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The Rise of Shenzhen and BYD –

How a Chinese Corporate Pioneer is Leading Greener and More Sustainable Urban Transportation and Development

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While the world is focusing on if the Chinese government can be a trusted and reliable leader in dealing with global climate change, a Chinese company – BYD – has been leading the industrial and technological frontier of green energy transportation and contributing to more sustainable urban development in China.

China has been a dominant factor in the global response to climate change as the world's largest emitter of CO₂. China got central attention and much praise at the 2015 United Nations Climate Change Conference held in Paris after President Xi Jinping had pledged to cap its rapidly growing carbon emissions by 2030 when he met with Obama in 2014. China also set an ambitious goal of raising the share of non-fossil fuels in its energy mix from 10% to 20% by 2030.

The success of BYD is a timely case for understanding what can be done to curb massive pollution in China's major cities. This pollution is producing health hazards, slowing social and economic progress, and sustaining China's status as the largest global emitter of CO₂. Is it possible for one start-up in China with a vision for a sustainable future to help solve these

problems? What can we learn from its success that has a positive impact on sustainable cities? Understanding how BYD has done it, in relation to its home city of Shenzhen in southern China, can teach us two important lessons. One is the critical importance of a bold corporate vision and its persistent execution. The other is how the pioneering role of a home-grown company, nurtured by its local government, can improve its urban environment and set it up as a model for other cities.

The Urbanisation-Pollution Nexus

Over the past three decades, China has experienced the most rapid urban expansion in human history. According to China's government statistics, the permanent urban residents grew from 170 million in 1978 to 730 million in 2013, with the proportion of people living in cities rising from 17.9% to 53.7%. With only 193 cities in 1978, China has over 700 cities today. Larger cities have been growing faster. From 1978 to 2010, China's cities with 10 million, 5-10 million, 3-5 million, 1-3 million, and 0.5-1 million people increased to 6, 2 to 10, 2 to 21, 25 to 103, and 35 to 138, respectively (see Table 1 on next page). Most of this urban growth has occurred through migration. In 1982, only 11.54 million



Shenzhen is a megacity today with around 11 million people.

Indicators	1978	2013	Net Increase
Total urban population	170 million	730 million	560 million
Percent of population in cities	17.9%	53.7%	35.8%
Number of cities	193	700+	500+
- Cities with 10 million people	0	6	6
- Cities with 5-10 million people	2	10	8
- Cities with 3-5 million people	2	21	19
- Cities with 1-3 million people	25	103	78
- Cities with 0.5-1 million people	35	138	103

Source: Chinese government official statistics.
 *The total number of cities in 2013 did not add up to 700 as we did not include those cities with less than 0.5 million people, which grew less rapidly than the larger cities, especially the largest cities.

people in China, or about 1% of the population, left their registered hometowns to work and live elsewhere. In 2012, 236 million people, or almost one out of every five people in China, were urban residents through in-migration.

The massive influx of people into cities has pushed up energy demand considerably. In meeting this demand, China has had to rely on fossil fuels, with coal accounting for about two-thirds of its energy generation. The millions of factories, large and small, manned by tens of millions of migrant workers are powered by coal. The millions of new cars driven by millions of middle-class consumers in the large cities gobble up so much gas that they keep China's oil consumption and imports sky high.¹

The release of this amount of carbon into the atmosphere is deadly. Heavy smog has become increasingly common over cities like Beijing. The blue sky that the second author remembers from growing up in Beijing is increasingly rare. One study found that "outdoor air pollution contributes to the deaths of an estimated 1.6 million people in China every year, or about 4,400 people a day."² On particularly bad days in many Chinese cities, pollution levels become so high that schools are advised to close, car use is

drastically limited, construction sites are forced to shut down, and even flights are cancelled. Breathing Beijing's air for one day is equivalent to smoking 36 cigarettes, according to a new study by *Berkeley Earth*.³

From a SEZ to a Megacity, Fast

While many people in the West have already heard about the dynamic Chinese city of Shenzhen, which is generally mentioned in the same breath with Beijing and Shanghai, four decades ago few within China were aware of this small fishing village, whose sole reputation was its location on the border with Hong Kong (see Map 1 on next page). Shenzhen's fortune took a drastic turn in 1979 when it was designated as China's first special economic zone (SEZ) for opening up an isolated China to the outside world. Not quite intended, this bold experiment set the Shenzhen SEZ off to rise as an 'instant city' but on a fast track and massive scale. In the 1980s, Shenzhen broke the record of constructing a skyscraper at an average of two and one half days per floor. With less than 100,000 residents around 1980, Shenzhen is a megacity today with around 11 million people.

Unlike all the major cities, none of which have grown nearly as fast, Shenzhen has the largest share of migrant population; while only 1% of the city's total population was temporary or migratory, this figure was 75% in 2013, much higher than all cities in China. This dominance of in-migration, which reflects a risk-taking entrepreneurial orientation, laid the foundation for successful local start-ups, especially in the high-tech sector.

Growth Pains and Industrial Upgrading

Shenzhen would never have experienced such explosive growth without its first-mover advantages working quickly and ahead of all

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Map 1



major cities in China. Shenzhen became the first and foremost destination for the initial and continued waves of foreign investment, especially from Hong Kong. However, the glorious early years of Shenzhen's development did not last forever. Shenzhen experienced the inevitable pains of economic growth, and ran into the constraints of limited land and rising labor costs, shortage of energy and water, and worsening environmental contamination.

Whether by anticipatory planning or strategic response, the Shenzhen government in 2005 began to address the city's economic and environmental challenges. It has since tightened land use approvals, raised the minimum wage to the highest among large Chinese cities, and elevated environmental standards by banning particularly polluting industries including dyeing, papermaking, tanning, and electric-coating. The inevitable rise in both land and labor costs due to rapid growth, coupled with pollution-fighting policies, led to some capital exodus and elevated

At heart, Wang Chuanfu is a battery chemist. He has been BYD's CEO, President, and Chairman since its inception, but also the brains behind his company's battery.

the importance and opportunity for successful industrial restructuring.

This industrial upgrading has benefited from Shenzhen's distinctive path and sequence of economic development as a new city. By building up the local economy on a clean slate of export-oriented light industries and then moving toward high-tech industries, Shenzhen partly skipped the conventional stage of heavy and polluting industrialisation that many of China's other manufacturing centers have experienced. Shenzhen has focused on establishing itself as China's top-ranked city in a number of new national and international brand-name products. Shenzhen became adept in developing the capacity to design products instead of merely manufacturing them. In June 2008, the national government approved Shenzhen to be the first experimental city for becoming an innovation center. With a vibrant graphic and industrial design industry encompassing more than 6,000 design companies and 60,000 designers, UNESCO named Shenzhen a "City of Design" in 2008.⁴

BYD as a Rising Star

Among the earlier entrepreneurs attracted to Shenzhen was Wang Chuanfu, a 29 year old Chinese battery chemist, who quit his job as a government researcher in 1995 to start his own battery company, BYD, which stands for "build your dreams." The young Wang raised \$300,000 from relatives, and opened his first factory in Shenzhen where he made rechargeable batteries for cell phones. In just five years, BYD was already the world's largest cell phone battery manufacturer.

At heart, Wang Chuanfu is a battery chemist. He has been BYD's CEO, President, and Chairman since its inception, but also the brains behind his company's battery. BYD's competitors quickly stopped trying to compete with Wang's battery, which was far superior, and instead used BYD as their supplier. Wang achieved rapid success because what Sony and other global handset companies did through mass production, BYD did through technology, and Wang's batteries were better and cheaper.

Seeing pollution from cars as a serious issue

and using Shenzhen as a platform, Wang Chuanfu purchased Xi'an Tsinchuan Auto Co., Ltd., a defunct Chinese automobile manufacturer, in 2003.⁵ It was no secret the battery company was going to put their battery in a car. Wang Chuanfu approached the electric vehicle (EV) market in such a strategic way that required incredible patience from the eager battery engineer and CEO. Wang's ultimate goal was to sell electric vehicles, but he couldn't just introduce the EV to a non-existent market. Wang's end goal was to make an affordable middle-class electric car.

BYD entered the automotive industry slowly, at first selling internal combustion (IC) engine cars. As the company learned the ins and outs of the automobile industry, they added their battery to an IC car, thus creating a hybrid. Their hybrid cars weren't as successful initially, however when the Shenzhen government stepped in to help, sales increased. Wang saw the hybrid as the stepping-stone from IC cars to pure-electric cars.

BYD's electric vehicles

The battery company-turned automaker now produces plug-in hybrids and pure-electric cars, as well as the world's first (mass-produced) electric bus. The BYD e6, first introduced in Shenzhen in 2011, is a pure-electric crossover that has been primarily used as a taxi in many Chinese cities, as well as in fleets for ride-sharing apps such as Uber in Europe and the United States. The BYD e5 is a similar all-electric sedan aimed for more of the consumer market, especially in China. The BYD Qin is a compact plug-in hybrid sedan and is the successor to the world's first (mass-produced) plug-in hybrid car, the BYD F3DM, and is currently the best-selling plug-in hybrid in the world. The newly released BYD Tang is a plug-in hybrid SUV, which has been praised for its performance in snow, sand, and mud, as well as its acceleration and horsepower, going 0-60 mph in just 4.5 seconds.

Many people believe EVs aren't popular because there isn't a lot of 'tree-hugger' environmentalists who are willing to spend more money for a car they have to worry will run out of electricity in the middle of the highway. While helping save the environment is a good deed, many individual consumers rarely

want to participate because they don't believe they can make a noticeable difference, and would rather see others make the leap towards electric mobility. However, could the economics behind the electric vehicle change this free-riding mentality?

Currently, it costs more to buy the EV version than the IC version for any EV on the market, simply because of the cost of the battery. However, the annual fuel savings and operating costs, even for a taxi (See Table 2 below), are significantly lower for a (BYD) EV taxi than for an IC taxi.

Table 2: Annual Operating Cost for Taxis in Shenzhen, China⁸

Average Daily Range	500 km	IC Taxi	BYD e6
Life Cycle	5 years		
Energy Consumption/100 km		10L	22kWh
Energy Price (US\$)		1.33/L	0.19/kWh
Cost (\$)/100 km		13.30	4.18
Annual Cost (\$)		23,474	7,377
Total Cost (\$)		117,372	36,888

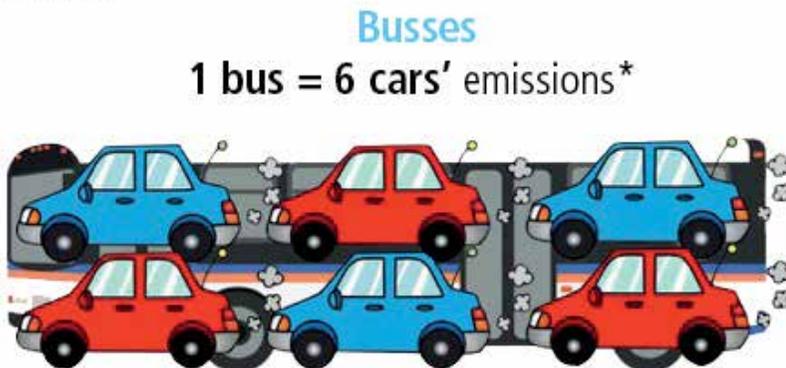
Table from: <http://cleanenergyinstitute.net/mod/page/view.php?id=4102>

BYD's all-electric bus, the K9, is popular among cities worldwide aiming to improve sustainability (see photo). The K9 has a range of 150 miles, and takes only three hours to fully recharge. IC busses emit the equivalent emissions of six IC cars (see figure 1 on next page).⁶ With about three million cars, the Shenzhen government is very keen on putting more such busses on the street. This is also of great appeal to city officials elsewhere.



Pictured above is the BYD K9 in front of their Los Angeles, California showroom.⁷

Figure 1



*Internal combustion bus/car

To help promote electric vehicles more, many governments offer significant subsidies to owners of EVs because of the higher cost. In Shenzhen, owners of new EVs receive \$9,520 for a pure-electric car, or \$7,940 for a plug-in hybrid car from the government. On top of that, they get an additional \$9,520 for a pure-electric car, or \$4,762 for a plug-in hybrid car from the Shenzhen government.⁹ Another selling point for EVs is the cost of maintenance. In an IC car, there is an engine with hundreds of moving parts, transmission, gears, and obviously gasoline. After a certain point, one of those parts is bound to break, which is expensive to fix. In a pure-electric vehicle, there is no engine, no gasoline, no gears, nor transmission; and the motor, which is the size of a watermelon, only has one moving part.

The heart of the EV is in the battery, which lies on the powertrain under your feet. Also, EVs use what's called regenerative braking, which means when the driver lets off the accelerator, the car's motor reverses, gradually slowing the vehicle to a stop (as if the brake were lightly pressed), all the while regenerating the battery. Think of it like a crank-up flashlight, only the reversing of the motor is recharging the battery. While brake pads need to be changed regularly on IC cars, most EVs will never need to have their brake pads replaced for the life of the car. There is virtually no maintenance needed for an EV, which is another selling point and money saver.

Most car buyers don't realise the benefits of

EVs simply because of the lack of information. Electric cars have been in the news more frequently thanks especially to Tesla Motors. The American start-up company has electrified the auto market with their Model S sedan. The Model S P90D is the fastest four-door car ever made, will go 0-60 mph in 2.6 seconds, and drive up to 268 miles on a single charge. It is fair to say that Tesla has glamorised the electric car, which has increased sales of EVs across the auto industry. However, with a base price of \$115,700, that 'family sedan' Model S P90D is out of most people's reach. Tesla has plans to make a 'car for the masses' in the next couple of years, but until then, customers will have to wait, or fork over a lot of money.

While there are other EVs on the market that are cheaper than the Tesla Model S (Nissan Leaf, BMW i3, Chevy Volt), none will go over 100 miles on a charge, and aren't practical for most drivers, which is why their respective sales have been low. BYD, however, has a line of pure-electric and plug-in hybrid cars that will go further on a charge, and cost less. BYD's EV sales have been so strong that they have recently taken the title as the world's largest EV manufacturer.

The Battery Is Everything

BYD has been the top selling EV manufacturer due to its low price and far range, both aspects entirely linked to its battery. In China, before any government subsidies and tax exemptions, the e6 sells for \$35,000, the e5 is \$22,000, the Qin is \$31,000, and the Tang is \$48,000. BYD's two pure-electric cars, the e5 and e6, have a range of 150 miles and 124 miles, respectively.

Currently, BYD is the largest rechargeable battery manufacturer in the world, having over a 25% market share. While BYD makes batteries for many cell phones, power tools, robots, etc., they are also **the only EV manufacturer that makes their own battery**, which is why they are able to achieve such low cost and high range. Any other EV manufacturer must rely on the battery technology from a separate battery manufacturer whose battery isn't designed for a specific vehicle, plus they have to buy the battery from that manufacturer. BYD, which is a battery

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> 25%
market share

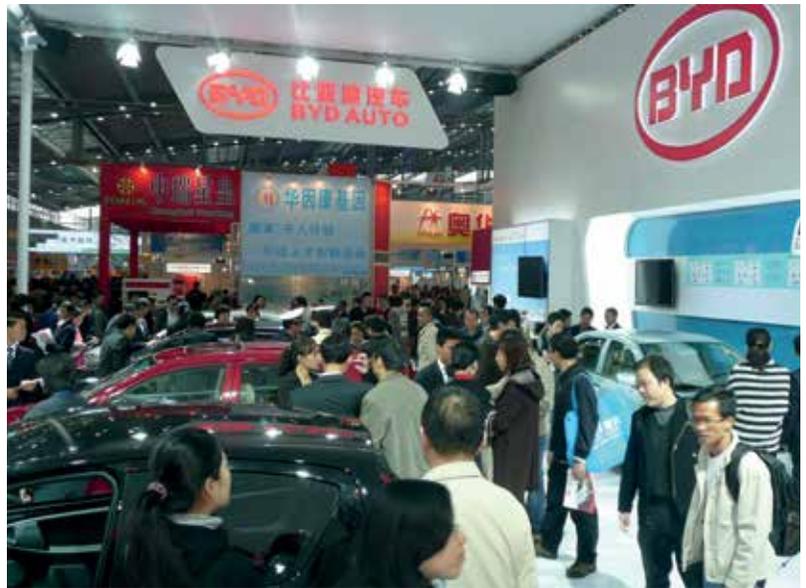
company in the first place, is able to leverage its battery production, as it doesn't have to buy its battery wholesale, plus they have the advantage of making each battery according to the vehicle's needs. BYD's batteries are cheap in comparison, and have other technological advantages.

Battery technology

BYD's custom-blended lithium-iron-ferrous-phosphate (LiFePO_4) battery is the first of its kind in an EV. Its advantages are what currently distinguish BYD from its competitors. The cyclability, meaning how many times the battery can be charged before it significantly degrades, is a long-term advantage of BYD, as their battery can be charged over 4,000 times and still hold a 70% charge. Safety is another industry-leading component in BYD's battery, and is hugely important to Wang Chuanfu. BYD's LiFePO_4 battery can be completely engulfed in fire and not explode, a feature other battery manufacturers desperately aspire to achieve. The biggest downside to BYD's LiFePO_4 battery is the energy density, which is the amount of energy that can be stored in a given space. Increasing energy density would mean further driving range for an EV.

To increase energy density in their battery, BYD has added manganese to the LiFePO_4 , which is another industry first. Although BYD hasn't released the lithium-manganese-iron-ferrous-phosphate (LiMnFePO_4) battery in an EV yet, the advantages to adding manganese are vast. Not only does manganese increase the energy density of the battery, it also improves the rate of charge (how quickly the battery can be charged) and rate of discharge (essentially why the Tesla Model S can go 0-60 mph in 2.6 seconds). BYD's LiFePO_4 battery already can be charged extremely rapidly to 80% in just 20 minutes, or 100% in only 40 minutes using a BYD DC fast charger, which is used by e6 taxis.

While BYD's battery may be cheaper than most, batteries overall are still expensive. In order for EVs to achieve parity with IC vehicles, the cost of the battery will have to decrease quite significantly. Tesla Motors plans to lower the cost of the battery they use, made by Panasonic, through economies of scale. Tesla's highly



publicised "Gigafactory" being built in Nevada, USA is planned to open in 2017. Tesla hopes to have an annual battery production capacity of 35 gigawatt-hours (GWh) by 2020, and aims to "drive down the per kilowatt hour (kWh) cost of our battery pack by more than 30 percent," according to their website.¹⁰

EV manufacturers can only increase EV production by increasing annual battery production capacity. BYD currently has an annual battery production capacity of 8 GWh in one factory in Kengzi, Shenzhen. The Kengzi factory is currently the largest "Gigafactory" in the world, and BYD plans to expand it by 6 GWh in 2016, then by 8 GWh every other year. BYD's Kengzi factory is quite different from other Chinese factories; over 95% of the factory is automated, and the building emits no emissions into the air outside, as all the emissions are captured and recycled in the factory, which further pleases the Shenzhen government.

BYD at the Central China High-Tech Fair, Shenzhen, November 2009. BYD Auto Co., Ltd. is a Chinese automobile manufacturer based in Shenzhen, Guangdong Province, and a wholly owned subsidiary of BYD Company.

PHOTO: Brucke-Osteuropa

BYD has already reduced the cost of their battery by one half in the past three years, and plans to further reduce the cost of the battery by one half over the next three years.

Map 2

A Global Company



↑ Indicates a BYD factory or office

Making the battery cheaper

BYD has already reduced the cost of their battery by one half in the past three years, and plans to further reduce the cost of the battery by one half over the next three years. BYD aims to achieve this in 2016 and 2017 by adding manganese (which reduces the cost of the LiFePO_4 battery), and through mass production. In 2018, the company plans to significantly lower the cost by decreasing the cost of raw materials. BYD currently has outstanding trade agreements with other countries from which the company imports its raw materials for its battery, thereby having to pay a hefty import tax, despite tax deductions from the Shenzhen government. BYD currently imports over one-third of the raw materials for its battery, however by 2018 they plan extract 90% of their raw materials for their battery in China, supported by the government.

Making a Difference

For BYD, 40% of the cost of manufacturing their EVs is in the battery alone. If BYD's aspirations go according to plan, its EVs will be far more economical than any other IC or EV. BYD stated at the 2015 Shanghai Auto Show that it is focusing on entering seven conventional vehicle fields: Transit Buses, Coach Buses, Taxis, Logistics Vehicles, Construction Vehicles, Waste Management Vehicles, and Consumer Vehicles.¹¹

BYD's forward-looking vision and innovative technology have materialised in its hometown of Shenzhen, which has the largest electric bus fleet and largest electric taxi fleet in the world. Shenzhen also uses BYD's e6 as a police car, and BYD frequently uses the city to test its products. Shenzhen has benefited from having BYD as both a home-grown company and the latter's demonstrative role in helping reduce car emission. It is no coincidence that in 2014 Shenzhen ranked the 179th among the 190 Chinese cities in the level of pollution, or as China's 11th least polluted city.¹²

Moving far beyond Shenzhen, BYD has electrified transportation in over 110 cities in 36 countries. It has begun to spread its operational footprint globally (see Map 2 on left). With its commanding position in making EVs and batteries, which is bolstered by a huge workforce (see Figure 2 on next page), BYD is poised to remain a corporate leader in advancing sustainable urban transportation and development in China and globally.

The future of BYD appears bright as it has drawn major investors like Warren Buffett, Charlie Munger, and Bill Gates. To many investors, Tesla Motors has drawn a great deal of excitement and attention, and as a result, that is reflected in the very high price in its shares. Today, Tesla is valued at the market price of nearly \$30 billion. BYD, on the other hand, possibly since it isn't as well known, has a market price of around \$13 billion. Yet BYD has

BYD's forward-looking vision and innovative technology have materialised in its hometown of Shenzhen, which has the largest electric bus fleet and largest electric taxi fleet in the world.

arguably more potential since it is multi-faceted and catering to the middle class by selling much more affordable EVs.

Ultimately, looking at BYD in relation to its Chinese/Shenzhen government environment may carry the most important lens for understanding the relative roles of government policy and corporate innovation in advancing sustainable development goals. Some may see BYD's close ties with the local government as a drawback, while others see it as an opportunity, considering that China's national and local governments are fighting pollution through both administrative fiat and market mechanism. By supporting businesses to be more environmentally focused, the Shenzhen government has contributed to BYD's success. BYD, on the other hand, has leveraged Shenzhen's first-mover advantage to its end, as stated by its corporate motto of "Losing is not an option if you are first", which is printed at no other place than above the urinal in its Shenzhen headquarters. 

About the Authors

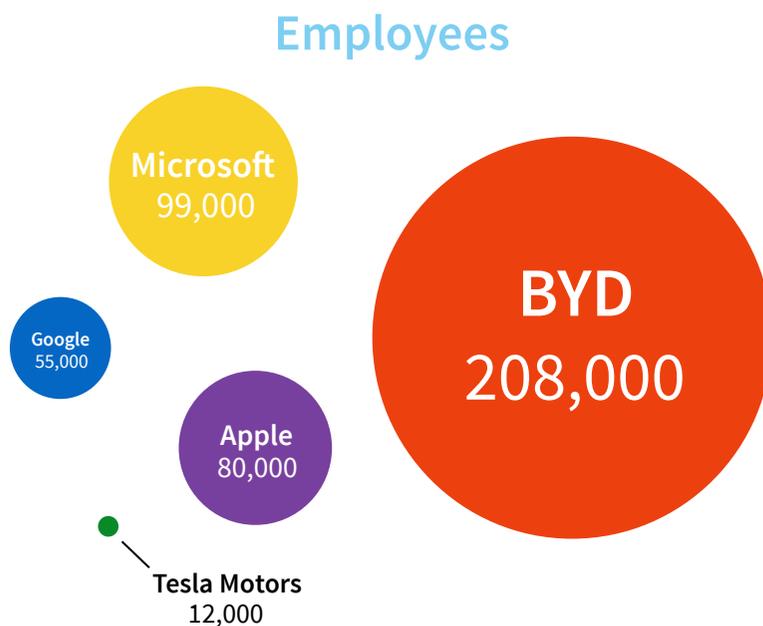
Taylor Ogan is currently a sophomore at Trinity College, Connecticut, majoring in Urban Studies. His focus is on the implementation and investment of sustainable energy and electric vehicles, specifically in China. He did research in Shenzhen, China in the summer of 2015 supported in part by the Henry Luce Foundation, as well as in New York City, Chicago, and Los Angeles.

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Figure 2



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By supporting businesses to be more environmentally focused, the Shenzhen government has contributed to BYD's success.