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Shenzhen's New Energy Vehicles and charging infrastructure – policies, instruments and development

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Summary

Billions for green growth. Shenzhen, one of China's richest cities and home of New Energy Vehicles (NEV) producer Build your Dreams (BYD), will invest 5 billion Yuan (804 million USD) in NEV development by the end of 2015. Especially for pure electric vehicles. The megacity is using electric mobility as an instrument to reduce carbon emissions while creating economic growth. Against the background to the negative effects of traffic-related air pollution in China, the key is to promote sustainable transport. Comprehensive solutions have been adopted in several low-carbon city projects that prioritize Transit-Oriented Development (TOD) strategies. From 2011 to 2020, Shenzhen wants to reduce carbon emissions by 40-45 %. To activate green public and private investments, the city leaders formulated several policies for New Energy Vehicles (NEV) and charging infrastructure promotion and application. With the development of existing fast charging networks from 1,100 to 1,800 piles for commercial NEVs and slow charging piles in 5 % of all residential and 10 % of all public parking spaces, policymakers hope to overcome the bottleneck constraint in a lack of charging infrastructure. From 9,392 NEVs by the end of 2014, an additional 15,000 new energy taxis, buses, municipal vehicles, e-car-sharing services and private NEVs are to be subsidized in the coming years. Several top-down policies support these goals, for example purchase or tax incentives connected with sanctions for fuel car number plates. Shenzhen's challenge is to encourage citizens to use NEVs while finding the balance between economic development and environmental protection.

Keywords: New Energy Vehicle (NEV), charging infrastructure, sustainable transport, policies & instruments, Shenzhen

1. Introduction

Electric mobility provides a strategic technological solution towards sustainable transportation systems - particularly for China's urban growth. Therefore, the Chinese government is pushing the rapid development of New Energy Vehicles (NEV). China's cities suffer from high levels of air pollution, and NEVs are needed in order to reduce carbon emissions by 40-45 % by 2020,

compared to 2005 levels [1]. Eighty-eight Chinese cities and 26 provinces are part of the Chinese NEV demonstration regions [2]. These regions serve as test sites for NEV policies and instruments. Besides Beijing and Shanghai, Shenzhen is one of the top cities for NEV development.

Founded in 1980 as China's first special economic zone, Shenzhen is well known for its rapid and successful development. The implementation of NEVs in public transport is connected with low-carbon plans that follow the guidelines of the 12th Five-Year Plan. The 35-year-old megacity has more than 10 million inhabitants and approximately 3 million cars, as of the end of 2014 [3]. With more than 10,000 NEVs, the southern Chinese metropolis is one of the leading cities in the application and promotion of electric vehicles worldwide. In 2015, Shenzhen's target is to increase the number of NEVs to 25,000 NEVs [4].

Shenzhen's construction land is still expanding and sustainable solutions are needed. Several new urban development projects that integrate electric mobility from the beginning stages of the planning process were started in recent years. TOD strategies, a city of short distances and green transport concepts have been used as examples from international good practice cities like Copenhagen or Seoul. The 'International Low-Carbon City (ILCC)' in Longgang District, in cooperation with the EU and Dutch government or 'Qianhai Shenzhen-Hongkong Modern Service Industry Cooperation Zone of Shenzhen', are popular examples, but are still under construction.

However, in existing and new development areas there are still many constraints. The lack of charging infrastructure, imperfect auxiliary facilities, incomplete supporting policies, inadequate business models, insufficient enterprise innovation or a lack of highly skilled labour were identified as main constraints by municipal leaders. To overcome these bottleneck constraints, in January 2015 the Shenzhen municipal government formulated very ambitious policies to improve municipal instruments for future NEV development. These policies are covered by a 5 billion Yuan (804 million USD) fund in the form of a municipal incentive and subsidy to enhance full electric vehicles, a citywide charging network and a unified charging standard. This funding is connected to the two-year high-tech plan by the National Development and Reform Commission to create globally competitive homegrown brands in six industries, including electric cars [5].

The first hypothesis assumes that Shenzhen and the central government set up strong policies to successfully integrate NEVs into the public transport system by 2020. The hometown of battery and NEV manufacturer BYD has strong economic interests and uses green public procurement to replace the public buses, taxis and municipal fleets with electric vehicles. Today, most NEVs belong to public transport. The second hypothesis suggests a gap between planning instruments and realisation in new and existing urban development projects. On the one hand, the hierarchical top-down planning is well organized, a lot of money is available and construction phases proceed very fast. On the other hand, charging facilities are not included in urban planning and charging facility land cannot be guaranteed. This inhibits public and private investment in charging facility construction. On-site research showed that many slow charging facilities are rarely or not used. This leads to the third hypothesis that a number of barriers affect the private NEV market. As in other regions all over the world, private users are reluctant to use NEV technology. Purchase or tax incentives connected with sanctions for fuel cars are the Chinese methods to solve this problem. Electric cars and buses that use green energy reduce carbon emission in the field of sustainable transport. The integration of new mobility concepts requires new methods and flexibility in urban governance and planning processes. Stakeholders, planners and the scientific community have to consider how electric mobility changes the urban landscape. Fast growing Chinese megacities have the opportunity to take a leading position in the field of electric mobility. Shenzhen can be a best practice for other megacities if the policies and instruments prove successful in future. The challenge is to change citizens' transportation preferences while finding the balance between economic development and environmental protection.

2. Methodology

This paper firstly outlines the context of Shenzhen's NEV and charging infrastructure development until 2015, and summarizes the current policy targets and instruments. In particular, an examination of 'The Several Policies and Measures of New Energy Vehicles' Promotion and Application' and its 'Working Plan to Develop New Energy Vehicles in Shenzhen (2013-2015)' is included, outlining and discussing NEV instruments that will be applied on municipal- or micro level urban development projects. The conclusion gives some projections for future development.
Based on a quantitative data collection from relevant urban development projects in Shenzhen, the main actors in the field of electric mobility and urban development were identified. In cooperation with Peking University Shenzhen Graduate School (PKUSZ), more than 25 qualitative expert and stakeholder interviews were done in spring 2015 in Shenzhen and Guangzhou. The language difficulties and the loss of details during translation are not to be underestimated in the Chinese context. The following forms of data collection can be distinguished between secondary research (desk research) and primary research (field-research):

- Expert and stakeholder interviews with group discussions (and professional interpreters)
- Translation and analysis of policies, planning documents and official statistics
- Leap-frog method (inventory analysis, observation, site visit)

3. Results from Shenzhen

3.1 Organization and development

The municipal government set up the 'Shenzhen Leading Group Office of Promotion and Application of New Energy Vehicles' (SZLGO) as responsible policymaker for NEV and charging infrastructure development. The SZLGO is guided by the Shenzhen Development and Reform Commission and gets support from the Municipal Science, Technology and Innovation Commission, the Municipal Transport Commission, which is responsible for the application, and the Finance Commission. Other municipal departments like the Housing and Construction Bureau or the Planning, Land Use and Resources Commission are, for example, responsible for supporting the construction of charging infrastructure. The mayor and vice-mayor of Shenzhen make final decisions in a top-down hierarchy. The government has worked closely with BYD since 2004, which is Chinas biggest NEV producer. Its competitor, Wuzhoulong Motors, is the second biggest manufacturer for Shenzhen's NEV fleets. BYD is at the top of the supply chain of the Shenzhen NEV Union. Company representatives are leading negotiations with municipal policymakers to establish a win-win situation for all actors.
According to Shenzhen's working plan to develop NEVs, the plan is based on three principles: (A) Successful demonstration and promotion, (B) rapid industry development and (C) the steady development of charging infrastructure, planning instruments and business models.
(A) By December 2014, there were 9,392 NEVs on Shenzhen's roads. This number includes 850 full electric BYD e6 taxis, 1,253 pure electric shuttle buses, 26 pure electric mini buses and 1,771 hybrid buses that are omnipresent in public transport. In addition, there were 4,910 private full electric and hybrid vehicles, 62 fuel cell vehicles and 520 full electric municipal police cars. With a cumulative distance travelled of more than 800 million km, over 220,000 tons of CO2 were saved [6].
(B) Shenzhen has strong industry goals. The promotion of the NEV industry should help reduce air pollution and greenhouse gas emissions, improve energy security and upgrade China's industry with economic growth into the 'third industrial revolution' [7].

(C) Shenzhen has 81 fast charging stations (DC flow) for commercial use. Seventy-four are used by e-buses and seven used by e-taxis. The fast charging duration is about 100 Minutes. More than 3,000 slow charging piles (AC flow) were installed mainly for private maintenance around the whole city. The charging duration lies between five and eight hours, depending on the charging facilities. Security systems, business operation models for NEV buses and taxis were improved to a mileage of more than 250 km for buses and 300 km for taxis now.

3.2 Policies

Shenzhen has an open NEV development strategy and comprehensive policy support. That means the development of hybrid-, fuel cell- and full electric vehicles can be government-funded. The use of plug-in hybrids is only an interim solution to follow the municipal's green strategy. The future target is to change NEV fleets to full-electric models [8]. Shenzhen belongs to the eight low-carbon pilot cities and five provinces that implemented a low-carbon development plan, supporting policies, develop low-carbon industry, establish CO2 emission statistics and encourage low carbon lifestyles and consumption [9]. The target for 2020 is no CO2 emissions in the public transport sector, connected with a gradual transformation towards commercial and private NEVs. Since 2009, several policies and subsidies like the 'Shenzhen Energy-Saving and NEV Demonstration Program (2009-2012)' and the 'Shenzhen Private Purchase NEV Pilot Subsidy Plan' covered by 5.6 billion Yuan in funding were implemented [10]. To compile overall national guidelines Shenzhen follows 'The 12th Five-Year Plan for the National Economic and Social Development', national industry plans known as 'The 12th Five-Year NEV Industry Development Plan', or 'China's Policies and Actions Addressing Climate Change' from 2011. Several upgrading incentives out of the '863 R&D Program' since 2001 or the national application demonstration project 'Ten Cities, One Thousand Vehicles Program' provide a good policy environment mainly for NEV industry development. The guiding concept for further NEV development in Shenzhen is based on the national 'Instruction about Accelerating NEV Demonstration and Application' and the national 'Development Plan of Energy-Saving and NEV Industry (2012-2020)' by the State Council. Out of these documents, the SZLGO prepared over the course of two years the central guideline 'The notification of Several Policies and Measures of New Energy Vehicles' Promotion and Application', which will be financed by the 'Shenzhen Energy Saving and New Energy Vehicle Demonstration Promotion and Support Fund (2013-2015)' covered by 5 billion Yuan [11]. This funding is covered by the good financial resources by the municipality of Shenzhen. It aims on the key areas of NEV industry development: purchase incentives, charging infrastructure construction, standardization and the improvement of policies and regulations. The following policies summarize the most important NEV regulations and connected policies on the local level.

Policies and regulations for NEV development in Shenzhen	Connected plans that include NEV development in Shenzhen
• Shenzhen Energy-Saving and New-Energy Vehicles Demonstration Programme (2009-2012) • Shenzhen's New Energy Industry Development Planning (2009-2015) • The Notification of Several Policies and Measures of New Energy Vehicles' Promotion and Application (2013-2015) • Shenzhen Energy Saving and New Energy Vehicle Demonstration Promotion and Support Fund (2013-2015) covered with 5 billion Yuan	• Low-Carbon Development Plan for Shenzhen (2009-2020) • Shenzhen Clean Transport Plan (2012-2014)

Fig. 1: Central NEV policies and guidelines from Shenzhen Municipal Government
Source: Own compilation

It is obvious that the policy set up is guided by economic interests. The implementation in sustainable urban development strategies and low-carbon plans is just in the testing and starting phase. An integration of charging stations into Shenzhen's masterplanning is still missing. It should be done a new plan or an integration into Shenzhen's 'Vehicle Petrol Station Plan' in future. Shenzhen is since its funding an experimental zone for central governmental reform projects. High planning standards and practical concepts from Hongkong and western countries could evolve [12]. In comparison to other Chinese cities, the rule of law, containment of corruption and other sustainable approaches have more influence on local policies. The city act as national model region with its systematically approach of NEV promotion and application in public transport and municipal fleets, the evolution of an NEV innovation system, rapid industry development and the construction of charging infrastructure. Concrete evidence is that municipal and private fleet providers should meet their specified quotas for NEV integration. The NEV manufacturers should be able to lower sale prices by achieving economies of scale. Related to article two and three of Shenzhen's policy document [13], public transport bus, taxi and municipal fleets should include no less than 70 % NEVs. Sanitation trucks should include no less than 50 %, small freight vehicles; commuter and tourist buses should meet a 30 % NEV quota. Individuals and companies are encouraged to purchase NEVs.

3.3 Instruments

Instruments for electric mobility can be defined as the municipal action as configurer, licensor, supporter, operator and user [14]. The Municipality of Shenzhen developed a wide range of instruments to implement NEV technology systematically to reach the number of 25.000 NEVs. While the public transport sector and municipal fleets receive different subsidies depending on the vehicle length, range or NEV-type, whereas private enterprises and private persons receive various financial and tax advantages, depending on the range and NEV-type. For example, Taxi service companies benefit by purchasing NEV taxis and receive a subsidy of 55,800 Yuan per NEV taxi. By end of 2015, the purchase of 4,000 pure-electric taxis will have been funded by the government. The subsidy amount is based on the sale price of the electric car. For the 2014 to 2015 period, the government expected that 10 to 15 % of the taxi companies, which are approved for the special economic zone in Shenzhen (red taxis), will have replaced some of their fuel cars with electric vehicles. Based on the full electric BYD model e6, there is a cost advantage for local taxi companies around 20.000 Yuan per vehicle because the taxi licence for pure electric taxis is free. Transportation authorities of the districts are responsible for specific programmes.

Electric carsharing companies should extend their rental service for the large scaled application, charging and maintenance of NEV vehicles. With a target of 2,000 NEVs, the government wants to foster this transportation model to reduce traffic congestion. Since June 2015, the 'Shenzhen Jinqianchao Electric Vehicle Leasing Service Co.' introduced the first electric carsharing stations, including Shenzhen Airport and Shenzhen North Railway Station [15]. More suppliers will follow. Private NEV buyers and private companies receive state and local subsidies upwards of 114,000 Yuan (17.900 USD) per vehicle [16]. No other Chinese city gives more subsidies for NEV users.

Besides the push of charging infrastructure development (discussed in 4.1), there are other non-monetary incentives and restrictions. With a limit of 100.000 car number plates, Shenzhen government started a car plate lottery with a NEV quota of 20.000 car number plates end of 2014. Motorized bicycles were prohibited more than 10 years ago. Lifestyles in using electric bicycles are very popular. Based on the legally binding policy structure, there are various instruments that can be identified for the development of municipal NEV and charging infrastructure. This makes the city leaders confident they will be able to close the gap between economic development and environmental protection. Up to 25 instruments are formulated in the following table.

Category	Instrument	Category	Instrument
Public transport and municipal fleets	Subsidy for Public Transport Companies (e-Bus and e-Taxi)	**Charging infrastructure**	Construction of charging piles
	NEVs for the municipal service and special fleet (Sanitation, Police, Logistics, e-Carsharing)		Construction of large-scale charging stations
NEV purchase incentive	Subsidy to manufacturer and supplier		Implement site location planning
	National and local subsidy to private and commercial buyer		Definition of construction standard
Other monetary incentives	Tax incentives		Set up operator service
	Toll road privilege		Public parking lots (existing > 10%, new 20 %)
	Privileges for accident insurance		Residence area parking lots (existing > 5%, new 20 %)
Non-monetary incentives	Security system		National charging standard
	Privilege for parking	**Other infrastructure**	Power supply network
	Car number plate lottery (20,000 NEV)		Technology research center
	NEV service platform	**NEV innovation system**	Creation of attractive frameworks for NEV manufacturing and battery technology
	National NEV traffic management policy	**Industry development**	Free or cheaper land for industry development
Penalties	Number plate restriction for fuel vehicles		
	Prohibition of motorized bicycle		
	Prohibition of electric bicycles with maximum speeds greater than 20 km/h speed		Industrial cluster promotion

Fig. 2: Instruments for NEV and charging infrastructure development in Shenzhen
Source: Own compilation

4. Discussion

The policies and instruments mentioned are the key framework for NEV development in Shenzhen, but the urban space in this fast growing megacity is very heterogeneous. Whereas overall urban planning follows strong top-down decisions led by the government [17], districts governments act a bit more independent. Out of this reason, the implementation process will be timed differently, depending on the local priorities. Some new city areas are designated as application areas, while some others, especially the urban villages, are more separated from this development.

4.1 Municipal level

On the municipal level, Shenzhen's transportation circulation system is used by 10 million people per day. Among them, 6 million travel by bus, 3 million by metro and 1,2 million by taxi. Taxis and buses account for 1,1 % of all vehicles in Shenzhen, but they are responsible for 20 % of traffic-related air pollution. For that reason, the municipal leaders decided to start with the

promotion and application of electric vehicles in the public transport sector. Today, the megacity is a global pioneer in this sector. The omnipresence of e-taxis and NEV buses are a good marketing tool to strengthen political support and acceptance among citizens for electric mobility. Many years of experience in this field are reflected in the core content of these policies. There are nearly 4,000 NEVs in the public transport fleet, including the 1,600 pure electric buses and 850 pure electric taxis on Shenzhen's roads. This is combined with 830 km special bus lines, making it the second largest network after Chengdu in China. By the end of 2015, the government will have procured 1,500 pure-electric buses, increasing the total number of NEV buses to 6,650. This will be 44 % of the total fleet of public transport buses running in Shenzhen [18].

Nevertheless, there are contradictions between large-scale expansion of the fleet with NEVs and the limited construction of charging facilities, the inadequate supporting policies and the inadequate business models. For that reason, the Shenzhen Leading Group Office improved policies. As a result, the state owned service providers for charging infrastructure like POTEVIO will construct nine comprehensive large-scale NEV bus charging, maintenance, and parking service centers for 4,000 NEV buses during the 13th Five Year Program from 2016 to 2020 [19]. District governments are responsible for the selection of urban space for charging stations, but available land is limited. From 950 sq kilometers allowed land for development, there were only 140 left in 2010 [20]. This land is mainly occupied by other commercial or residential use. There are projects with implementation challenges, especially for private users. After 2010, the government selected 14 residential areas in which to integrate hundreds of slow charging facilities. On-site research performed by the authors showed most of these piles are not in use or do not exist. The main challenge identified by the government was the inadequate integration of charging facilities in urban planning. For that reason, land for charging facilities cannot be guaranteed and investment is constricted. Furthermore, there is a shortage of land for construction and it is almost impossible that undeveloped land can be used for charging infrastructure. This inhibits investment in charging facility construction. Therefore, policymaker decided the constructions of slow charging facilities should cover no less than 5 % of parking in existing residential areas, and no less than 10 % of parking in existing public parking lots [21].

While private NEV owners mainly use slow charging facilities, fast charging is just for supplementary use. Slow charging should be included in the standard of new construction design, green building design standards and energy assessment specification, in order to ensure adequate power capacity. Due to the successful application of NEV buses and taxis, fast charging piles for commercial NEVs are frequently used. Over the last years, the municipal leaders identified the lack of charging infrastructure as the main bottleneck constraint. They decided a spatial distribution within a radius of 5-10 km over the city. In total, 1,800 charging points must be built [22]. By the end of 2014, there were already 1,100. Therefore, the districts have to build 700 in one year and give franchise to companies like POTEVIO for maintenance. According to urban planners from Shenzhen, there are five ways to integrate charging infrastructure in urban planning: the creation of statutory plans for new construction areas, the addition into public parking space, the alteration of residential area planning, an addition to fuel stations without changing the land use policy or the expropriation of temporary land [23]. The SZLGO tries to fasten the construction process while charging operators do not need to apply for approval of land use planning.

4.2 Micro level

On the micro level, there are some outstanding projects of national significance, like the 'Qianhai Shenzhen-Hongkong Modern Service Industry Cooperation Zone of Shenzhen'. More than two kilometres of land were captured from the sea to develop a new city center. Three hundred electric carsharing cars will be implemented there [24]. Nine metro and railway lines will connect an intermodal TOD concept that includes NEVs to promote a city of short distances. The new

public transport traffic hub will connect Guangzhou and Hongkong on a new north-south axis. Here, urban planners take a reduction of individual transport up to 50 % into account. Another important project is the Shenzhen International Low-Carbon City (ILCC) in Pingdi (Longgang District). This flagship project, based on the 'Sino-EU sustainable urbanization cooperation partnership agreement' from 2012, is located at the intersection of three cities: Shenzhen, Huizhou and Dongguan. It aims on the integration of low-carbon technologies like electric mobility. The 53 sq km urban development zone has 160,000 inhabitants and is relatively low-income area when compared to the average GDP-level of Shenzhen. The showcase project has lower land prices than other urban areas. The city leaders have integrated TOD concepts and charging infrastructure from the very beginning to attract highly skilled workers and low-carbon investments. The goals for traffic development are mixed use, the optimization of the public service system, reduced walking distances for residents, priority to public transport and emphasis on the design of pedestrian zones to encourage low-carbon transportation [25]. Furthermore, the ILCC will use green energy, like solar panels, to power the charging infrastructure, which is not standard in Shenzhen. It is important to keep in mind that nuclear power is included in the new energy sector which represent up to 60 % of energy production in Shenzhen [26]. The comprehensive plan of land use density (2010-2020) shows the spatial distribution of Qianhai and Pingdi urban development projects and the very high density (dark red areas) of Shenzhen's urban regions.

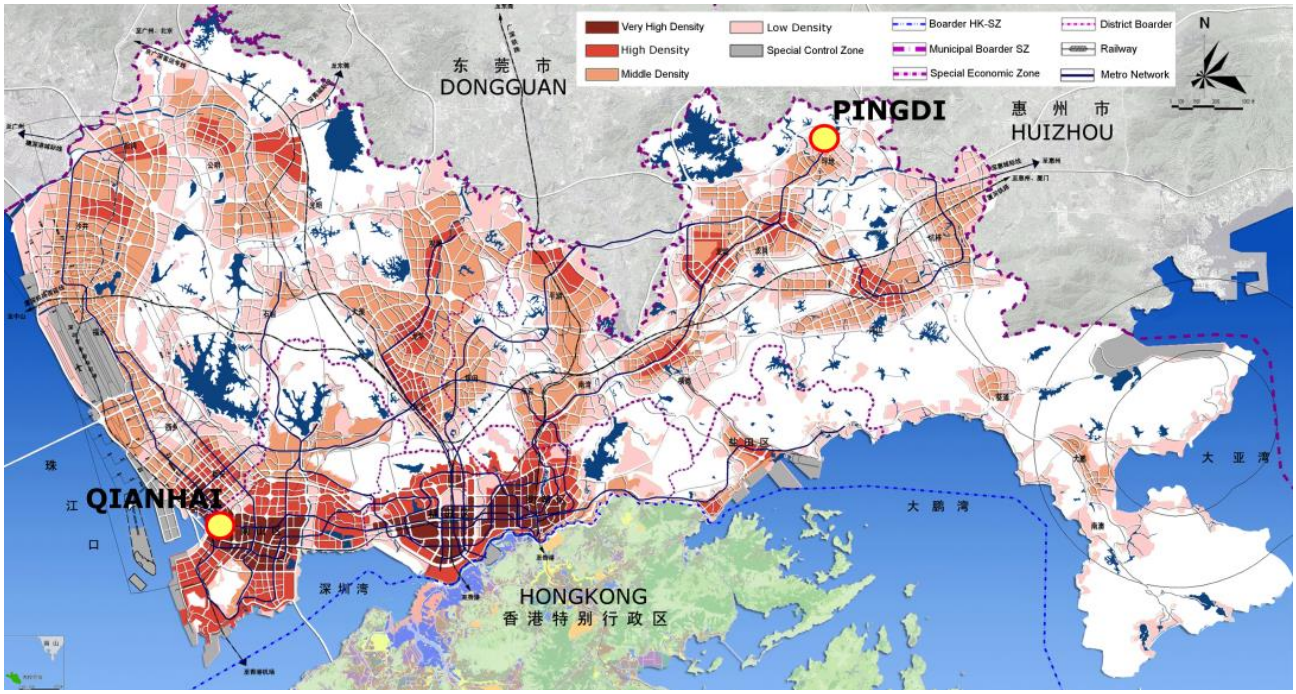

Fig. 3: Shenzhen land use density map (2010-2020) including the location of Qianhai and Pingdi
Source: [27] with own illustrations

Qianhai, Pingdi and many other new development projects are already under construction. While Qianhai seems to gain from big private investments, Pingdi is in a half-stagnant status. Further evaluation of the effects on urban development has yet to be performed.

5. Conclusion

Shenzhen is a leading city as a test laboratory for NEV policies, instruments and development worldwide. Investments in NEV and charging facilities as a driver for industrial development are exemplary. The megacity focuses on sustainable transport solutions, where comprehensive NEV

strategies are seen as a complementary instrument to make private and public transport cleaner. Vehicles should not be replaced 1:1 from fossil fuel to NEV. Using a mix of restrictions for fuel cars and incentives for NEVs and charging infrastructure, the municipal leaders place pressure on district authorities, industry and private individuals to implement this technology. If municipal leaders follow the target to promote public transport introduced in 2010, NEVs in the form of electric carsharing can be used to reduce traffic congestion, while limiting harmful emissions. The use of green energy is rising, but as long as nuclear power is considered 'green' energy, it is difficult to compare emissions reductions successes with similar programs in countries that do not consider nuclear power 'green', for example, in Germany. NEVs should be a complementary part of an efficient urban transportation system in a city with short distances, where walking, bicycle, electric carsharing and public transport are promoted as well. This is only possible if a private market can be activated and citizens of Shenzhen can raise their affinity for the use of electric cars. While implementing the new technology in urban development areas, there are still many of contradictions. Limited experience, mismanagement or the shortage of available land for charging infrastructure are challenges the city faces. The availability of billions for 'green growth' is a step in the right direction for a Chinese megacity like Shenzhen. However, it is only one part of what should be a comprehensive system where stakeholder, commercial and private users follow a unified path. Future research may show which instruments work and which have to be adjusted.

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