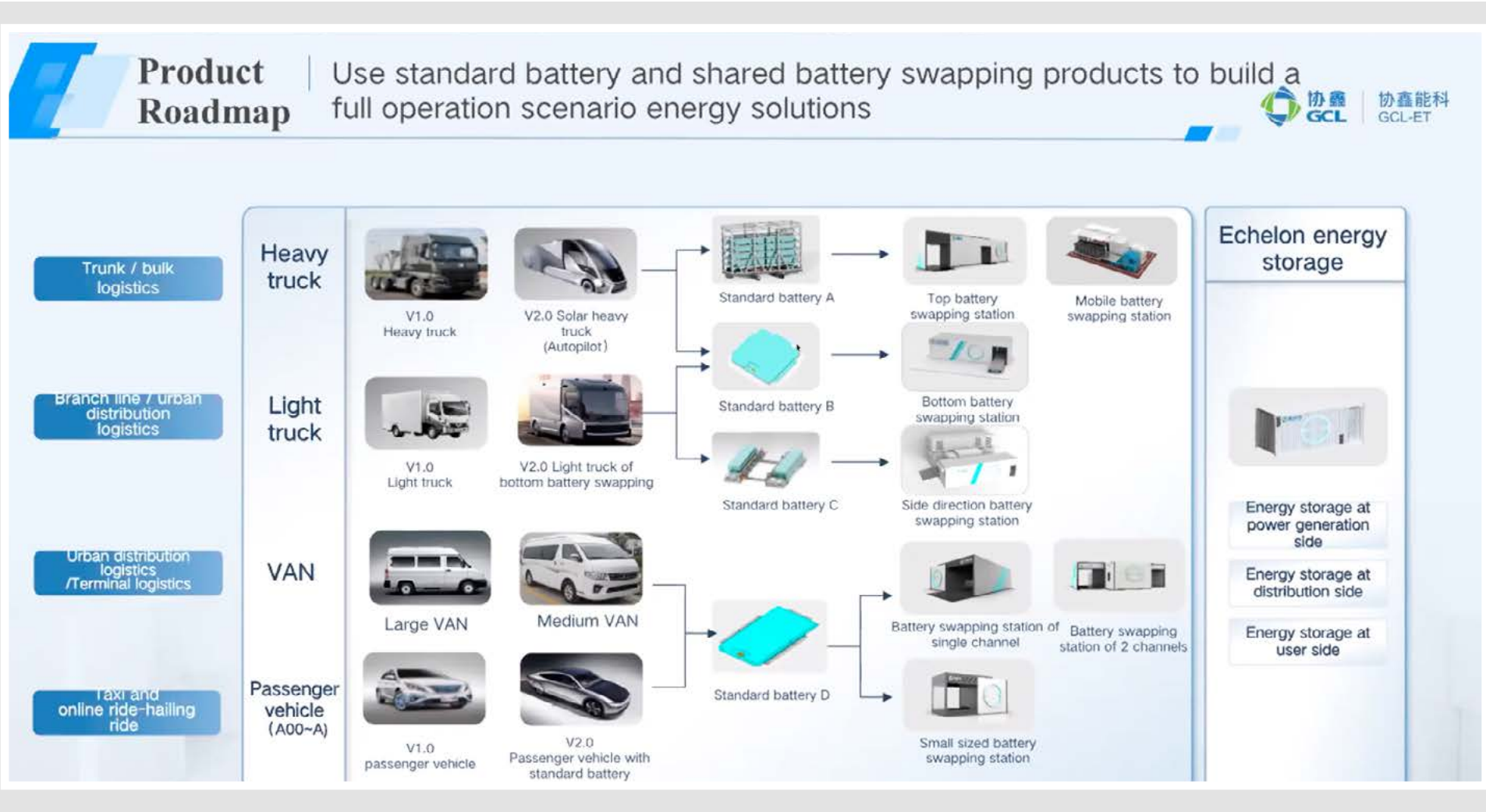
Driver
- Increase daily mileage

Battery swapping operator
- Improve the utilization rate of the battery swapping station

Battery owner
- Improve the full life cycle value of battery

Land/power provider
- Strengthen preferential policies and convenience

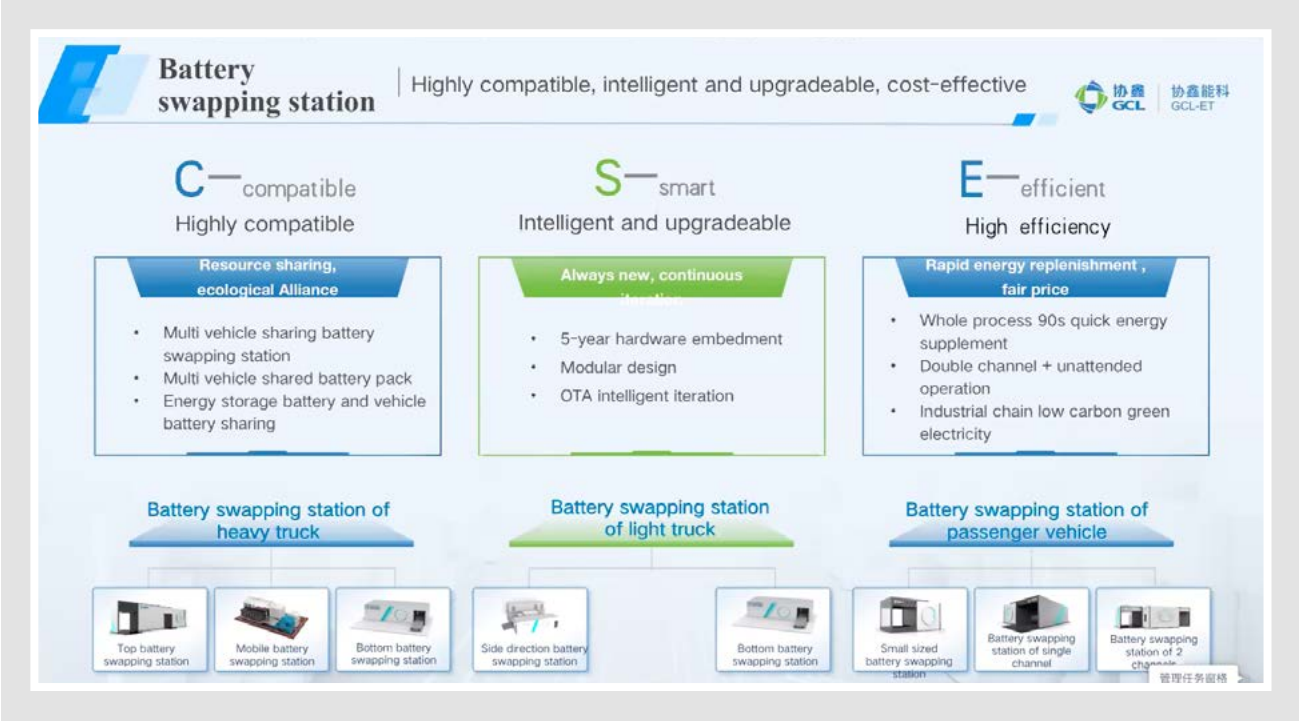
Industrial ecological construction demand



Battery swapping technical route

Location of the battery behind the driver's cabin and battery swapping overhead as the earliest battery swapping solution for EHTs has been well applied nationwide, especially in terms of battery standardization. Battery swapping across multiple truck models and manufacturers has been gradually realized, which provides a technical basis for us to build a battery swapping network for commercial vehicles. At the same time, however, we can also see that this solution has been developed based on modifying traditional diesel trucks into electric trucks, and there is still a lot of room for upgrading in terms of energy consumption, weight, and center of gravity ratio.

We are now developing the next generation of battery swapping heavy trucks based on totally new platforms. We are cooperating with a domestic heavy truck enterprise and expect to launch the next generation of products on the market next year. For several core indicators of the new generation of products, energy consumption will be reduced by 30%, and the space for the battery pack will be nearly doubled. The range of this vehicle can reach 500 km. The new truck can be applied in all areas and scenarios with battery swapping.



Key characteristics of battery swapping stations

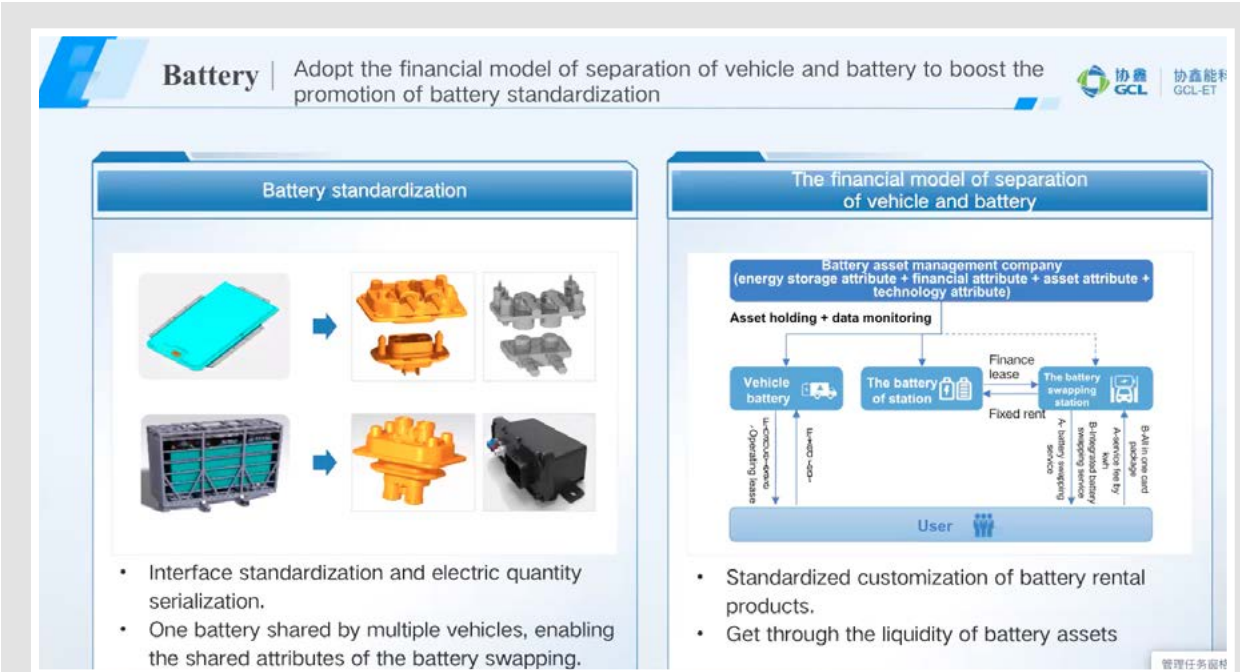
1. **Compatibility**
   On the premise of keeping the characteristics of different brands, the interconnection of the battery swapping network is realized through compatibility at battery swapping stations. In terms of batteries, to achieve interchangeability, we must achieve the unification of electrical, communication, and mechanical interfaces.

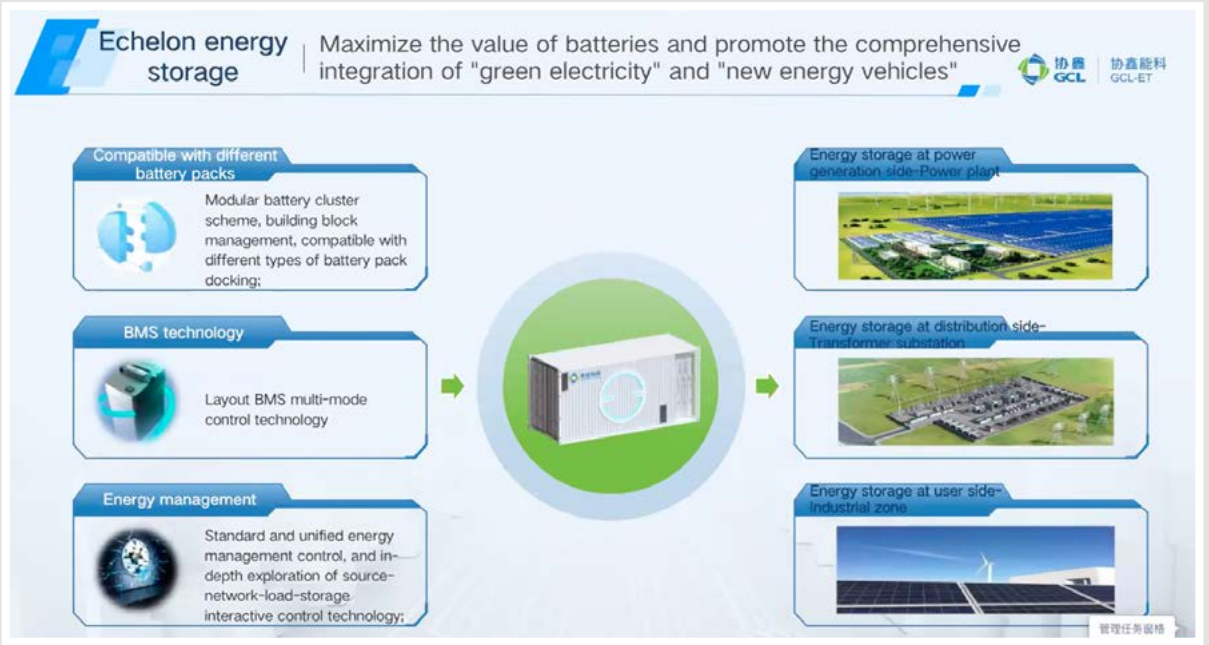
2. **Intellectualization**
   To cope with the progress of technology development, on the infrastructure (battery swapping station) side, hardware embedding, and software intelligent upgrading should be done, including the development of a software strategy based on the data drive.

3. **High efficiency**
   The battery management system of the battery pack for battery swapping mode should be a full scenario, full life cycle manager, so its design and development requirements and functions are very different from the BMS under the charging mode. Of course, this is inseparable from cloud management and deployment, including battery status monitoring and evaluation.

The concept of a battery swapping station as a “super home port”

We believe that for passenger cars, the battery swapping station should be a place where the next generation of electric vehicle owners can benefit from leisure, entertainment, and energy supply. For heavy trucks and commercial vehicles, the battery swapping station is a distribution center of goods, an industrial park, a logistics park, an energy supply center, and a source of clean energy and electricity. This is the core of the “super home port” we are currently committed to building. By the end of this year, we will build such battery swapping stations in Inner Mongolia, South China, and southwest China.





Case studies

Power supply, power grid, load and energy storage

Xinjiang Zhundong ' Integration of power supply, power grid, load and energy storage' ——Effectively reduce the operation cost of power exchange network

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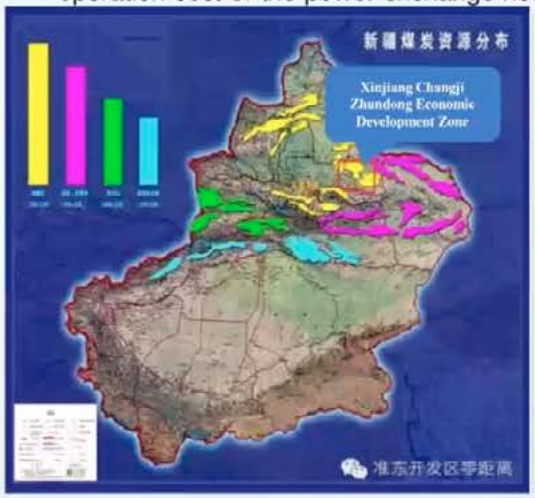
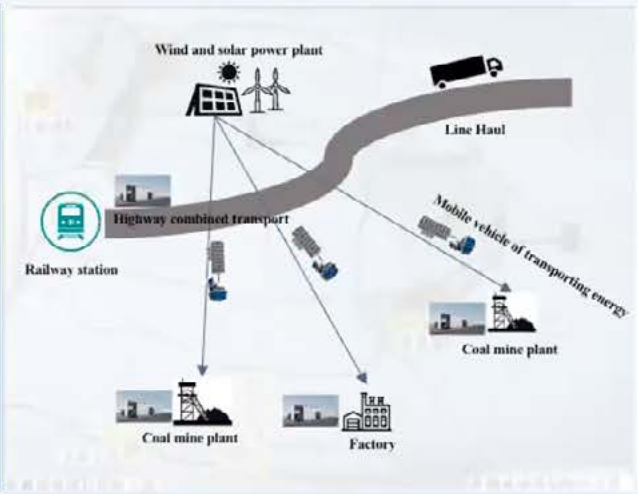
- Relying on "cloud computing, big data, Internet of things, mobile Internet, artificial intelligence" and other technologies, we will further strengthen the multi-directional interaction of power supply side, power grid side, load side and energy storage, increase the peak load regulation capacity of the power grid, improve the PV acceptance capacity of wind power, improve the security and stability of the power grid, and effectively reduce the operation cost of the power exchange network.





- Construction site: Zhundong Xiheishan area, Changji, Xinjiang
- Advantages: rich scenery resources and heavy truck logistics scenes
- Scale: 700000 kw
- Integration project of power supply, power grid, load and energy storage :

✓ The energy storage battery is shared by the battery swapping station and the wind power plant to reduce the investment cost of battery swapping operation equipment.

✓ The charging separation mode is adopted for the battery swapping station . The energy storage capacity of the wind and solar power plant is more than 50% and the power cost can be reduced by 0.05 yuan /kwh.

✓ The utilization rate of equipment energy storage in wind power plants has increased from 8% to more than 80%.

Project introduction

300000 kW PV

400000kw wind power

Configure 5% energy storage, and the energy storage duration is 2hours

1250 heavy trucks of battery swapping can be served

Bulk material transportation

Erdos coal mine short shift – battery swapping mode can efficiently match short shift transportation scenarios

协鑫 GCL | 协鑫能科 GCL-ET

- Taking Ordos coal mine short trip project as an example, with a one-way trip of 54 km and an average daily operating mileage of 324 km, the battery swapping mode can efficiently match the short trip transportation scenario.
- The project adopts the vehicle and electricity separation financial scheme, and the purchase cost of the battery swapping vehicle is the same as that of the fuel vehicle, which is 47% lower than that of the charging vehicle.

Erdos coal mine short shift scenarios

Coal mine loading silo

Short haul reshipment

power plant

管理任务窗格

Line Haul

Guangxi trunk line logistics - expand the short-term reverse scenario into long-distance trunk line transportation

协鑫 GCL | 协鑫能科 GCL-ET

- Guangxi battery swapping network layout has successfully expanded the short-term reverse scenario into long-distance trunk line transportation; Compared with fuel vehicles, the energy cost saved by the battery swapping vehicles is about 137900 yuan.

Place of departure	Battery swapping station A	Battery swapping station B	Destination;
Place of departure Loading - departure	About 50 km ----Remaining power 15%	About 100 km ----Remaining power 15%	About 50 km To the destination Unloading, loading - return starting the place of departure

- The battery has been replaced for 4 times in the whole journey of about 400 km, one round trip every day, and 200 times in total according to the current daily battery swapping times of 50 battery swapping vehicles.

Data type	fuel	gas	Battery swapping【Vehicle and electricity separation】
Energy consumption per 100 km L/L/kWh	45	50	160
Unit price (yuan)	8.2	6	1.5
Energy cost per 100 km (yuan)	369	300	240
Annual operation days (days)	330	330	330
Daily operating mileage (km)	324	324	324
Annual energy cost (10000 yuan)	39.45	32.07	25.66
Annual energy saving cost (10000 yuan)	/	7.38	

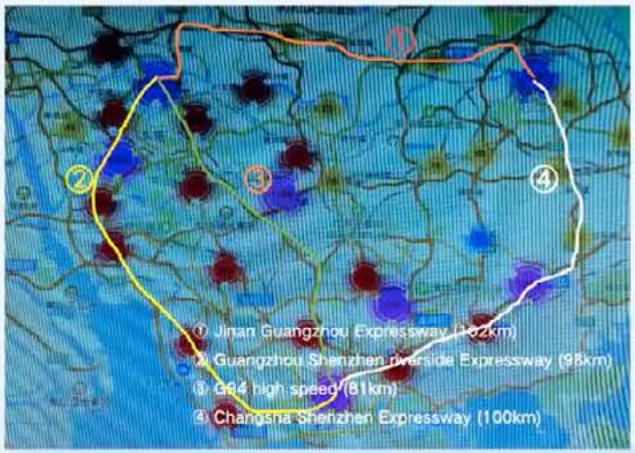
管理任务窗格

Urban distribution logistics

Logistics and transportation of light trucks around the city in Dongguan -- effectively improving the daily operating mileage of electric vehicles

协鑫 GCL | 协鑫能科 GCL-ET

- The battery swapping mode will increase the driver's daily operating mileage to more than 200 km, creating more revenue for the driver, with an increase of 21% over the charging version and 33% over the diesel version.



project		Battery swapping	Charging	Fuel
Energy cost	Energy consumption per 100 km L/L/kWh	43	43	18
	Unit price (yuan/kWh/L)	1.657	1.06	7.18
	Energy cost per 100 km (yuan)	71.25	45.58	129.24
	Energy cost per kilometer (yuan)	0.71	0.45	1.29
Operating charge per kilometer (yuan / km))		5	5	5
Five year total revenue of single vehicle (10000 yuan)		210	165	180
Five year total profit of single vehicle (10000 yuan)		155.7	127.1	117
Battery swapping vs. charging / fuel income increase (10000 yuan)		-	28.6	38.7
Income increase ratio		-	22.5%	33%

Dawan district west line (Shenzhen Guanhui) battery swapping network

- Logistics distribution around the city;
- The one-way distance is 80-100 km, and the driver's one-day operation mileage is more than 200 km;
- The maximum daily service capacity of each battery swapping station is greater than 400 times.

管理任务窗格

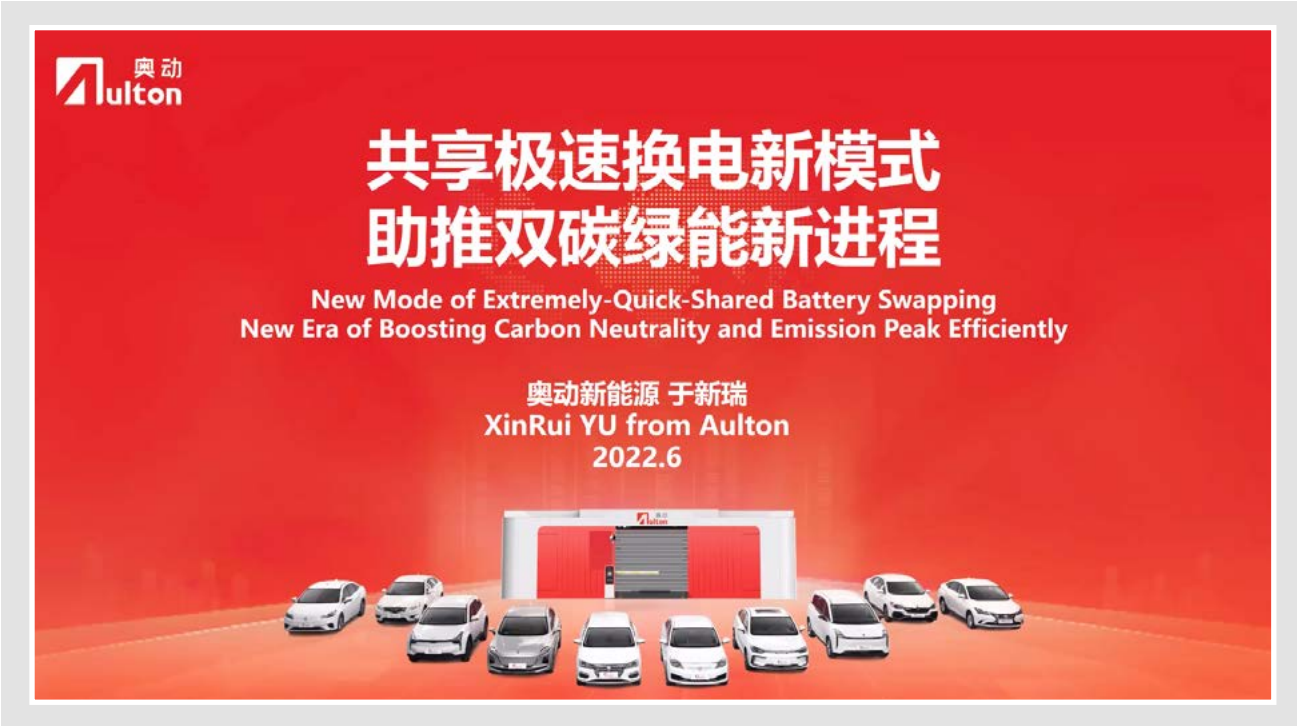
In our understanding, battery swapping is not only a solution for the electrification of transportation; it also brings opportunities for improving transportation and logistics efficiency.

AULTON

Pioneer in battery swapping and the leading third-party actor in battery swapping system development. Mainly operates in battery swapping for passenger vehicles and is now expanding to battery swapping for heavy trucks.

Speaker

Mr. Yu Xinrui, CTO



Aulton's practice and business experience

Aulton began its battery swapping business development in 2000. We have established 610 battery swapping stations and our battery swapping solution can achieve battery swapping for passenger vehicles in 20 seconds. Our company owns 2,600 patents.
Based on our 14 years of commercial operation experience, the battery swapping solution has proved reliable and safe. Up to now, we have not had a single fire incident in our battery swapping service.

Through more than 10 years of large-scale battery swapping practice, we have now established cooperative relations with 16 mainstream car companies and developed more than 30 models of battery swapping vehicles, which have been deployed in 36 cities in China. At the same time, we have launched our battery swapping business in Germany and Japan. To date, 26 million instances of battery swapping have been completed, and the vehicles have traveled a total of 3.6 billion km. Among them, the vehicle with the greatest mileage has reached 1.3 million km, which also testifies to the effectiveness of battery life extension of battery swapping mode.

Last year, Aulton signed a strategic cooperation agreement with Sinopec to build a comprehensive energy service ecosystem jointly. We will work together to build a battery swapping station at Sinopec's gas station. Last year, we also signed a strategic cooperation agreement with BP to create a city-level joint venture. Through cooperation, we will accelerate the implementation and promotion of our battery swapping business.

Aulton launched its business in the electrification of passenger cars earlier, so we have a lot of accumulation in this field. At the same time, Aulton also provides battery swapping for

commercial vehicles. Our battery swapping technology has covered the whole range of vehicle models, such as passenger cars, mini-vans, light trucks, heavy trucks, and buses. We use the same snap-fit locking technology for all models. Our cumulative driving data covering billions of kilometers have fully verified the reliability of this locking system.

Aulton's battery swapping solution for heavy trucks

Vehicle side

Power battery pack equipped under chassis: low gravity center, no occupation to the container. Aulton unified locking and connecting technology: high compatibility and high efficiency.

Compact vehicle structure design, lightened weight, lower cost, and optimized layout. Flexible adaptation to a new generation of electrical platforms for heavy trucks.

We also believe that electric heavy trucks should have a development process of gradual modification based on diesel vehicles to a new generation design based on pure electric platforms.

Battery swapping station side

- Extremely fast swapping finish within 40 seconds.
- Better service capability with dual swap electro-mechanic robots.
- Highly reliable connecting and locking technology. Durability is as high as 20,000 times connecting and locking.
- Modular design. Low area coverage. 10m*9m.
- Convenient. No need to dig a ground pit or hang the system from the high end. Modular installation.

We will launch the battery swapping station solution this year.

Battery pack

- Scientific and compact design in structure: battery height no more than 510mm, perfect adaptation to chassis layout.
- Standardized design and good compatibility, low space requirement.
- Accessible to over 450kwh battery capacity, suitable for high-frequency and long-haul scenarios. 450kWh battery capacity can support a driving range of 300km.
- Adaptable to multiple vehicle body types.

Figure 4: Aulton battery swapping station. Source: https://www.aulton.com/

Aulton battery swapping solution for EHTs application scenarios

- 450kwh battery pack capacity can meet the requirements of most application scenarios.
- Long-haul transportation: fixed route, long distance, high efficiency.
- Short-haul shuttle transportation: long operation time, frequent use.
- Dump trucks operating in urban settings: fixed and periodic operation time.

2 in 1: Battery swapping and energy storage

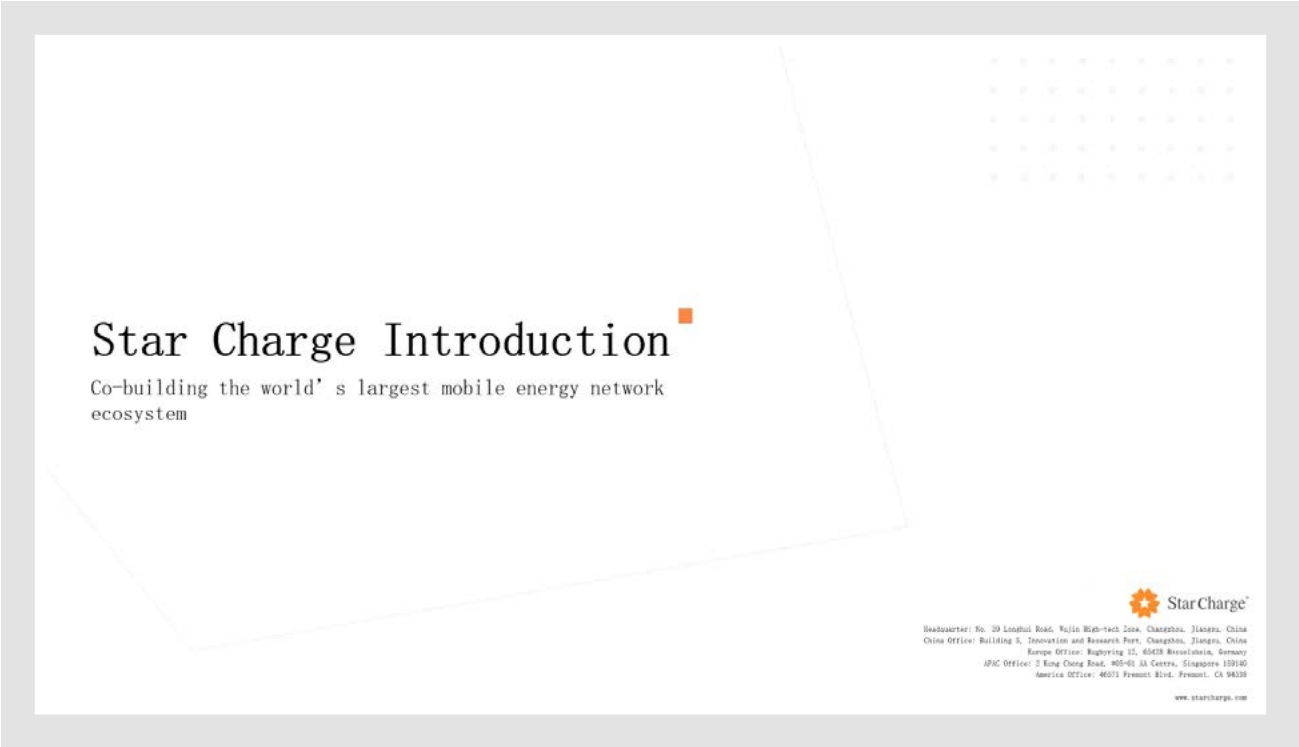
Our power exchange station offers a combination of battery swapping and energy storage. In this way, land, electricity, and batteries can be intensively utilized, energy can be efficiently interactive and locally consumed, and battery swapping and storage can be integrated. Power can flow in two directions. Our station is now fully compatible with two-way chargers. It can realize the charging and discharge of energy storage batteries, which are well capable of meeting the emergency power consumption in the station. It can also achieve the interaction between stations and the grid. Through the efficient energy interaction between vehicle, station, and grid, the user side can participate in the transaction with the power market. The battery swapping station and the power grid can realize the interaction of energy up and down, and can use electricity in an orderly manner, cut peaks and fill valleys. By constructing this new battery swapping system, it becomes possible to promote the new transformation of the power system, including the interaction with terminals.

STAR CHARGE

China's leading EV charging solution provider, now expanding to the battery swapping field. As a Chinese representative, the company has participated in drafting all of China's domestic charging standards and the IEC international standards.

Speaker

Mr. Li Tao, General Manager of Specialty Vehicles Charging Solution



Our company has been focusing on electrification of transportation and digitalization of energy. We are collaborating with the Mobility Team of the Shell group to establish charging and battery swapping networks in Italy and France.

In our view, in the future, specific products will be replaced by scenarios, and ecology system ecology systems will replace scenarios. (In applying a new product solution, identifying suitable scenarios for the new solution is very important.)

Scenario Analysis

Eight scenarios of commercial vehicles

01.City construction

Scenario: Muck truck, Sanitation truck, Cement mixer truck, etc.

Solutions: Charging, PV, Battery bank, Swap station, Green energy trade

02.Factory short barge

Scenario: Steelworks, Cement plant, power plant, etc.

Solutions: Charging, PV, V2V Battery bank, Swap station, Green energy trade

03.Port electric operation

Scenario: Truck and AGV for container ports

Solutions: Charging, PC Swap station, Auto-charging

04.City short barge

Scenario: City express, Green distribution, et.

Solutions: Charging, V2V, PV Swap station, Green energy trade

05.Mine transportation

Scenario: coal mine, metal mines, etc.

Solutions: Charging, PV, Battery bank, Swap station, Green energy trade

06.Construction machinery

Scenario: Excavator, Loader, Stacker, etc.

Solutions: Charging, V2V, PV

07. Locomotive transportation

Scenario: Charging for locomotive transportation

Solutions: Charging, PV, Auto-charging

08. Inland river vessel

Scenario: Charging for inland river vessel.

Solutions: Charging, PV, Swap sation

Eight scenarios for battery swapping mode

Currently, in China, 47% of battery swapping operation exists in the mine transportation scenario and 27% in city construction and construction machinery scenarios. With the right infrastructure support, inland river vessel transportation is also suitable for battery swapping mode. We believe that battery swapping, charging and automatic charging should complement each other to support future smart cities.

Scenario Solutions

Full scenario solution

Power source → **Green vehicle operation** → **Green power supply**

Green
Normal

国家电网
STATE GRID

Green energy to Grid

PV industrial park

All Green Energy 100%

Quota: 15%
Trade: 85%

Electric concrete mixer

Electric muck truck

Electric van

Digital platform improves efficiency 15%

EVSE Vehicle dispatching platform

All Green Energy 100%

Charging station

EVSE rate 3:1~4:1
Trans-Cap 300kVA*N

Swap station

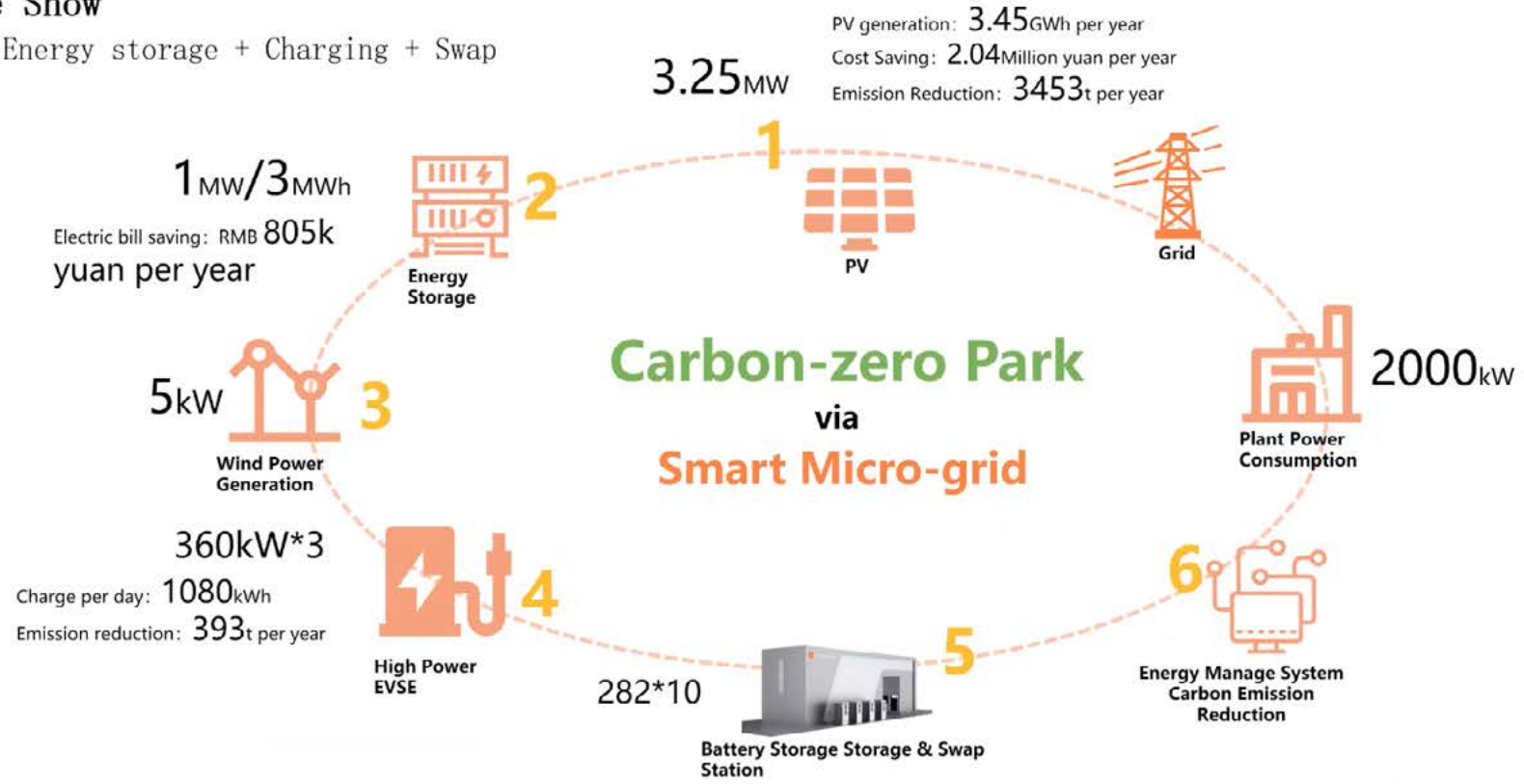
EVSE rate 30:1~50:1
Trans-Cap 2000kVA

Mobile swap station

Mobile energy storage

Case Show

PV + Energy storage + Charging + Swap



Carbon Neutralization		
	Cost Saving: **2.845Million** yuan per year	CO2Emission Reduction Rate: **38.5%**
	CO_2Emission Reduction: **3846t** per year	Purchase green energy: **600MWh** per month

CHINA BATTERY SWAPPING INDUSTRY PROMOTION ALLIANCE

Speaker

Professor Li Liguo, Secretary General of the Battery Swapping EHT Promotion Alliance of China and Professor of Qing Hua University

Under the guidance of the Chinese government's development strategy for new energy vehicles and carbon peaking and carbon neutrality, the central and local governments at all levels have issued a series of specific policies to encourage the electrification of heavy trucks and the construction of heavy truck battery swapping infrastructure, especially in 2021. In 2021, a program of pilot cities for battery swapping heavy-duty trucks was launched, and key promotional demonstrations were carried out.

The electrification of heavy trucks can effectively reduce oil consumption, reduce nitrogen oxides by about 70% and particulate matter emissions by 50%, and drive the new energy heavy truck industry at a scale of nearly CNY one trillion.

China has demonstrated and promoted electric heavy trucks for many years, but it is plagued by problems such as high purchasing costs due to large battery capacity, long charging times, battery space and weight encroaching on cargo capacity, and difficulty in constructing charging infrastructure. Development has been severely restricted and has progressed relatively slowly. The battery swapping mode involves the physical separation of the vehicle body and the battery, and the separation of the vehicle and the battery assets. Through physical separation, battery swapping can be achieved in five minutes instead of hours of charging. Asset separation means that the cost of the battery is subtracted from the vehicle purchase cost, which reduces the initial purchase cost.

The battery swapping mode will redefine electric heavy truck transport in the future. Through multiple 150-km short-distance ranges, plus five minutes of battery swapping, it can achieve unlimited range within the coverage of the battery swapping network, instead of charging for hours at a time, while traveling limited longer distances of around 300 km. In this way, the number of battery packs installed on the truck can be reduced. By reducing the number of batteries, the cost and the impact on cargo capacity can also be reduced, and the economic efficiency of operations can be improved. To sum up, the battery swapping mode helps the electric heavy truck transcend the limitations of charging mode, has good economic efficiency and applicability and has developed rapidly in recent years.

1.4 重卡换电进入高速增长阶段

1.4 Battery-Swap Electric Heavy-Duty Trucks Are Growing Fast

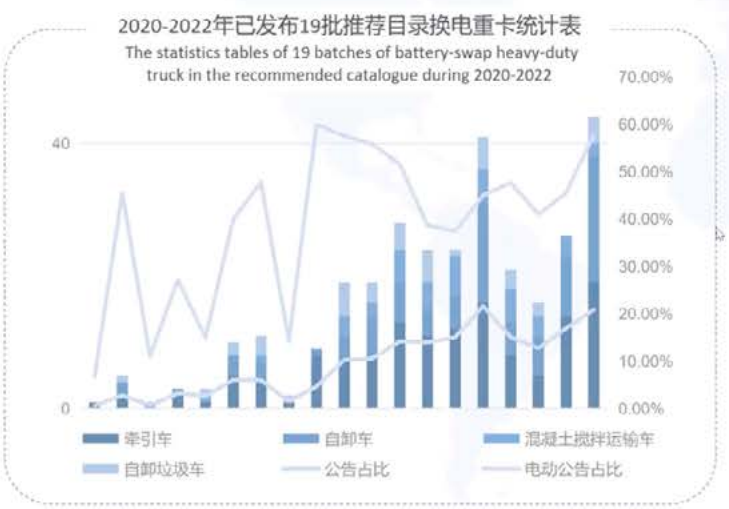
BSIP Alliance 中国电动重卡换电产业促进联盟

- 截止到2022年4月，国内换电推荐目录换电重卡累计达到**309款**，**牵引车和自卸车**是主要车型，且车型数量呈上升趋势。

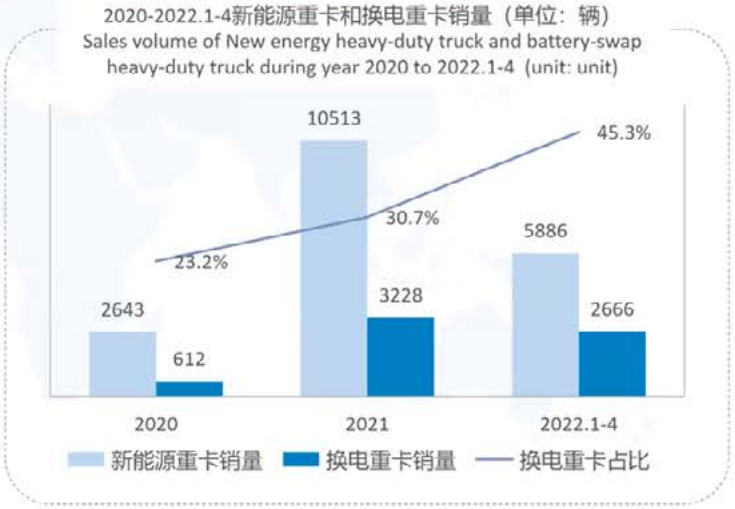
As of April 2022, there were **309 models** of heavy trucks in the catalog of recommended battery-swap EVs in China, among which **tractors and dump trucks** were the main models with a continuously increasing population.

- 2022年1-4月，国内新能源重卡行业累计销量为5886辆，其中换电重卡销量达到2666辆，占新能源重卡45.3%，**较2021年上涨14.6个百分点**；

In January through April, 2022, China's new energy heavy-duty truck sector sold **5886** units in total, including **2,666** battery-swap electric heavy-duty trucks, accounting for 45.3% of the total, an increase of 14.6 percentage points compared with 2021.



数据来源：工信部



数据来源：电车资源

This slide shows that since 2019, the proportion of battery swapping heavy trucks in each batch of new energy heavy trucks has increased from a very low level at the beginning to close to 60% of each batch of announcements (of newly launched new energy vehicle models in China).

Truck companies are focusing on the introduction of battery swapping EHTs. It can also be seen from the sales chart for new energy heavy trucks on the right of the slide that the sales and proportion of battery swapping heavy trucks are rising rapidly, and they are increasingly receiving recognition by market users.

At present, leading enterprises such as State Power Investment Corporation, CALT, Jinmao Smart Transportation, and GCL have entered the field of construction and operation of battery swapping stations in China. Major heavy truck manufacturers have launched models of battery swapping electric heavy trucks.

We have an optimistic attitude towards the construction of China's battery swapping heavy truck market and the development of battery swapping infrastructure. We predict that the sales volume is expected to reach 400,000 vehicles in the next five years, and the overall market size is expected to reach CNY 500 billion per year.

By 2026, we predict that the stock of battery swapping heavy trucks will reach 800,000 units and 1,600 battery swapping stations, which will drive a total of nearly 300GWh of power batteries and bring huge opportunities for the development of the entire industry.

Is battery swapping the best way to supply energy for heavy trucks? We conducted a modeling analysis using the ton-kilometer cost as the evaluation index. The results of our analysis are described below. We selected a 49-ton tractor as the research object, took full-load continuous transportation as the freight scenario, and carried out modeling simulations according to the following energy supplement conditions: 4C super-fast charging, 1C standard fast charging, and five-minute battery swapping. The ton-kilometer transportation cost is composed of the main costs such as the cost of the vehicle and battery (battery swapping station/charging station construction and operating cost) and the driver's salary.

This is a typical short-distance scenario with a driving range of 150 km. According to the cost calculated under the condition of 50% of the charging and swapping station load rate, we find that the cost of running electric vehicles is significantly lower than that of traditional vehicles.

We also analyzed the impact of different power supply intervals on the economy. This power supply interval refers to the energy supply point and the construction interval of the charging and swapping station. Super-fast charging can only have a slight cost advantage in the case of short-distance operations and densely distributed energy supply points below 60 km. However, under conditions of 68-272 km energy supply intervals, battery swapping mode has significant economic advantages. For scenarios where the recharge interval must be greater than 300 km, fast charging has a significant advantage. The average transportation distance of road freight in China is about 170 to 180 km. We judge that the battery swapping mode has very strong adaptability and promotion value in the context of freight transportation in China.

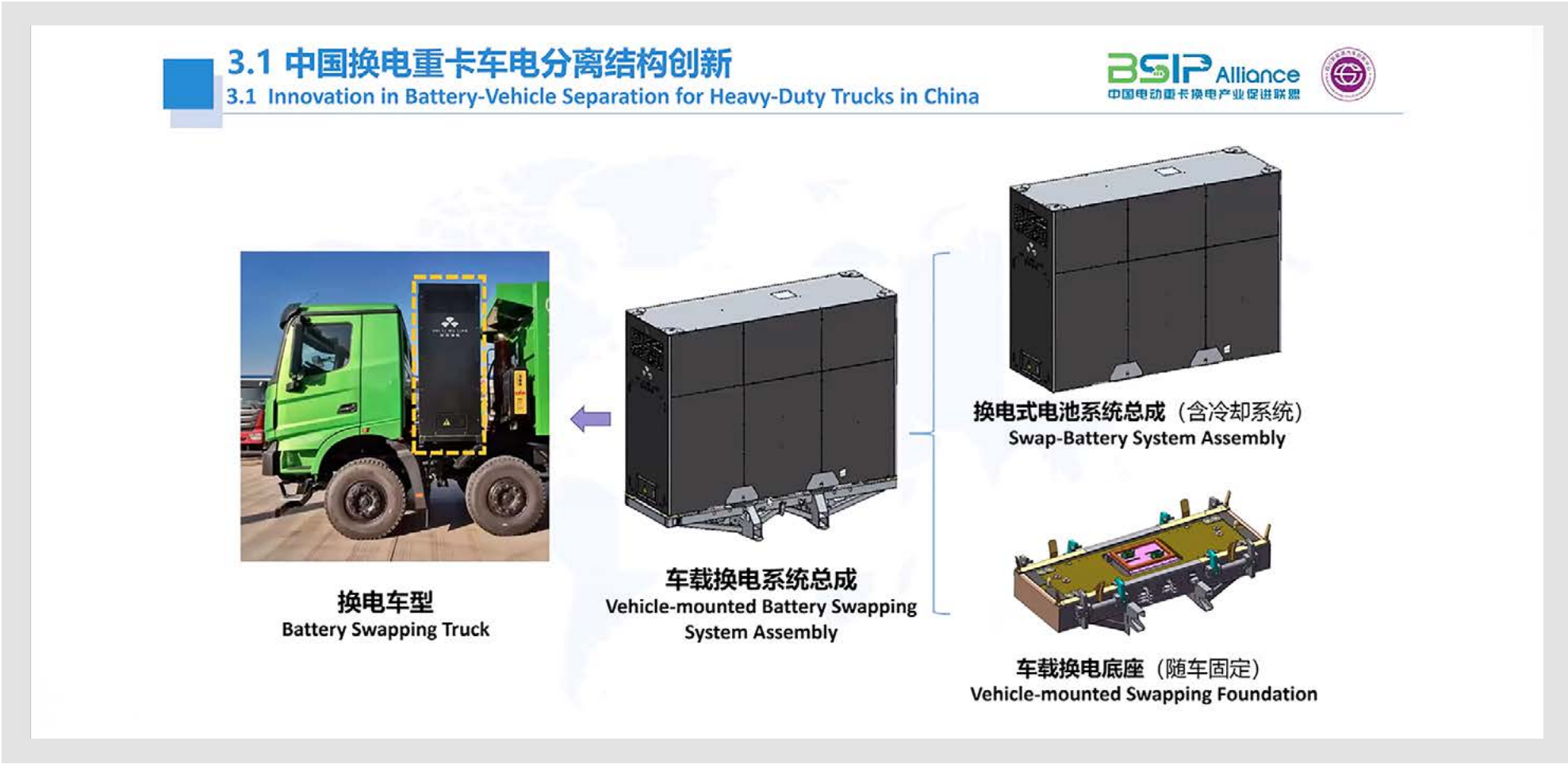
In addition, we also analyzed the change in the cost of different supply methods when a different number of vehicles utilize the energy supply network. We found that when the load rate is below 37%, fast charging remains the best way to replenish energy, but when the load rate exceeds 37%, battery swapping mode continues to have the strongest competitiveness. From this, it can be inferred that charging is more suitable

for low-frequency scenarios, and battery swapping is more suitable for high-frequency scenarios. The transportation network has different transportation densities and usage frequencies, so we judge that a heavy-duty truck power supply network where charging mode and battery swapping complement each other will be formed in the future.

All of these scenarios have already been demonstrated by battery swapping heavy trucks. However, we have seen that the industry generally believes that the highest proportion of applications is still in short-haul scenarios. What is the reason for this? Because in this scenario, it is often possible to build just one station to carry out operations, which is easy to implement. It does not mean that battery swapping mode is only suitable for short-haul scenarios. We have seen that battery swapping EHT demonstration projects in long-haul scenarios with more than 1,000 km distances has begun to emerge. For example, CALT company planned a line to transport batteries from Yibin to Shanghai by using battery swapping EHTs, which also reflects the wide adaptability of battery swapping EHTs for transportation scenarios.

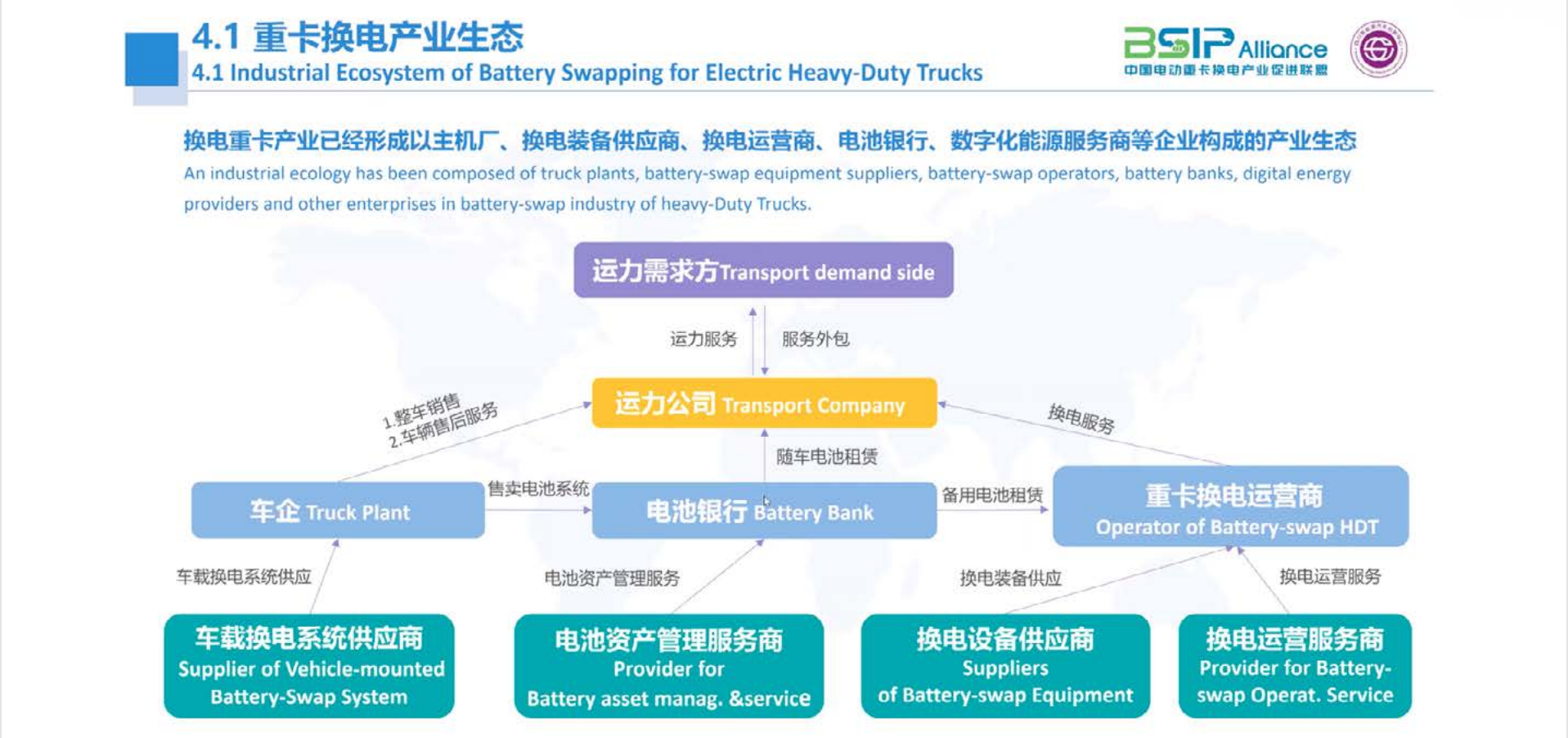
The successful application of the battery swapping mode of heavy trucks is inseparable from innovation by leading companies regarding technology and business models. The first key point is technological innovation, exchanging the traditional integration method of physical connection between vehicle and battery for a structure of automatic separation and automatic combination of battery and vehicle body. This has experienced practical verification in tens of thousands of vehicles, proving that the technical route of battery swapping is feasible.

On the other hand, there is the innovation of battery swapping equipment. It can automatically locate the vehicle and automatically complete the battery replacement. At present, there are two main domestic technical routes: side replacement type and top suspension type, and both have been tested in practical application. This slide shows a typical side-mounted power station. Through the fusion of lidar and vision, the vehicle and battery positions can be accurately identified, and then automatically grasped and replaced by a high-precision multi-degree-of-freedom robot, without the driver needing to exit the vehicle. All identification, payment, and replacement processes are completed automatically, the automatic replacement time is less than four minutes, and the total service time is less than five minutes. This is an actual muck truck operation scenario.



This slide shows the most common type of top-mounted battery swapping equipment. It adopts the structure of a gantry crane. Its structure is simple, the technology is highly mature, the sling is flexible, and the adaptability of automatic positioning is relatively strong. The driver completes the alignment and parking. The requirements for the control system are also relatively low. It is currently the earliest and the largest scale applied battery swapping equipment. The battery replacement time is five minutes, and the total service time is six to seven minutes.

What has just been discussed are several technological innovations that solve the problem of the physical separation of products. Another key point is the innovation of the business model which separates vehicles and batteries. The battery assets are held by battery banks, and users only need to pay a price that is similar to that of a traditional heavy truck to acquire the EHT vehicle body. Users then pay a monthly battery rental and battery swapping service fee that is lower than the cost of fueling a traditional vehicle. In this way, the operating and maintenance costs of



the vehicle can be reduced without increasing the initial investment. This payment model is very user-friendly and is also an important factor in accelerating the promotion of battery swapping heavy trucks.

The industrial innovation and ecological construction of Chinese enterprises have achieved good results. This slide shows a simplified diagram of the ecological chain whereby truck companies sell bare truck bodies, battery banks provide battery leasing services, and battery swapping operators build battery swapping stations and provide a complete user service for battery swapping. We call these actors direct suppliers. At the same time, a supply chain system has also been formed providing services to direct suppliers such as battery systems, onboard battery swapping systems, battery equipment, battery swapping station operation management, and other products and services. Several corresponding suppliers can provide a stable supply.

In the early stage of the demonstration of battery swapping EHT operation, we found that most of the battery swapping stations in China are owned by the users of the scenario and the battery swapping operators provide financial services. This is only applied to the situation when users own their vehicles, which we call closed-running battery swapping stations. What is now more often the case is that battery swapping station operators invest in the construction of stations.

The operation mode of the public interconnected battery swapping network has received wide recognition, and the battery swapping service network has been formed at the regional level.

This slide shows all enterprises in China's heavy-duty truck battery industry chain. At present, they have formed a relatively sufficient, active, and healthy industrial ecology.

5.1 标准体系
5.1 Standard System

BSIP Alliance 中国电动重卡换电产业促进联盟

电动汽车 EV

2021年11月汽标委发布了《中国电动汽车标准化工作路线图（第三版）》。路线图立足于我国新能源汽车产业发展需求，系统梳理了新能源汽车标准体系架构，分领域介绍了国内外现有标准和标准缺项。电动汽车换电标准被列入了短期、中期两个阶段任务。

In November 2021, CAAC issued the Roadmap for Standardization of Electric Vehicles in China (Third edition). Based on the development needs of China's new energy vehicle industry, the roadmap systematically combs the standard architecture of new energy vehicles, and introduces existing standards at home and abroad and the lack of standards by field. The standard of battery swapping has been included in the short-term and medium-term tasks.

At the same time, under the guidance of the Ministry of Industry and Information Technology and the Administration of Energy, the interchangeability standard system for battery swapping for heavy-duty trucks is also rapidly being constructed, which is paving the way for the healthy development of the industry.

This slide shows the ”Roadmap for Standardization of Electric Vehicles in China (Third Edition)” issued by the China Automobile Standards Committee in 2021, in which creating the electric vehicle battery swap standard is listed as a key task in the short and medium term.

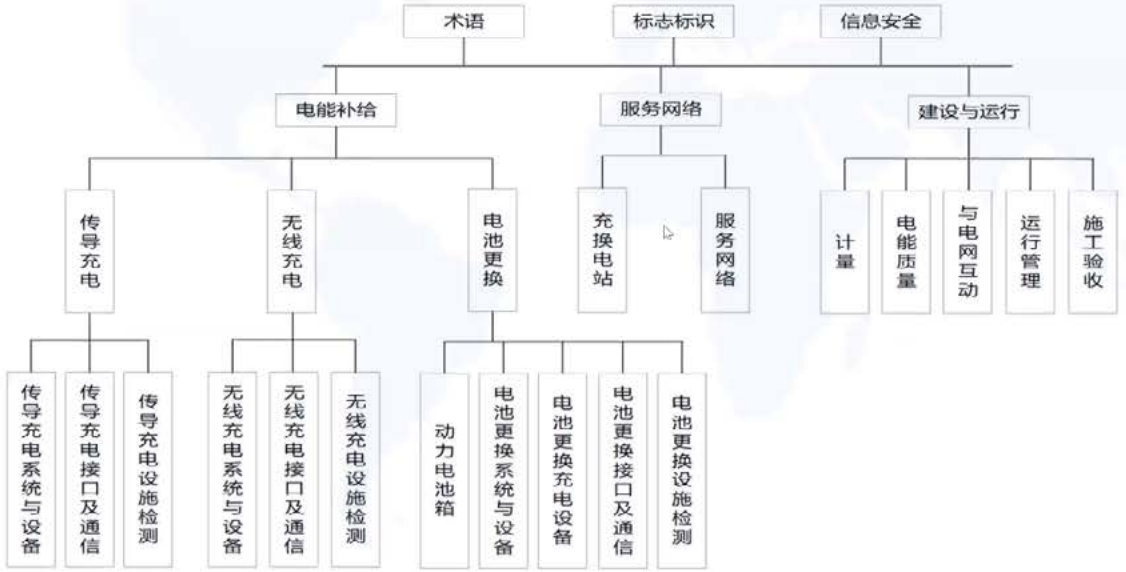
5.2 标准体系
5.2 Standard System

BSIP Alliance 中国电动重卡换电产业促进联盟

充换电设施
Charging & battery-swap facilities

中国电力企业联合会发布的**《电动汽车充电设施标准体系（2020版）》**中，标准体系涵盖了充电设备制造、检验检测、规划建设和运营管理等全方位，主要解决电动汽车使用过程中的充电安全、互联互通、设备质量、设施规划布局、计量计费等关键问题。标准体系共划分为基础标准、建设与运行标准、服务网络标准等3个部分。

Promulgated by CEC, Charging Infrastructure Standards of Electric Vehicle (2020 edition) covered the charging equipment manufacturing, testing, planning, construction and operation management, etc, mainly to solve key problems such as charging security, connectivity, equipment quality, facility layout, measuring the billing in the process of using electric vehicle. The standard system was divided into three parts: basic standard, construction and operation standard, and service network standard.



This slide shows the ”Standard System of Electric Vehicle Charging Facilities (2020 Edition)” issued by the China Electricity Council, which also focuses on the layout of heavy truck battery swapping.

This slide shows a list of specific standards. At present, there are seven national standards and five automotive industry standards in the process of revision and formulation, mainly focusing on the safety and interchange-ability of battery swapping.

At the same time, there are also several associations and regional standards involved in the designation process. At present, the regional standards for battery swapping in Jiangsu Province and the association standards from the Battery Swapping Connectors' Association have been released. All stakeholders are striving to realize interconnectedness and

compatibility within groups or regions as soon as possible. All attach great importance to exchangeability and interoperability and a consensus has been formed on the vision to build an interoperability and exchangeable battery swapping network for the entire industry in the future.

While there has been rapid development, there are many risks and difficulties to be overcome throughout the entire industry. Due to time constraints, today I mainly want to mention two that I think are the most important. The first is that the current differences between the standards of various groups and regional local standards are very large, and it is difficult to achieve national unity. If the development of regional and group standards is too fast, the development of national standards and automobile industry standards is too slow. It is easy to form the inversion of standards, hindering the development of the industry and leading to a waste of resources. This issue has also received the attention of the Ministry of Industry and Information Technology. Some coordination and promotion may be carried out in this regard in the future to speed up the introduction of industry standards and national standards.

The second problem is that the battery bank centrally holds 50% of the assets of the battery swap system, but there is currently no effective method of battery asset management. This brings great risks to the battery asset management of the battery bank and hinders the participation of many financial parties. The battery bank participates in the process of battery asset investment. We also perceive that this is hindering the speed of development of the current industry.

Our alliance has done a lot of work in interoperability, including research on standardized technical solutions, organization of interoperability groups, and identification of high-quality interchangeable products.

This slide shows our research on interchangeable standard technical solutions.

First, the formulation of the standardization scheme requires mature and proven products to reduce the technical risk of the standard formulation.

Second, battery swapping technology is currently in the early stage of industry development, product design optimization is not sufficient, and technological innovation is also very active. While ensuring interoperability and exchange, the restrictions on specific technical test forms should be limited as much as possible so that the innovation space of the industry can be protected. This is the hardest part of the job. Our alliance has innovatively proposed a unified battery frame interface, which can liberate the innovation of the lock mechanism. At present, it has received technical recognition and support from companies in the industry. We are currently conducting in-depth discussions in this direction. In the bottom left corner of this slide, we can see a typical locking base from each company. The differences are still significant; it is very difficult to exchange batteries directly. The main idea of battery swapping passenger cars is to share battery swapping stations. We propose a solution to standardize the single-side interface of the battery system so that

the mechanism on the left can be matched with the battery on the right. All parties involved are interconnected without changing their product and technology roadmaps. At present, we are also conducting detailed digital-to-analog matching with many companies. About three or four companies have had no problems at all utilizing our interface solution. Other companies may need to make slight changes. The feasibility of our interface solution is very strong, and it is expected that relevant standardization plans will be released this year.

Due to the complexity of the electrochemical characteristics of batteries, the management of battery assets faces many management pain points such as safety, life, performance, residual value, etc. We are also promoting the digital management of battery assets and the construction of a digital trading system.

This slide shows our establishment. It is the bottom-level infrastructure, the infrastructure for the digitization and operation, and maintenance of battery assets. We have now built a battery asset full life cycle management platform based on battery big data, AI algorithms, and cloud-controlled battery management technology. It can comprehensively record the operating data and status of the battery and provide support for the upper-level operation platform, operation, and maintenance platform, and asset transaction. If there is an opportunity, I will discuss it with you in detail at a later stage.

Finally, I would like to briefly introduce our Alliance. In September 2020, professor Ouyang Minggao of Tsinghua University and professor Wu Feng of Beijing Institute of Technology, China Electricity Council, China Youth Academy, CCID Research Institute, CALT, China Merchants State Grid, South Grid Electric, and other industry experts, standard supervisors, and leading enterprises jointly initiated the establishment, which is positioned to promote the formulation of technologies, standards, and industrial cooperation, and to promote the healthy and efficient development of the heavy-duty truck battery swapping industry.

I hope to have the opportunity in the future to communicate and cooperate with all parties in China and Sweden to jointly promote the development of the global battery swapping heavy truck industry. Thank you for listening.

SANY HEAVY TRUCK

Sany is one of the top truck OEMs in China deploying battery swapping for EHTs.

Speaker

Mr. Zhang Xing, Vice General Manager of Power Energy Technology

Sany has been deeply engaged in construction machinery, ranking first in China and second in the world. Sany entered the heavy truck industry in 2018. In 2019, we began to explore electrification. Today, electrification is one of the three strategies of our whole group. We have now launched our total solution encompassing electric trucks, battery swapping stations, and operation management platforms. With support from financial organizations, trucks, and battery swapping equipment are provided to operators.

Our solution is based on a battery swapping station for standard road transportation, while for non-standard-road operation, the battery is delivered by a mobile battery swapping truck.

Sany battery swapping truck products

We have launched three major types of battery swapping trucks: tractors, dumpers, and mixers. The battery swapping can be achieved in 1.9 minutes. The battery swapping tractor's energy consumption is 1.5kWh/km. The range of the dumper is 120km. The curb weight of the mixer truck is below 15 tons.

Because Sany is a world-leading construction machinery supplier, we have also explored the electrification of construction machinery. Our electric mining trucks, electric excavators, electric road roller, mobile electric crane, electric loaders, and electric reach stackers are undergoing testing and will be launched to market this year.

Sany battery swapping station solution

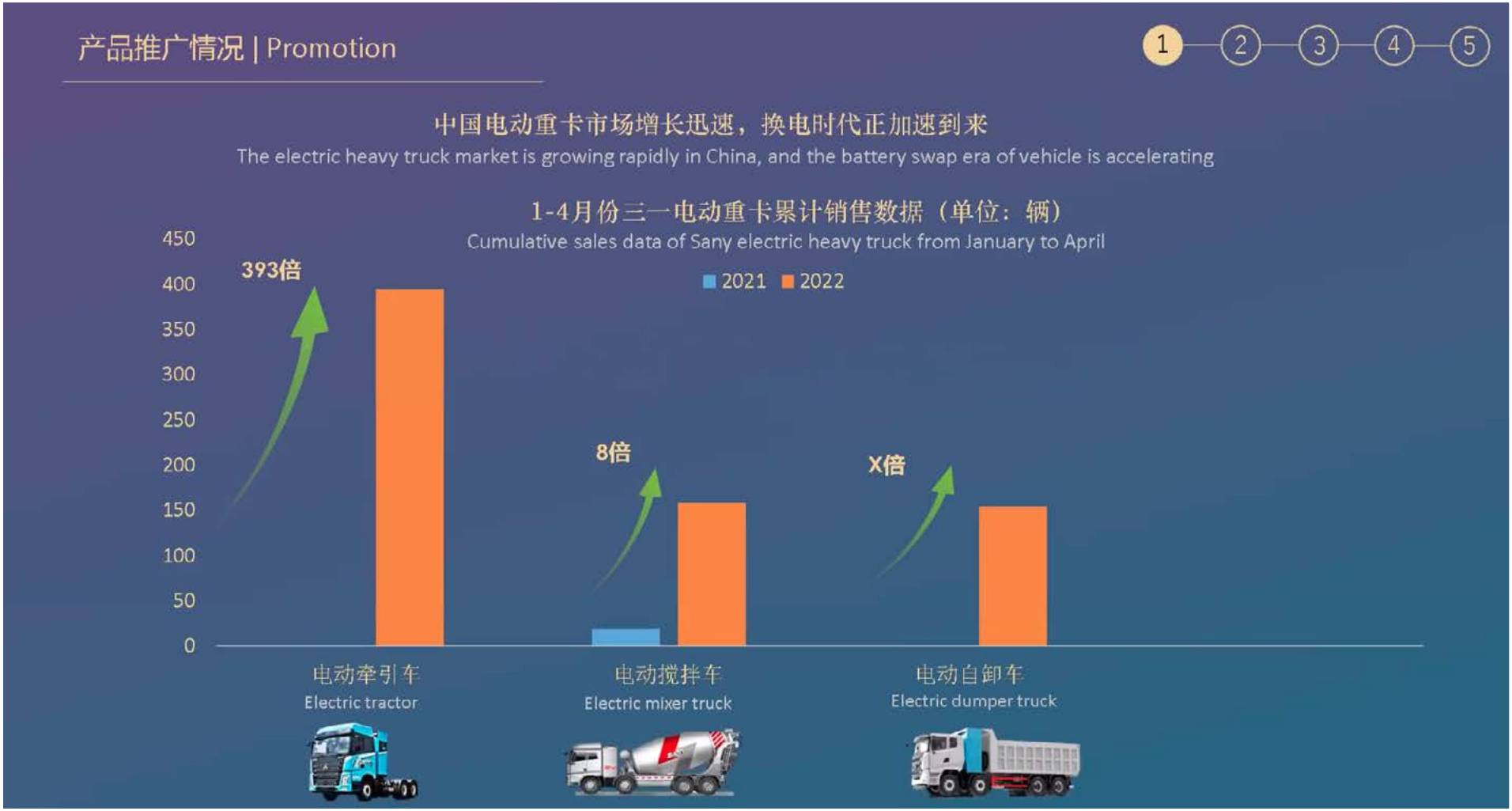
We have also launched our battery swapping station solution, now in its third generation.

The first-generation solution was launched last April. It is a fixed battery swapping station, which adopts visual positioning, a three-axis trolley, flexible charging, and other technologies, and is equipped with a restroom. The battery swapping time is five minutes, which is equivalent to the industry standard level.

The second-generation solution is based on integrated design, which adopts the idea of a container. It covers a relatively small area, and the installation time is relatively short. It can be installed in only three to five days, and the battery swapping time is five minutes.

The third-generation solution was launched last October and is a radical solution. The battery swapping station adopts a ring layout and a double gripper battery swapping mechanism so that the time of battery swapping action is controlled to within 90 seconds. From driving into driving out, the vehicle can complete the battery swapping in less than two minutes, that is, 1.9 minutes.

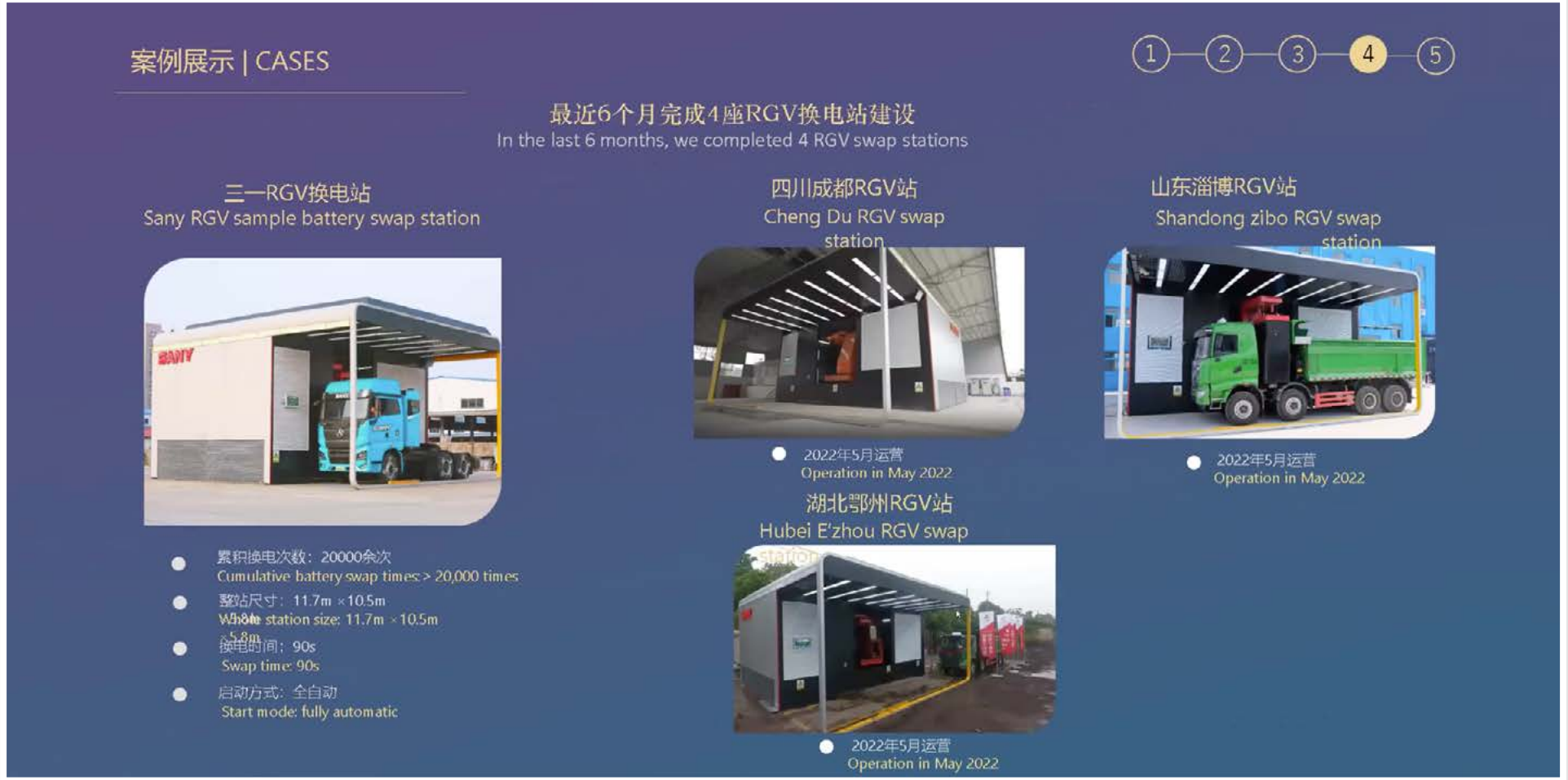
With 10 batteries in the station, there is no need for a spare cabin position, and the service capacity can reach up to 100 vehicles. We have been testing the system since its production last year, and there have been no faults in more than 10,000 tests so far. The battery swapping process is fully automatic. The station and vehicle, which are all our own, are deeply integrated. We have also developed our intelligent operation platform.



Sany's perception of battery swapping EHT market

The electric heavy truck market in China is growing rapidly. We believe that the era of battery swapping is coming fast, or has already arrived. Last year, more than 1,000 Sany heavy trucks were sold on the market, which is also the top-selling truck in the whole Chinese market. In April this year, it was also the top-selling truck. According to our sales data, the number of electric tractors sold has increased by more than 300 times from 2021 to 2022, and the number of electric mixer trucks has increased by eight times. Since the dump truck was not sold last year, its sales this year are also relatively good.

The two stations on the left of the image above are first-generation stations.
The three stations on the right are second-generation stations.



These are Sany's third-generation battery swapping stations. We call them RGV stations. The Hubei E'zhou swapping station can serve different kinds of trucks, as shown in the image above. Many of our stations can now serve different kinds of trucks.

In the next two months, we will build six battery swapping stations. In the city of Wuhan in Hubei province, we are establishing a city-level battery swapping network, which diverges from the traditional way of building isolated battery swapping stations for closed project scenarios. In Wuhan, we are trying to establish a public battery swapping station network.

In summary, we perceive that in the era of the electrification of transport, the charging mode has not succeeded in realizing the electrification of heavy trucks. It is with the application of battery swapping mode, we believe, that electrification of the heavy truck industry can be achieved.

FOTON

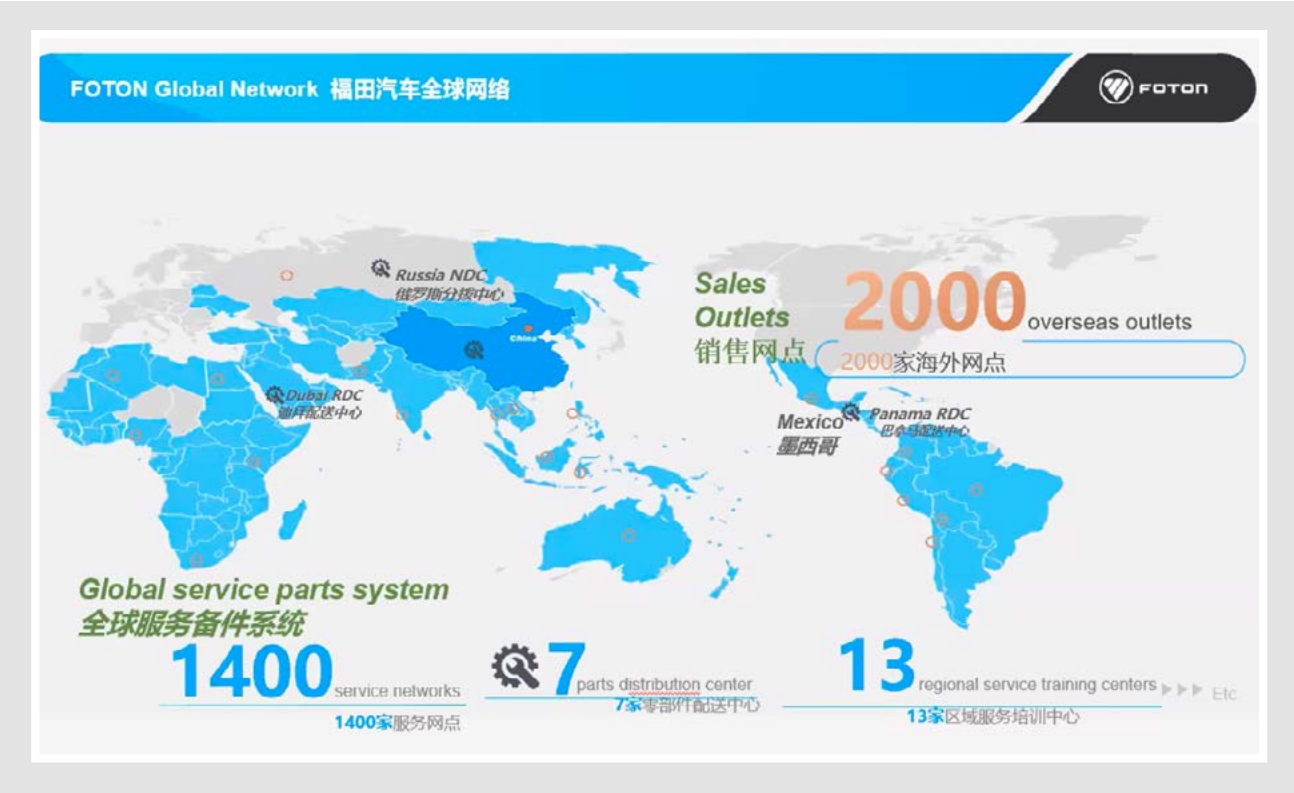
Foton is one of the pioneers in battery swapping for EHTs and one of the top truck OEMs in China deploying battery swapping for EHTs.

Speaker

Mr. Gao Yi, Vice President, Foton Intl. & General Manager, Europe Business Unit, Beiqi Foton Motor Co., Ltd.

Introduction to the company

Founded in 1996, our company is the largest manufacturer of commercial vehicles in China and the largest exporter of commercial vehicles. We have exported our commercial vehicles to more than 10 countries, with a total export volume of about 720,000 vehicles.



We have a series of commercial vehicle products, including heavy trucks, light trucks, pickups, buses, etc. Our first hybrid bus was launched in 2003, and then we began to produce and manufacture China's first hybrid bus. Meanwhile, we also provided electric bus fleet services for the 2008 Beijing Olympic Games.

Later, in 2009, our first electric truck was launched. Later, our range of electric vehicles was expanded to other product categories, such as trucks. As well as electric trucks, in 2019, we launched the first liquid hydrogen-fueled truck, with a total mileage of 1,000km. At the 2022 Beijing Winter Olympic Games, we provided 1,223 new energy vehicles, including 511 fuel cell electric vehicles to serve the event. In addition, we also took the lead in launching driverless trucks in China in 2016. At present, L3-level automatic driving technology has been put in use for this purpose.

Battery swapping for heavy trucks

Why?

Heavy trucks consume a large volume of power, and we must consider how to solve the problem of energy supply reasonably and effectively.

First, let’s calculate that for a typical heavy truck if the daily mileage is 500 km, the daily power consumption is 600 kWh. So, if we choose to have a large battery capacity and charge it once a day, the battery capacity needs to be very large. The capacity of the battery is 750 kWh, and the weight will reach 4,300 kg. The charging time is about six to eight hours overnight. The loading capacity will be very small because the battery weight is very heavy. In addition, the cost will be extremely high. Thus, these conditions are unacceptable, and the customer will not choose such an option.

The second option is to charge three times a day, and the battery capacity can be relatively small. In this case, the battery capacity is 250 kWh, the weight is 1,400 kg, and the charging time is at least six hours. It takes a long time to charge, once at night and twice during the day, so there is a need to develop the technology of battery swapping with heavy trucks.

Suitable scenarios for battery swapping heavy truck operation

First, the running mileage of the whole truck fleet of the battery swapping mode operation is relatively high; that is, the work intensity is relatively high. For example, the fleet's operation intensity is more than 300 km per day. Its operation time will be relatively long; for example, the daily operation time can reach 16 hours or even 24 hours. The haul distance is relatively short, and the one-way haul distance is less than 150 km.

The number of truck fleets is relatively large, and there are a relatively high number of vehicles. A fleet of more than 40 vehicles should be more suitable for battery swapping heavy trucks.

The suitable operation scenario is probably at ports, construction sites, mining areas, steel mills, power plants, etc.

FOTON battery swapping vehicles

FOTON launched our battery swapping buses in Beijing in 2009, and those buses are still in operation today. In 2020, we delivered our first batch of 20 battery swapping heavy trucks to customers in Beijing. By the end of 2021, we had sold 2,000 units of battery swapping heavy trucks.

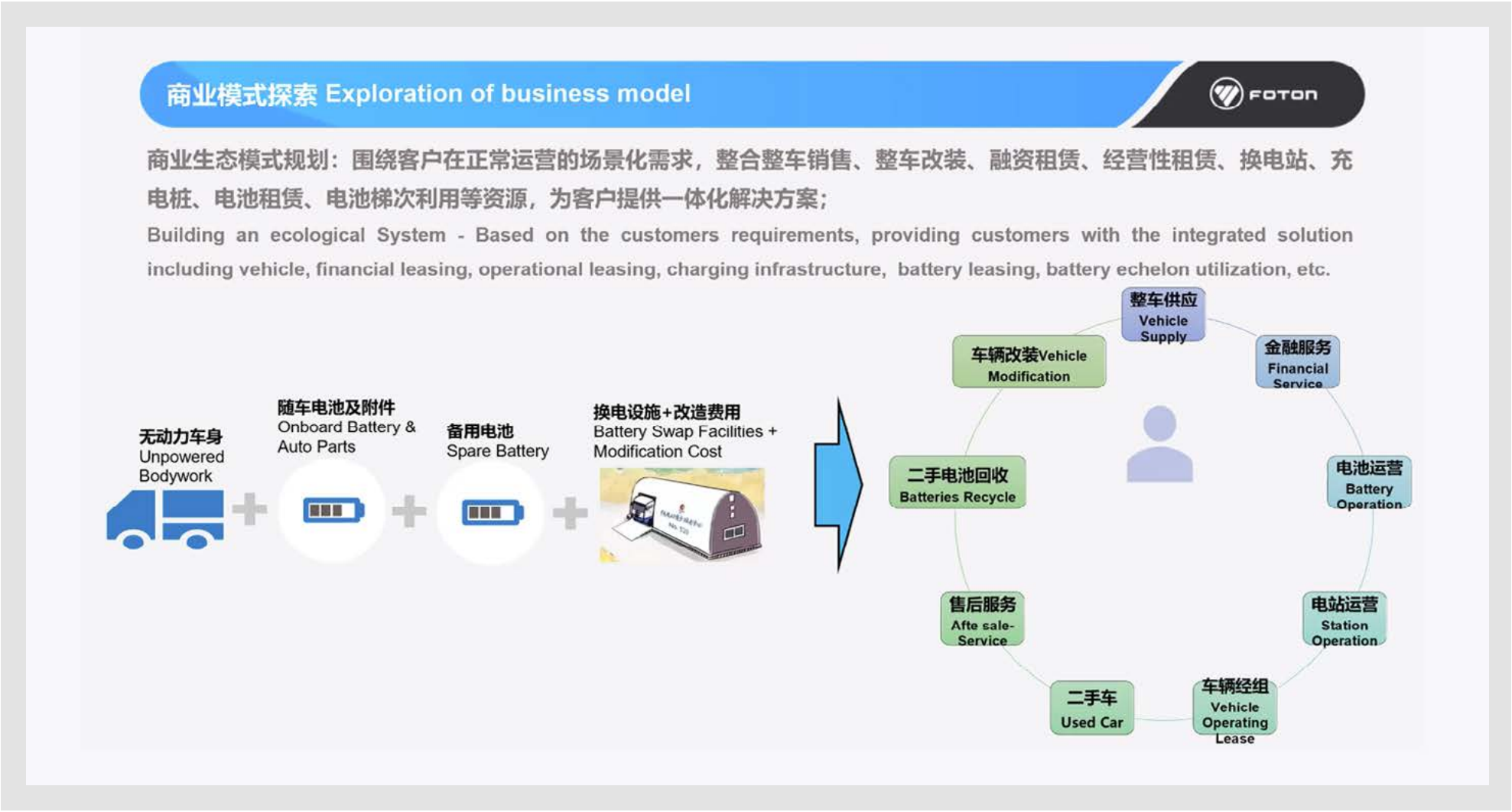
Vehicles

Our company's products in terms of battery swapping heavy trucks include tractors, mixers, and dump trucks. For example, the series driven by tractors includes 6 × 4, the dump truck is 8 × 4, and the mixer truck is 8 × 4.

The total weight of the tractor truck and dump trucks can reach 49 tons to 55 tons. For the mixer, the total weight of the vehicle is 40 tons.

Stations

The design of the battery swapping station is composed of four parts, which can meet the daily battery swapping demands of 50 vehicles. The total power distribution capacity has reached 2,000 kVA, and the area of the battery swapping station can be less than 120 square meters. The time taken for battery swapping is three to four minutes.



A total solution for customers

We have established a good business eco-system based on the needs of customers. For example, we work with our partners to provide customers with integrated solutions, including vehicle sales, vehicle modification, financial leasing, operational leasing, battery swap-ping stations, charging piles, battery leasing, and battery echelon utilization. Therefore, the overall business model does not concern only a single party but rather integrated solutions provided together with our partners.

Case studies

The first case is the concrete industry. There are two power stations in this project, which mainly serve tractors and mixers for aggregate and concrete transportation.

The second project is for the Qinghai lithium mine. They have a total of 150 vehicles, including tractors, trailers, and mixers, which are used for transportation throughout the entire lithium mine, including at the mine site and outside the mine.

The third case concerns port transportation, mainly vehicles used in port loading and unloading. There are a total of 50 vehicles. This port is also one of the largest in China, including these operating vehicles inside and outside the port.

Mining Industry cases in China 中国矿业案例

FOTON

Mine(Area Closed)
矿山（封闭区域）

Qinghai Lithium Mine
青海锂矿

Cargo 运输货物	Transport 运输工具	Volume 容量	EV quantity 电动车数量	Operating distance（km） 运营里程（公里）
Salt mine 盐矿	Tractor/trailer/Dumper 牵引车/挂车/搅拌车	19500 Tons/day 19500吨/天	150 units 150辆	200km/day 200公里/天

Dubson Train Station
杜布森火车站

90km
90公里

Outside
外部

45km
45公里

Qinghai Lianyu Potash Fertilizer Plant
青海联宇钾肥有限公司

Mines（Salt precipitation）
矿井（盐析沉淀）

12km
12公里

Inside
内部

Mine yard
矿山工业场地

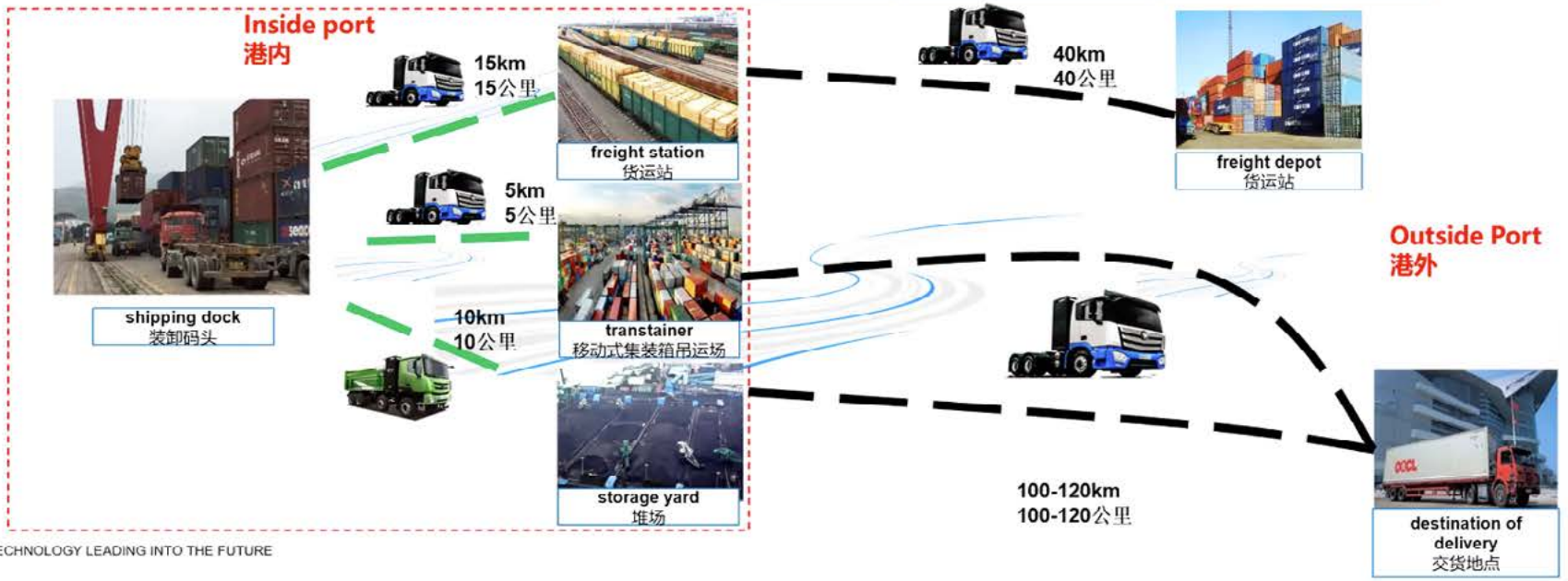
Port Transportation cases in China 中国港口运输案例

FOTON

Port Handling(Area Closed)
港口装卸（封闭区域）

Guangzhou Port (One of the largest ports in China)
广州港（中国最大的港口之一）

Cargo 运输货物	Transport 运输工具	Volume 容量	EV quantity 电动车数量	Operating distance (km) 运营里程（公里）
Grain, coal, containers 谷物、煤炭、集装箱	Tractor/trailer/Dumper 牵引车/挂车/搅拌车	1.74 million Tons/day 174万吨/天	50 units 50辆	80-150km/day 80-150公里/天



BEIJING HIGHWAY & RAILWAY GREEN MULTIMODAL TRANSPORTATION

The first transportation company that pioneers operating battery swapping trucks in China.

Speaker

Mr. Wang Bo, Vice President

Battery swapping operation experience

Founded in August 2019, our company is the world's first transportation service company to build and operate battery swapping stations for electric heavy trucks.

We began to invest in establishing China's first three battery swapping stations in November 2019 and 2020. The total investment in the construction of station 1 is about CNY 6 million, and for station 2 and station 3 about CNY 5.9 million each. The cost of batteries is CNY 410,000 for each station. By 2022, the cost of construction for a battery swapping station (including the cost of equipment) has been greatly reduced to below CNY 4.5 million. We now have 96 battery swapping dump trucks and 96 tractors, among which 15 are charging electric vehicles. The total annual transportation capacity has reached 4 million tons. One power station can meet the battery swapping needs of 40-45 vehicles.

At present, the time taken for battery swapping is five minutes, the success rate of automatic battery swapping is 99.9%, and the charging power is 2,100 watts. There are a total of eight charging cabins in each station, and the service capacity is 168 times in 24 hours. All kinds of heavy truck models can be served. At present, one station covers an area of 200 square meters. In 2022, the construction cost of our battery swapping station, including equipment, is about CNY 4.5 million.

We have now reduced the energy consumption of our truck fleet by 10% under the battery swapping mode. First, the vehicle is separated from the battery, and the purchase cost is relatively low. Second, energy replenishment is faster than refueling. Third, power distribution and land are saved. Fourth, the vehicle operating cost is low, and the battery operation is safer.

Device data

Average daily driving distance: 600 km

Daily freight of sand and gravel: 100 trucks travel four times with 28-ton loads each time. 11,200 tons per day in total.

Annual transportation volume: 340 million tons.

Annual driving distance: 100 trucks * 600 km * 300 days/year= 18 million km

Annual electricity consumption: average electricity consumption is 1.4 kWh/km, 23.58 million kWh per year.

Annual electricity bills: average electricity bill is 0.72 Yuan/kWh, 17 million Yuan per year.

Decreased carbon emissions compared to diesel trucks: calculated by 50 liters per 11 km and 300 days a year with 30,000 liters per day, the annual diesel consumption is 9 million liters. This means a decrease of 23,670,000 kg of CO_2 emissions.

Disadvantages of electric heavy truck charging mode

Heavy battery weight. Cargo capacity declines by 10% to 20%.

High-power charging facilities are in short supply.

Conventional fast charging takes a long time, and the operation time declines by over 20%.

The size of the vehicle is relatively large and occupies a large space in charging sites. The utilization rate of charging power is low, the capacitor occupation is high, the impact on the power grid is relatively high, and the planning and construction of the charging station is also relatively difficult.

Advantages of electric heavy truck battery swapping mode

High efficiency.

Decreased cost. When separating the vehicle body and battery, the purchase cost of trucks decreases to a level similar to traditional diesel trucks.

Flexibility. According to the working conditions, we can flexibly replace different batteries and battery packs. According to the transportation distance, at present, our battery pack is 282 kwh, and the approximate weight is less than 3 tons, reducing the body weight and improving the effective utilization rate of battery assets.

Safe. Centralized charging management, safe and reliable. It can extend the service life of the battery by more than 20% and increase the echelon utilization value of the battery.

High efficiency in utilizing urban land resources. Avoids long charging times and occupies large areas of land, which is the greatest advantage of the battery swapping mode compared to the charging mode.

Q&A FROM THE AUDIENCE TO THE CHINESE PARTICIPANTS

Below are some questions asked by the Swedish audience to the Chinese participants and their answers.

1. **What is the influence of battery swapping mode on the gravity, stability, and balance of heavy trucks?**

   Sany: Based on our road testing results, the safety performance satisfies national regulations. After the battery is placed, the width of the truck is still the same as before; however, the length of the vehicle will indeed increase by 850 mm, which is equivalent to a decrease in the turning radius. This is the main change the battery swapping mode brings to heavy trucks.

2. **Under the battery swapping mode, truck OEMs have concerns that they might lose control of batteries and the whole vehicle. How does the current business model of battery swapping mode for EHTs address this issue?**

   Sany: At present, this kind of situation in China generally does not happen. Why? The data from the battery throughout the whole operation process is connected to the cloud and can be retrieved through the network. On the other hand, in China, we have the advantage of this battery and vehicle separation mode. Centralized management will be of great help to the health of the battery.

3. **Truck OEMs have concerns that they will lose economic benefits under battery swapping mode. How can we address these concerns?**

   Sany: This is a situation we have encountered, and I can share our experience here. In the beginning, we adopted the charging mode

for our electric mixer trucks. We thought that the price of charging mode electric mixer trucks is high and can therefore bring a higher profit when we sell the truck. However, this perception ignores the fact that even though the charging mode brings higher unit profit when the price is too high and customers are unwilling to buy the truck, in the end, we will sell fewer units of trucks and achieve lower economic results.

As I have said earlier, charging mode does not open up for the era of electrification of heavy trucks. Based on our past two years of experience in the field, after we adopted battery swapping mode for heavy trucks, and especially after we established our battery swapping station solution, the sales of electric heavy trucks increased significantly. It is beneficial very much to support OEM's sales volume. The reason is the advantages of the battery swapping mode. First, there is the advantage of fast energy replenishment. Second, there is the decreased purchase cost of EHTs. As long as battery swapping stations are established

in one area, when other customers see operators, operating battery swapping EHTs, they will also opt to buy battery swapping EHTs and establish stations.

In terms of concerns that battery swapping mode EHTs might decrease OEMs' economic benefit, this did cause hesitation among OEMs in the early stages. However, as long as OEMs have tried the mode, especially when the mode opens door to market sales volume, it won't be a problem anymore.

4. What is the influence of battery swapping mode for EHTs on the grid side?

SPIC: Compared with the charging mode, there are great differences in the structure and operation of the battery swapping mode. First, in terms of structure, the battery swapping station is positioned not only as a stable and orderly charging load but also as a distributed energy storage unit. On the contrary, the charging mode reflects more of the characteristics of a pure load, and because the customer's vehicle needs to be charged immediately after it arrives, it may require a very large number of charging piles and a large amount of land to allow several vehicles to charge concurrently. The impact on the power grid is therefore inevitable because the load is unplanned. Once the customer's vehicles come into the charging station, their vehicles need to be charged immediately and concurrently. The generation of high-power loads can easily impact the power grid. I believe we will encounter this problem when pushing large-capacity heavy vehicles all over the world.

Second, in terms of the operation mode whether it is the charging mode or the battery swapping mode, the V2G (vehicle-to-grid) mode we mentioned previously is essentially the interaction between the battery and the power grid. In the charging mode, the battery goes with the vehicle without being removed. The time when the battery will interact with the grid is highly random. Only when the vehicle needs to be charged and stops can it participate in the interaction with the power grid, so there is no way to form a truly planned scheduling, and it is difficult to match the auxiliary power response time required by the V2G power grid. When the frequency and power required by the power grid cannot match the rhythm of heavy truck operations of logistics companies, it cannot provide matching services.

There is a lot of overlap between the logistics industry and the peak-to-valley period of power grid dispatching. Manufacturing companies need a lot of electricity. When they are producing at full power, it is precisely the busiest time for logistics, so under the charging mode, it is difficult for the EHT to provide support to the grid side.

There are always backup batteries in the battery swapping station. V2G in the battery swapping station has become the interaction between the backup battery and the power grid. Because there is always a backup battery, the interaction with the power grid becomes smooth and orderly.

If the battery swapping station is public, it is not easy to forecast patterns of customer consumption. However, for scattered single battery swapping stations that serve specific projects, the load of the battery swapping station can be well planned and scheduled. We can predict exactly the idle period of the battery swapping station. We can use the predicted idle power and the energy storage capacity of the backup battery to interact with the power grid. Therefore, in terms of the feasibility of the interaction with the power grid, the battery swapping mode is also significantly better than the charging mode.

To sum up, the first point is that because the battery swapping station and the battery swapping mode have the characteristics of energy storage, they can provide the feasibility of frequency modulation and

peak shaving, to improve the operational stability of the power grid. At the same time, as the end point of the power grid, the battery swapping station can smooth the load fluctuation and reduce power loss at the distribution network level. In the process of renewable energy power generation, namely wind power and photovoltaic power generation, natural energy storage are needed to improve the quality of electric energy. The combination of battery swapping stations and clean energy power generation can supplement the current weak links of the grid system and provide a backbone network for stable power generation.

5. What is the progress of standard development in the field in China?

Professor Li Liguo: At present, from the management department of the automotive industry to the China electricity union under the Energy Bureau responsible for charging, the focus is on the standardized layout in two directions. The first is the interchangeability standard and safety standard of the vehicle end, and the second is the interchangeability standard and safety standard of battery swapping infrastructure. These standards are currently in the process of project approval, opinion consultation, and standard formulation and have not been released at the industry and national levels. However, we predict that there should be some releases this year, and major standards may be released next year.

Internationally, we have participated in the communication of international heavy truck supercharging standards. We see that internationally, we mainly follow the standard of megawatt charging level.

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