Artificial Intelligence and the Rise of the Chinese EV Industry

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***Abstract*—This paper examines how artificial intelligence (AI) has enabled China's rapid emergence as the dominant force in global electric vehicle (EV) production. While Western analyses often emphasize demand-side subsidies, this study demonstrates that China's competitive advantage stems primarily from systematic AI integration throughout the entire EV value chain—from initial design and battery development through manufacturing optimization and supply chain management. AI technologies enable Chinese manufacturers to accelerate product development cycles, reduce production costs, enhance vehicle performance, and respond dynamically to market demands. The analysis reveals how AI-powered tools facilitate advanced capabilities including generative design, digital twin prototyping, intelligent battery management systems, autonomous driving features, and predictive supply chain optimization. Furthermore, this paper highlights complementary government policies that have been instrumental to industry success, particularly strategic investments in enabling infrastructure such as ultra-high voltage power grids and nationwide 5G networks. This study argues that China's leadership position results not merely from subsidization but from a comprehensive innovation ecosystem where AI serves as the foundational technology driving competitive advantage across design efficiency, manufacturing excellence, and operational intelligence throughout the EV industry.**

***Key Words*—Electric vehicles, artificial intelligence, product development, manufacturing, China, industrial policy.**

I. Introduction

In May 2024, the Biden administration imposed a 100% tariff on Chinese-made electric vehicles (EVs). Canada followed suit in August. Across the Atlantic, the European Union has also introduced its anti-subsidy duties targeting EVs made in China. Behind this new wave of trade protectionism is the rapid rise of Chinese EV manufacturers and component suppliers. After all, more than 70% of EVs produced globally in 2024 were manufactured in China [1].

Western policymakers and their advisors tend to highlight Beijing's intervention to stimulate demand–that is, sales tax exemptions, purchase rebates, and public procurement requirements–as the explanation for the success of Chinese EV manufacturers [2][3]. To be fair, the over $200 billion spending does deserve a special treatment[4]. However, there are more worth noting. In particular, this article argues, Western policymakers should pay more attention to Chinese EV manufacturers' efforts to integrate artificial intelligence (AI) into the design and manufacturing of EVs and their core components, which has significantly shortened the research and development cycle and reduced production cost, and policies of the Chinese government that have complemented the manufacturers' efforts.

The rest of this article will elaborate on this argument in three steps: First, to establish the need to look into the subject, more details will be provided on the dominating influence of Chinese EV manufacturers and component suppliers in the global EV market. The article will then move on to explain the four stages of an EV's design and manufacturing cycle and give examples of how AI can be integrated into each stage. Many policymakers will find this technical aspect new to their knowledge. Thirdly, the article will turn to the Chinese government's role in funding research and development (R&D) and two infrastructure investments that have been critical to the mass adoption of EVs in China. Technical specialists tend to be less familiar with this political side of the story. The article will conclude with a short discussion of what the West might learn from the Chinese experience.

II. The Rise of EVs and Chinese Manufacturers' Dominance

According to the International Energy Agency, over 17 million cars sold globally in 2024, or one in five cars sold, were EVs. For reference, only three million EVs were sold in 2020, and the share of EVs in overall car sales is set to exceed 40% in 2030 under today's policy settings [5]. While it is still unknown if EVs will eventually displace conventional internal combustion engine cars in the market, it is certain that the history of automobiles has entered a new era. Importantly, the dawn of the EV era is accompanied by the emergence of Chinese automakers.

By definition, all vehicles that are at least partially powered by electricity stored in rechargeable batteries and use electric motors for propulsion are electric vehicles (or new energy vehicles as they are more widely known in China). Currently, the global EV market is dominated by battery-electric vehicles (BEVs), which run solely on electricity from batteries, and plug-in hybrid electric vehicles (PHEVs), which are equipped with both electric motors and gasoline/diesel engines. Based on sales data in 2024, the world's leading BEV manufacturers are Telsa and BYD, which share 16.5% and 16.3% of the market respectively (see Figure 1). When PHEV sales are added, Tesla's market share drops to 10.4%, while BYD's rises to 24.7% (see Figure 2). The only legacy automaker that entered top five is the Volkswagen Group and yet Volkswagen,

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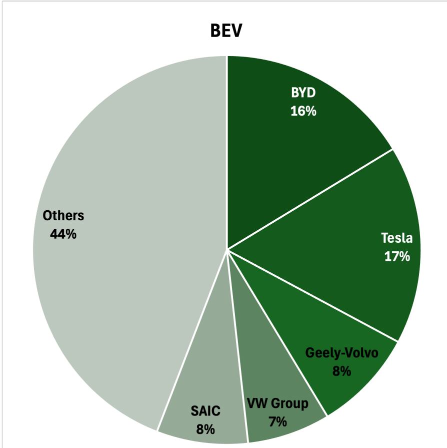

Fig. 1. Global Market Share by Major EV Manufacturers, 2024 (BEV).

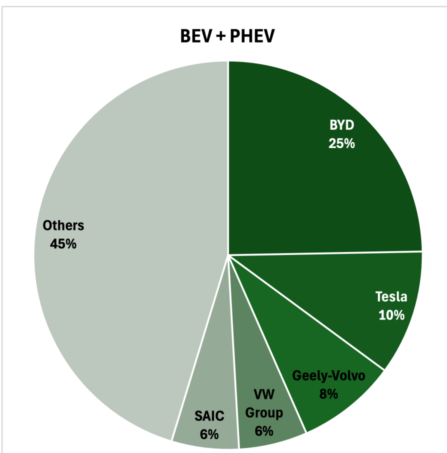

Fig. 2. Global Market Share by Major EV Manufacturers, 2024 (BEV+PHEV).

Audi, Porsche, and so on all brands owned by the German conglomerate together hold a market share of just 5.7% [6].

As mentioned earlier, EVs' share of global passenger car sales is set to exceed 40% in 2030. What will the market look like then? China offers a quite upsetting possible scenario: For decades, legacy automakers like Germany's Volkswagen, Japan's Toyota, Honda, and Nissan, and America's GM dominated the world's largest passenger car market. As shown in Figure 3, as recent as 2020, foreign brands still accounted for 64% of the sales. By 2024, however, that share had fallen to 35%. In the meantime, EVs' share of total passenger car sales surged from 5% to 44%, and the best-selling brands today are BYD (Chinese EV manufacturer, private), Geely (Chinese automobile manufacturer, private), Chang'an (Chinese automobile manufacturer, state-owned), Chery (Chinese automobile manufacturer, mixed ownership), and SAIC (Chinese automobile manufacturer, state-owned)[7].

Even more upsetting is that, for legacy automakers, perhaps the best way to catch up with their Chinese competitors is to rely more on Chinese suppliers for components. Having recognized the difficulties in breaking legacy automakers' monopoly

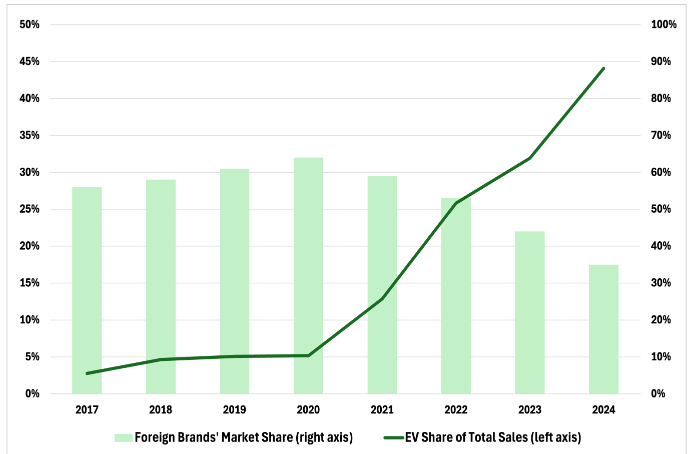

Fig. 3. China's EV Boom and Foreign Automaker's Crisis.

on internal combustion engine technologies, China's industrial policy makers went all-in into EVs, especially lithium-ion batteries, in the mid-2000s [8]. The venture turned out to be highly successful. Today, the world's leading battery producers are China's CATL and BYD, which together share 55% of the market [9]. Even if an EV manufacturer decides to make its own batteries, it will find 85% of cathode active materials and over 90% of anode active materials on the global market are supplied by Chinese companies [10].

III. AI's Transformative Role in EV Design and Manufacturing

The success of Chinese EV manufacturers and component suppliers is closely linked to the integration of AI into vehicle design and manufacturing.

Artificial Intelligence (AI) refers to a set of technologies that enable computers and machines to simulate human learning, comprehension, problem-solving, and decision-making processes. The field of AI originated from the idea that machines might be able to learn and think as humans. AI systems are based on neural network models and can mimic how our brains process information and use it to perform new tasks and adapt to un-encountered situations. Because they can learn and think, AI systems can handle more complex, ambiguous tasks than traditional software programs. Because they can process millions of data points in seconds, AI systems have outperformed humans in many data-heavy domains. Core AI technologies include machine learning [11][12], natural language processing [13], computer vision [14], and generative AI [15]. These technologies can be applied in healthcare [13], financial services [16], transportation [17][18], and manufacturing [19].

The advent of AI has also transformed the automotive industry. This section will provide nine examples. A fuller list of AI's potential applications in EV design and manufacturing can be found in the Appendix.

A. Conceptualization and Design

As in the case of petrol cars, the making of an EV begins with conceptualization and design. Based on pre-researched

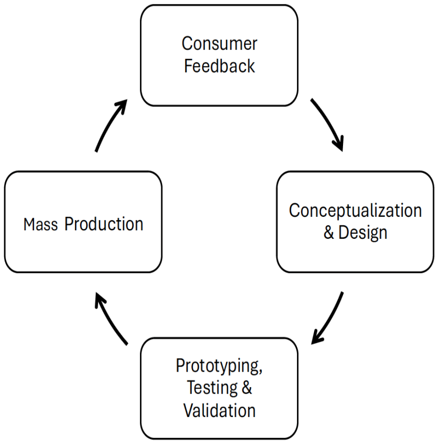

Fig. 4. The Design and Manufacturing Cycle of an EV.

consumer demands and market trends, the designers will put forward a rough idea of the next car's form and function. Examples of the former include, with respect to the exterior, shape and color and, with respect to the interior, cabin layout and seat fabrics. Examples of the latter include advanced driver assistance (or autonomous driving if the driver wants to set her/his hands completely free) and infotainment (a dashboard which can be controlled through touch and voice to provides information like navigation and entertainment like music). The engineers will then try their best to realize the design by experimenting with different materials and technologies.

1) AI and Car Body Design: AI can play two transformative roles in this stage. The first one is to expedite design–AI-powered computer-aided design (CAD) platforms allows designers to visualize their ideas for the car body in 3D and make adjustments with ease [20]. The most advanced platforms can also provide simulation and validation, which gives the designer quick, if not spontaneous, feedback on aerodynamics and safety.

2) AI and In-Car Voice Assistant: Secondly, AI allows engineers to turn more features from imagination to reality. One feature that can be particularly appealing to contemporary drivers is the voice assistant, which gives them hands-free control for vehicle setting (e.g., adjust seats), navigation (e.g., find the nearest service area), and entertainment (e.g., play a specific song). The two key AI technologies enabling this feature are natural language processing, which allows the voice assistant to comprehend the driver's verbal commands, and generative AI, which allows the voice assistant to respond [21]. Voice assistant is now a standard feature in Chinese EVs. For example, BYD has Xiao Di, XPeng has Xiao P, and AITO uses Huawei's Xiao Yi (Celia).

3) AI and Autonomous Driving: Another smart feature that can boost sales is autonomous driving [22]. According to standards set by the Society of Automotive Engineers, autonomous driving can take place at five levels–from Level 1 basic driver assistance such as providing lane warnings to Level 5 full automation, in which case no human intervention is needed at all. In other words, to achieve Level 5, a vehicle must be able to see as clearly and react as swiftly as a human. And AI technologies like computer vision and deep learning are making human-level performance possible. While an EV is on the road, powerful AI algorithms continuously process real-time traffic data captured by sensors (i.e., cameras, radars, and LiDARs), identifying vehicles, pedestrians, traffic signals, and so on road conditions, and send instantaneous commands for steering, accelerating, and braking. Moreover, AIs can learn from real-world driving experiences to continuously improve their accuracy and adaptability to different environments.

No automaker or technology company has been able to bring Level 5 full automation into reality yet. Google's Waymo (since October 2020) and Baidu's Apollo Go (since August 2022) have been rolling out Level 4 robotaxis in the United States and China respectively [23]. Those looking for taxi rides can now hail a driverless robotaxi via a smartphone app similar to Uber in Phoenix, San Francisco, Atlanta, Beijing, Shanghai, and Shenzhen. Chinese EV manufacturers, meanwhile, are preparing for mass Level 3 production [24]. For long-distance drivers, being able to take their hands off the steering wheel can be very tempting, especially when highways get congested during holidays.

More often, however, one car model outsells another not for offering eye-catching, unique features but for offering features that are essential to all EVs in higher quality at a lower price. The most important component of an EV is the battery pack, which determines its driving range and largely determines its lifespan (because of the high replacement cost). The battery pack alone can make up 40% of an EV's total cost. An on-board charger converts alternating current (AC) from home outlets into direct current (DC), so that the battery can be (re-)charged at home. Another important component of an EV is the electric motor, which is responsible for converting electric energy stored in the battery into kinetic energy that moves the wheels. An inverter converts DC from the battery back into AC to drive the motor. In addition, there is the low-voltage DC-DC converter, which converts high-voltage battery DC to 12V for lights, infotainment, and so on electronic systems in the vehicle. The Vehicle Control Unit (VCU) processes driver inputs such as accelerating/decelerating and sensor data and issues commands to these devices.

4) AI and Battery Performance: AI can help improve the design and therefore the performance of these components. Take the battery as an example. A car that can travel farther on a single charge naturally appears to be a better deal than a car that needs charging more frequently. Larger batteries are generally capable of traveling farther, but they are also heavier and occupy more space in the car, which can cost a car more energy to move. Nickel, Manganese, Cobalt (NMC) batteries offer higher ranges, but lithium iron phosphate (LFP) batteries are both cheaper and safer [25]. AI tools can help designers and engineers make choices between these pros and cons. AI can also help expedite the development of next-generation batteries by evaluating millions of chemical compounds in days, whereas traditional screening and validation methods can take years. And CATL is even using AI to create molecules based on performance targets from scratch [26].

Apart from altering the materials, a battery's performance can be improved with smarter energy management systems

[27, 28, 29]. A battery pack is composed of hundreds or thousands of small battery cells, which are grouped into modules. These modules are integrated and managed by a Battery Management System (BMS). Machine learning algorithms can help optimize an EV's energy usage and extend battery life by analyzing voltage, current, and temperature data and balancing cells and controlling charging/discharging, power flow, and temperature accordingly while the vehicle is on the road. In addition, machine learning algorithms can help provide more accurate State of Charge (SoC) and State of Health (SoH), so that drivers can optimize their travel plans and vehicle maintenance schedules.

5) AI and the Control Units: Another example is the control system. The operation of an EV is supported by many control units. The Vehicle Control Unit (VCU), in particular, serves as the brain, translating signals from the driver and the various sensors built in the vehicle into action instructions to other electronic control units, including the battery management system, the motor control unit, the electric power control unit, the thermal management system, the body control module, and so on.

Researchers from the academia and the industry side have actively employed AI in improving the design of these control units. For example, a novel electronic differential system (EDS) control architecture is proposed to offer a new approach for the traction system that can be used with a great variety of controllers in [30].

B. Prototyping, Testing, and Validation

The next stage involves prototyping, testing, and validation. Before a new car can be introduced to the market, it must be tested for performance, durability, and safety. For example, can the car travel the desired distance on a single, full charge? Can the battery manage extreme temperatures and sudden temperature swings? Can the chassis endure hard road surfaces? Can the autonomous driving system deal with more complex road conditions such as cut-in vehicles when traveling on a highway? Can safety features like seatbelts and airbags effectively protect the occupants during a crash?

Traditionally, the tests are conducted in real-world settings on full-sized physical models and as a result can be very costly (in the case of crash tests) and time-consuming (when major design changes are found necessary by the tests). Today, AI tools allow manufacturers to first create a virtual replica of the car, including all its components and the whole control system, and use the "digital twin" to run virtual battery performance tests, integration tests of complex systems like the motor controller and thermal management systems, aerodynamic and structural stress tests, weather simulations, road condition tests, and crash tests. A physical prototype will be built based on results from the virtual testing, and the "physical twin" will be sent to physical testing. During the physical tests, machine learning algorithms will analyze live data collected from sensors equipped on the physical twin and suggest design improvements. The improved design will then be tested virtually using a new digital twin [31]. The cost for building an automotive proving ground can easily go over $100 million and for a completely new car the physical testing and validation phase can last multiple years [32]. For virtual prototyping and testing, these costs can be dramatically reduced as a significantly smaller number of physical prototypes and real-world tests are needed [33].

C. Mass Production

Finally, the vehicle is ready for mass production. Breaking the complex process of producing a car into a sequence of specialized yet simple, repetitive tasks and connecting these tasks with a conveyor system has been practiced by automakers around the world since the days of Henry Ford. A typical assembly line is composed of a body shop where parts of the car body are either casted or stamped into shape and welded together, a paint shop where paint is applied, the main assembly where the dashboard, the electric motor, the battery pack, seats, windshields, lights, wheels, tires, and doors are installed, and quality control where the finished car is inspected and tested before being released to the market. Complex components like battery pack and electric motors, of course, need to go through their own production process. Some EV manufacturers are building their batteries in-house, while others have decided to source dedicated battery makers. Examples of the former include Tesla and BYD. Examples of the latter include Hyundai and LG Energy Solution and Stellantis and CATL [34, 35].

1) AI and Automated Assembly: Henry Ford's assembly lines were primarily operated by humans. In 1961, General Motors introduced the first industrial robots to the assembly line. While automation has already significantly extended production hours and reduced labor cost and human error, AI-powered assembly lines can do even better [36]. Robots on traditional automated assembly lines can only perform pre-programed simple tasks like stamping and lifting and fix a limited number of pre-defined errors. Equipped with sophisticated vision systems and force sensors, AI-powered robots can handle more delicate tasks like welding and installing tiny electronics. Being able to "see" more details also allows AI-powered assembly lines to detect smaller flaws and therefore implement stricter quality control. Because they are capable of learning, AI-powered robots can predict machinery failures based on past experience and real-time production data and carry out preventive maintenance, thereby reducing factory downtime.

The EV industry is arguably the most globalized industry in the world. A European consumer can easily find her BMW car designed by a German engineer but manufactured in China using aluminum from Russia for car frames and lithium from Chile, nickel from Indonesia, and cobalt from the Democratic Republic of Congo for battery. Such a geographically dispersed supply chain can be highly susceptible to disruptions like natural disasters, political conflicts, or simply accidents, and the cost of a single disruption to production can be huge. For example, a six-day blockage of the Suez Canal by a stranded container ship cost the global economy more than $50 billion in March 2021 [37]. One way to insure against supply chain disruptions is to stock up on inputs. However, inventories will need space to store and, if demand falls short of supply, unutilized inventories become profit losses. AI tools can help managers forecast demand and optimize inventory levels.

2) AI and Inventory Optimization: Traditionally managers have relied on historical sales data, static forecasting models such as weighted average, and their business intuitions to predict future product demand. The accuracy of these predictions averaged 70-80%. In comparison, machine learning algorithms–Gradient Boosting Machines [38], Support Vector Machines [39], and Long Short-Term Memory [40] to name a few–can achieve accuracy rates of 90-95% [41]. Such high accuracy rates are achieved because machine learning algorithms are capable of processing not only historical sales data but also real-time Point of Sale (POS) data, competitor activities, economic indicators, policy signals, weather, and even social media trends.

With more accurate forecasts, managers can optimize their stock levels, thus minimizing carry costs. Importantly, because AI forecasting is based on real-time data, managers can now make real-time decisions on production scheduling, inputs procurement and replenishment, and outputs distribution. According to McKinsey, the integration of AI-driven forecasting into supply chain management can reduce supply chain errors by 30-50%, which equals up to 65% reduction in lost sales due to product unavailability, 5-10% reduction in warehousing costs, and 25-40% reduction in administration costs [42]

D. Consumer Feedback

Once a new model is introduced to the public, the next design and manufacturing cycle kicks off. The basis for this next cycle is consumer feedback on the new model and general demands and market trends.

In the past, consumer feedback could only be seen in sales data and collected in stores and through mail-in questionnaires or telephone interviews. Sales data might be able to tell what consumers prefer among a limited number of model choices, but cannot tell what individual consumers want, which is key to optimize customer experiences and build lasting brand loyalty and to identify market segments and the unique concerns within each segment and guide product development. Surveys that rely on structured questions–that is, scales or multiple-choices answers–also only reveal preferences not wants. It is well possible that what a consumer truly wants is not included in one of the choices. One-on-one interviews might allow researchers to get more details and nuances through interactions, but the interviewee can be influenced (intentionally or unintentionally) by the interviewer. Most importantly, traditional market research methods can reach only a small sample. Can a few hundred interviews represent hundreds of millions of consumers?

Today, automobile manufacturers can use natural language processing tools such as topic modeling and sentimental analysis to collect and process unstructured data like product reviews posted on e-commerce sites and specialized review platforms, customer support conversations and chats, and related social media posts to understand more complex, emotional responses towards a product or brand in real time at massive scale [43][44]. In addition, through monitoring these web resources, AI tools can help manufacturers identify emerging topics and predict the next big market trend. The more an EV manufacturer knows about its consumers, the better it can cater to their needs and build their brand loyalty. The more the manufacturer knows about the market, the more effectively it can introduce new EVs and expand its consumer base.

IV. Complementary Policies of the Chinese Government

The Chinese government has undoubtedly played a crucial role in the EV industry's rise. Much attention in the West, however, has been attracted by subsidies targeting the demand side, namely, sales tax exemptions, purchase rebate, and public procurement requirements. Such policies might stimulate consumer demand for EVs in the short run but are fiscally unviable in the long run. This section, instead, will focus on Beijing's efforts to accelerate research and development and promote private-sector investment in the electric alternative and to provide the infrastructures that are essential to vast deployment of next-generation EVs.

A. Policies Targeting the EV Industry

China had virtually no EV industry before the government intervened. Inspired by Ronald Reagan's *Star Wars*, China launched its own *State High-Tech Research and Development Program* in 1986. In 2001, "new energy vehicles" were officially incorporated into the Program. The government took the lead in pairing state-owned automotive manufacturers with China's top research universities, and between 2001 and 2005 ¥880 million were allocated to explore different powertrain designs [45]. In 2008, 55 electric, 25 hybrid, and 20 hydrogen fuel cell vehicles made their debut at the Beijing Summer Olympics [46].

The next major push for EVs came in 2009. In part to revive the Global Financial Crisis-hit economy and in part to clean up the sky, the State Council's National Development and Reform Commission (NDRC) issued an *Automotive Industry Adjustment and Revitalization Plan* in March. An additional ¥10 billion were allocated to the EV industry. On top of that, state-owned banks were instructed to provide low-interest loans to promote the private sector to invest in EVs. The goal was to produce 500,000 battery, plug-in hybrid, and hybrid electric cars and to raise the electric alternative's share of total new passenger car sales to 5% by 2012.

Also in 2009, the Ministry of Finance (MOF) and the Ministry of Science and Technology (MOST) jointly launched the "Ten Cities, Thousand Vehicles Project" [46]. In the next three years, a total of 25 cities signed up for the Project. These "pilot cities" would give each hybrid-electric car up to ¥50,000 subsidy depending on its fuel economy, each battery-electric car ¥60,000, each fuel cell car ¥250,000, each hybrid-electric bus up to ¥420,000, each battery-electric bus ¥500,000, and each fuel cell bus ¥600,000.19 These are the subsidies that Western policymakers are more familiar with.

In 2015, China first revealed its ambition to become a "manufacturing superpower." According to *Made in China 2025*, through promoting breakthroughs in (1) next-generation information technology, (2) high-end computer numerical control machine tools and industrial robots, (3) aviation and aerospace equipment, (4) marine engineering equipment and high-tech ships, (5) advanced rail transportation equipment, (6) energy-saving and new energy vehicles, (7) electrical equipment, (8) agricultural machinery, (9) new materials, and (10) biotechnology and high-performance medical devices China would enter the prestigious group of manufacturing superpowers by 2025, reach the average level of the group by 2035, and become a global leader in technology and innovation by 2049, the 100th anniversary of the People's Republic. The master plan for China's Industry 4.0 thus confirmed the EV industry's strategic importance.

In the subsequent years, detailed action plans were released. For example, the Ministry of Industry and Information Technology (MIIT), the NDRC, the MOST, and the MOF jointly issued the *Action Plan for Promoting the Development of Automotive Batteries* in March 2017. The Plan pledged support for research into battery designs for higher energy density and integration of AI into battery manufacturing. In May, the MIIT, the NDRC, and the MOST issued the *Medium- and Long-Term Development Plan for the Automotive Industry*, which set the goals to raise annual EV production to 2 million and battery energy density to 300Wh/kg by 2020 and to begin commercialize autonomous vehicles in 2025. In July, the State Council issued the *Development Plan for Next-Generation Artificial Intelligence*.

B. Policies Targeting Complementary Infrastructure

Apart from policies targeting the EV industry itself, the Chinese government has also made various infrastructure investments to ensure smooth deployment of the EVs. Two such investments are of particular importance.

1) Securing Power Supply: The first one is the power grid. To encourage consumers to switch to electric cars, electricity must be readily accessible, both on road and at home, and affordable, at least not more expensive than gasoline. However, geography has given Chinese policy-makers more challenges than blessings: As illustrated in Figure 4, nearly the entirety of the Chinese population lives in the central and eastern provinces. However, 75% of China's coal reserves are located in the northern and northwest regions, and 80% of its hydropower resources are far in the southwest. The best sites to produce solar and wind power are also in these remote regions [47].

To bridge the thousands of miles of distance between the supply and the demand, the Chinese government has, though the state-owned electric utility company State Grid, built a massive ultra-high voltage (UHV) power grid across the country. This West-East Power Transmission Project was officially launched in 2001. In 2008, the first UHV line (±800 kV DC) was opened between Yunan and Guangdong. Shanghai residents began using hydroelectricity produced 2,121 km away in Yunnan in 2010. In 2018, the Changji-Guquan line

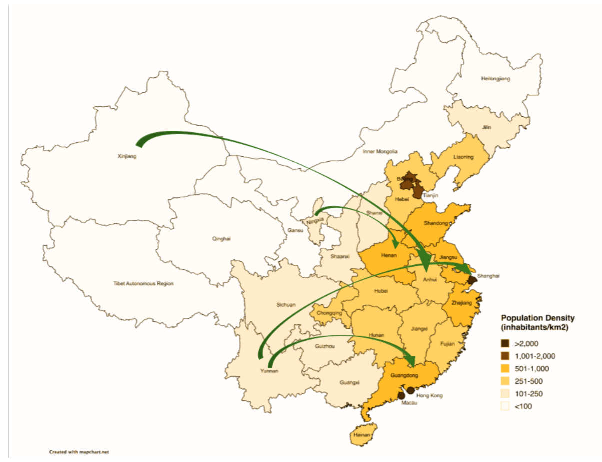

Fig. 5. Connecting Supply and Demand (Source: The Economy).

(±1,100 kV DC) between Xinjiang and Anhui broke the world record in both distance (3,400 km) and capacity (12,000 MW). And, in 2025, the first UHV line specialized in transmitting green energy – the Ningxia-Hunan line (±800 kV DC) – went online [48, 49]

To build such a massive UHV power grid requires hundreds of billions of dollars of investment. If electricity were a market commodity, every additional kilometer of new lines would lead to a higher utility bill. However, in China, electricity is a public good, and the government is an investor with no rush for returns. As a result, while China's power generation was growing at a compound annual rate of about 7.9% between 2005 and 2024, electricity prices were growing at only 1.1% [50].

2) Securing Connectivity: The second infrastructure investment led by the Chinese government that has benefited the EV industry concerns the fifth-generation mobile network (5G). Chinese policymakers began to explore the possibility of leading the development of next-generation mobile networks in 2013, and 5G development was officially promoted to national strategy status in Made in China 2025 and the 13th Five-Year Plan. Trials were conducted in 2016-2018. In mid-2019, commercial 5G licenses were issued and China's state-owned mobile network operators began to provide 5G services on November 1, 2019 [51]. Large-scale infrastructure construction followed. By mid-2024, over 3.7 million 5G base stations had been installed across the country [52].

Smart features are a major selling point of EVs. While basic smart features like remote locking and basic GPS can also function on 4G networks, 5G networks' higher speed (up to 10-20 Gbps vs up to 1 Gbps), higher capacity (over 1 million devices per square kilometer), and ultra-low latency (1-10 milliseconds vs 30-70 milliseconds) are required for running the most advanced smart features such as Level 4 and 5 autonomous driving, voice assistant, 4K video streaming, cloud-based gaming, and augmented reality (AR) powered head-up displays.

5G connectivity also helps make some of the EV's "hard" features more appealing. For example, 5G connectivity is essential for advanced battery management systems to carry out real-time diagnostics and to optimize power usage by analyzing real-time driving and traffic data. 5G connectivity is also essential to Vehicle-to-Everything (V2X) communication, which allows vehicles to "see" better and therefore better protect the occupants through exchange real-time data with in-network vehicles, traffic lights, and pedestrians (via their smartphones).

V. CONCLUDING REMARKS

This article has

1) provided a comprehensive analysis of how AI can be integrated into each stage of EV design and manufacturing, for example, generative AI and conceptualization, digital twin and prototyping and testing, machine learning and mass production, natural language processing and consumer feedback, and transform the whole process.
2) challenged the conventional Western narrative that attributes the rise of the Chinese EV industry primarily to demand-side subsidies, and instead demonstrated that systematic AI adoption has enabled Chinese manufacturers to achieve superior R&D efficiency, reduced production costs, shortened development cycles, and enhanced product quality—factors that provide sustainable competitive advantages.
3) It also demonstrated how government investments in critical infrastructure—particularly the ultra-high voltage (UHV) power grid and nationwide 5G network—have accelerated EV adoption by ensuring affordable, accessible electricity and enabling advanced smart features and enhanced safety features.

Has Beijing been unfairly subsidizing Chinese EV manufacturers and component suppliers? Yes. Will anti-subsidy duties help Western automakers? It depends. Extra import duties are calculated to bridge the price gap between Chinese-made and locally-manufactured EVs, but differences in functionality remains. And provocative tariffs (as in the eyes of Chinese policymakers and consumers) are not going to help American and European cars regain their market shares in China. Moreover, since many of the subsidies provided by the Chinese government can be claimed by automakers regardless of their national origins as long as they are producing in China (as in the case of Tesla's Gigafactory in Shanghai), legacy automakers still have strong interests in keeping China as their production base for emerging markets in Southeast Asia and the Middle East. Thus, to bring automotive manufacturing jobs back home, Western policymakers must complement protectionist trade measures such as tariffs with policies that can motivate Chinese EV manufacturers to move production to their countries. More efforts are also needed to scale up power production and stabilize electricity prices, which is key to make both EVs affordable to consumers and AI affordable to developers and manufacturers.

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TABLE I AI Features and Applications in Major Electric Vehicle Components

Component	AI Features	Functions and Benefits
Powertrain and Energy Systems		
Battery Management System (BMS)	• AI-enabled Battery Management System • State of Health (SoH) prediction • Remaining Useful Life (RUL) estimation • Thermal management optimization • Adaptive charging strategies • Cell balancing algorithms	• Monitors voltage, current, temperature, and state of charge (SoC) • Prevents thermal runaway and physical degradation • Optimizes charging/discharging cycles to extend battery life • Predicts battery aging behavior and degradation • Extends EV range by up to 10% through intelligent charging • Provides context-aware recommendations to drivers
Electric Motor and Drive System	• Torque control optimization • Efficiency mapping • Predictive maintenance • Motor design optimization • Regenerative braking optimization • Failure prediction algorithms	• Intelligently allocates energy from battery to motor • Optimizes motor performance based on driving conditions • Detects motor wear and potential failures • AI-optimized design reduces weight and improves efficiency • Maximizes energy recovery during deceleration • Enables preventative maintenance for increased reliability
Power Electronics	• AI-based failure prediction • Cognitive power modules • Thermal management • Efficiency optimization • Load balancing • Component design optimization	• Predicts potential power converter faults before they occur • Integrates AI with GaN/SiC devices for intelligent operation • Monitors temperature and optimizes cooling strategies • Reduces drivetrain weight and improves conversion efficiency • Optimizes power distribution across vehicle systems • Uses ML for optimal placement of passive components
Powertrain Integration	• System-level optimization (OPED) • Evolutionary algorithms • Multi-objective optimization • Digital twin modeling	• Automatically optimizes entire powertrain • Considers production costs, efficiency, and package space • Includes CO_2 emissions across entire supply chain • Accelerates development phase by several months
Autonomous Driving and Safety Systems		
Advanced Driver Assistance Systems (ADAS	• Deep learning for perception • Computer vision (CV) • Sensor fusion algorithms • Path planning and decision-making • Pedestrian/cyclist detection • Traffic sign recognition • Driver monitoring systems	• Object detection, classification, and tracking in real-time • Processes data from cameras, radar, LiDAR for 360° awareness • Combines multiple sensor inputs for robust perception • Lane keeping, adaptive cruise control, collision avoidance • Detects vulnerable road users even in poor visibility • Reads and interprets road signs and traffic signals • Detects fatigue, distraction, and drowsiness
Autonomous Driving (AD)	• Full Self-Driving (FSD) algorithms • Neural network-based control • Real-time situational awareness • Behavioral prediction • Multi-agent decision systems	• Enables hands-free, eyes-off autonomous navigation • Learns from billions of miles of driving data • Creates bird's eye view and 360° scene understanding • Predicts actions of other vehicles and pedestrians • Coordinates complex driving maneuvers in traffic
Energy Management and Charging		
Range Prediction	• Multi-factor range prediction • Energy consumption forecasting • Route optimization	• Analyzes traffic, terrain, weather, and driving behavior • Predicts power consumption per trip with high accuracy • Suggests energy-efficient routes based on real-time data
Smart Charging	• Dynamic charging optimization • Grid load balancing • Demand prediction • Fault detection	• Schedules charging during off-peak or renewable-rich periods • Reduces grid stress and lowers electricity costs • Optimizes charging station locations and capacity • Monitors charging stations for potential problems
Design and Manufacturing		
Vehicle Design	• Generative design algorithms • Aerodynamic optimization • Multi-agent design frameworks • Virtual prototyping • Material optimization	• Creates optimized aerodynamic exterior designs • Reduces drag coefficient to maximize range • Balances aesthetics with engineering performance • Reduces development time from months to weeks • Identifies lightweight materials for structural components
Manufacturing	• Virtual testing & validation • Quality control automation • Production optimization • Battery chemistry optimization	• Simulates crash tests and performance scenarios • Detects defects in real-time during production • Optimizes assembly line efficiency and reduces waste • Accelerates development of new battery materials
User Experience and Connectivity		
Infotainment and User Interface	• Natural Language Processing (NLP) • Personalization algorithms • Gesture recognition • In-cabin monitoring	• Enables accurate voice commands and voice assistants • Learns user preferences for climate, music, routes • Allows natural, touchless interaction with systems • Detects occupant position and adjusts safety systems
Predictive Maintenance	• Component health monitoring • Anomaly detection • Diagnostic systems	• Analyzes real-time data to identify potential issues • Detects unusual patterns before failures occur • Provides detailed fault analysis and recommendations
Over-the-Air (OTA) Updates	• Software update management • Feature deployment • Security patching	• Delivers firmware upgrades for powertrain and infotainment • Adds new capabilities without dealer visits • Addresses vulnerabilities in real-time