REEI Energy Review 2019

Energy Transition In China:

The Way Toward A Low-emission Transport Sector

磐之石 ROCK ENVIRONMENT AND ENERGY INSTITUTE
环境与能源研究中心

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Reviewer: Li Ying, Jiang Chao

Designer: Beijing Shape and Color Advertising Co. Ltd

Publication: Novermber 2019

Publisher: Rock Environment and Energy Institute

Non-profit publication for free distribution

Sponsor: Heinrich-Böll-Stiftung

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Preface

Rock Environment and Energy Institute (REEI) has been paying attention to transport-related issues since 2015, from the climate action of the aviation industry to the projection of carbon emission in the transport sector. The "REEI Energy Review 2019" focuses on how the transport sector to achieve a low emission future. With the past seven years of research experience in energy transition, carbon pricing, and clean air policies, among the six review articles, we cover the sustainable transport decision-making framework, low-emission transport policies, public health impacts of the transport sector, and the life cycle assessment of electric vehicles. The review report presents the situations and case studies of sustainable transportation development in China and abroad, the related policy and technical challenges, and the policy recommendations for low carbon transformation in China. We hope that the articles could help to promote the policy discussion of sustainable energy transition policies in China's transport sector.

The report begins with a discussion on the 21st century sustainable transport policy framework, pointing out that the development of sustainable transport can start from changing the ways residents travel, focusing on the development of urban public transport networks and service capabilities, one of the long-term key options for mitigating climate change. Under this framework, we analyze the existing policies of China's low-emission transport and give policy recommendations. At the same time, we use Japan as a case to explore the pathway to sustainable transportation development, and also compare the more ambitious climate commitments in China's transport sector. For the analysis, it is suggested that China's transport sector needs to accelerate the process of low carbon development to cope with the increasingly severe climate change. We also analyze China's urban traffic-related health impacts and the benefits from prevention and control measures. Finally, we use the Life Cycle Assessment to examine how electric vehicles and conventional internal combustion engine vehicles differ in the externalities of climate change, ecological environment and public health, and suggest that China should prioritize the decarbonization of power systems at this stage.

As REEI's core annual report, “REEI Energy Review 2019”, for the first time, focuses on the transport sector, expecting to advance the policy exchanges among researchers and practitioners who work on the issues of low carbon transport and energy transition. The accomplishment of this annual report is attributed to the generous support of the Heinrich Böll Foundation (HBF) China Office and the concerted efforts of REEI staff. We would also like to take this opportunity to thank Professor Pan Xiaochuan of the Peking University School of Public Health for his special contribution to this report.

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November 01, 2019

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Contents

Decision-making Framework of Sustainable[1] Urban Road Transportation Policy in the 21st Century: a "Triple Bottom Line" Approach

Zhao Ang

The development of urban road transport in the 20th century (hereinafter referred to as urban transportation) is closely related to the national economic growth level (including growth rate and quality). For more than half a century from the World War II to the first ten years of the 21st century, the highlights of world economic growth appeared in North America, Europe and East Asia. The developments of urban transportation in these regions are to seek a balance between building more roads for more private vehicles and increasing public transportation investments, supplies as well as improving services. As the increasing contribution of transportation to urban air pollution and the global efforts to deal with climate change, the traditional urban transportation decisions aiming at promoting GDP growth, improving population mobility, controlling transport congestion and providing cost-effective and safe public transport services, are facing challenges, which include social and environmental justice, inclusiveness of economic development, climate change and its impacts, public health and other factors resulted from the transportation decision process and activities, and a low-emission (including conventional pollutants and carbon dioxide emissions) transport system for the future. This paper discusses the policy framework of urban sustainable transport in the 21st century by combining the model of transport decision in the United States and the case of low-emission development of urban transportation in the city of Los Angeles.

1. The comprehensive decision for urban transportation

The transport system includes three interrelated fields: transportation policy and planning, design and construction of transport system, and operation, maintenance and disposal of transport systems after its service life expires. Although this paper mainly discusses the first aspect, consideration of the last two aspects will also affect planning and policies. In planning and policy decision-making, it should consider how to effectively cope with the waste from the end use stage of transport systems in the application of Life Cycle Assessment and how to implement a comprehensive transportation planning and policy decision making after taking into account the factors of investment and economic feasibility, as well as the design and construction of transport system, environment and user friendliness.

The complexity of urban transportation planning and policy decision-making is reflected in that it not only involves social issues (transport convenience, safety and distribution of transport resources), economic issues (affordability of travel time and financial costs, social and economic costs of congestion) and other issues, but also has a direct impact on urban environment (air pollution, water pollution, impact on natural ecosystem/biodiversity-habitat destruction-segmentation, noise, etc.), public health and global climate change. The policy decision-making framework for sustainable urban transportation in the 21st century needs to break through the limitation of the urban areas and interests tangling, examine the problems and solutions from a long-term time dimension (e.g. more than 50 years) and a global perspective, break away from the previous traditional decision-making model, and establish a decision-making framework including new evaluation indicators:

- Whether to undertake the global responsibility to deal with climate change and promote the development of net zero emission in the transport sector as the goal;

- Whether to aim to improve the quality of urban environment, and continuously reduce the emission of pollutants harmful to public health;

• Whether to control the supply and demand balance of urban transportation resources, an important public good, to limit the growth of private cars and increase the capacity and level of various public transportation services;

• Whether to consider the inclusive nature of economic development to provide affordable, safe and reliable public transportation for the low-income urban population;

• Whether to integrate urban design and planning to provide support and solutions for the future low carbon development of urban areas.

Next, let's look at what American organizations, including government agencies, have done in enhancing the decision-making process in order to promote sustainable transportation development.

2. Low-emission transportation decision models

Each city has its own characteristics of the current transportation systems, and the basis and ability to achieve sustainable transportation with low emissions are also different. However, the abovementioned indicators are largely universal for sustainable low-emission transportation decision making in cities. The following decision-making models being used in the United States are worthy of noticing as they try to address the sustainability issues in the transportation policy making process. Here is a brief review.

GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) is an assessment model for greenhouse gases, pollutant emissions and energy use in transportation systems. It was developed and continuously updated by the Argonne National Laboratory of the U.S. Department of Energy. This model aims at how changes in energy and transportation policies lead to changes in output throughout the life cycle of energy use. For example, if in the next five years, 30%-50% of the passenger car is driven by charging electric or hybrid power, how much carbon will be reduced for the full life cycle of the U.S road transportation and the how much cost it will take.

Traffic decisions cannot be made without urban planning and community design. The namesake decision model developed by EcoDistricts, a non-profit organization, focuses on decision-making at the community level and helps integrate infrastructure, construction and transportation decisions into community actions. This model is currently developing four decision-making frameworks, covering institutional organization, performance and evaluation, financing and policy support. This decision-making framework involves many new concepts and technologies, including bicycle lanes, green streets, community energy and water resources management, public art and smart grid.

UrbanSim/UrbanFootprint is an interesting model for how to consider sustainable transportation in urban planning decisions. This model supports the planning and analysis of urban development and integrates land use, transportation, economy and environment into the decision-making process, which helps to discover the impacts of policy changes and infrastructure on communities, such as the convenience of transportation, housing affordability and corresponding carbon emissions. With the aid of the model, scenario analysis can be done, for example, how to take economic, environmental and public health factors into consideration, so as to make analysis of future transportation development under different scenarios.

Local governments in the United States, including states and cities, also use modelling methods in decision-making.

For example, New York State Department of Transportation has developed the GreenLITES Model for sustainable development of transportation and environment, in order to recognize and promote the integration of sustainable development methods into planning, project design and evaluation related to regional transportation development by state decision makers, thus to improve the sustainability of transportation systems.

Similarly, the Illinois State Department of Transportation has also developed a tool: Illinois-Livable and Sustainable Transportation Policy Tool (I-LAST), which provides a detailed list of sustainable practices and a brief method for evaluating whether a project is sustainable. This tool aims to minimize the impact on the environment, reduce resource consumption and energy consumption. The tool is highly practicable because it provides a set of lists of potential sustainable practices that can be referenced and includes a corresponding list of raw materials for each practical operation, which greatly helps decision makers to put concepts and methods into practical operations.

These models suggest that policy makers urgently need a decision-making framework or model that can comprehensively examine and consider sustainability from the life cycle of the transportation system. As model developers are often among the stakeholders of policy decision-making, from the perspectives of organizational structure, experience, habits and specialty, the models are usually focused on one specific aspect, and lack a macro and long-term strategic perspectives to think about what kind of the decision-making framework for future sustainable low-emission transportation should look like. Such challenges have been fully recognized by the researchers in this field. The Transportation Research Board (TRB)[2] of the United States published a series of "Strategic Issues of Transport" reports in 2015. One of the reports, entitled "Sustainability as an Organizing Principle for Transportation Agencies", analyzes how transportation agencies manage and organize to support a more sustainable society. The model explains in detail how to focus on long-term and systematic methods to provide public services from immediate and short-term interests. One concept put forward in the report is "Triple-Bottom Line (TBL), that is, economic, environmental and social factors should be measured and calculated as the bottom line in decision-making. "The TBL is a comprehensive concept that does not exclude any policy areas and systems. It is difficult to isolate the transportation system because transportation has the fundamental attribute of integration with other human activities. Sustainable transportation requires considering a broad definition of sustainability. Under such requirements, it is necessary to consider how transportation affects the sustainability of the whole society and how policies other than transportation coordinate and cooperate with each other to achieve sustainability."[3]

TRB's latest report Critical Issues in Transportation 2019 points out 12 critical issues,[4]involving transportation system governance (decision-making and institutional arrangements, system performance and asset management, investment and financing, and cultivation of more efficient and diversified transportation human resources); how to develop a low carbon transportation system; fairness, safety and health of transportation services and resilience to population changes and frequent disasters; research and technological innovation in the management of transportation, as well as the discussion by a special department on protecting the ecological environment and achieving sustainable development. In fact, these 12 critical issues are all related to the sustainable development of the transportation system, in which the transport sector governance, technological innovation and energy transformation are the top priorities. Many local governments have already made efforts to take immediate actions to seize the short time window to deal with climate change and introduce the transportation system into the track of sustainable development. Next, we will briefly observe a case. This city was a global model of urban development in the 1960s and 1970s, encouraging private car ownership, and building ever expanding highway network. However, it is currently making a fresh start to create a low carbon urban development model that responds to climate change, local air pollution and green economic growth with sustainable transportation as one of the cores of policy initiatives and development model innovations.

3. Los Angeles: Rebuilding a global model?

Los Angeles County (Greater Los Angeles area with the city of Los Angeles as its core and more than 80 cities included) covers an area of more than 10,000 square kilometers, has a population of more than 10 million (4 million people in the city of Los Angeles), and its total economic output (GDP) exceeded 1 trillion U.S. dollars in 2017, ranking the 16th position in the world's GDP in the same year.[5]

On average the residents in Los Angeles County lost 61 hours per year due to congestion. Los Angeles has been ranked as the most congested area in the United States for more than a decade.[6] Facing the worst situation, Los Angeles has been making changes in the past ten years. In Regional Transportation Planning 2012-2035, Los Angeles County Metropolitan Transportation Authority plans to invest 525 billion US dollars to develop sustainable transportation by 2035.[7] By 2012, Los Angeles's public transportation networks such as subways, light rails, liquefied natural gas (LNG) bus lines, bicycle lanes, and so on. have increased significantly.

Los Angeles's transportation and construction sectors account for three quarters of all carbon emissions.[8] Moreover, Los Angeles has undoubtedly placed transportation emission reduction in a key position in its action to mitigate climate change. Los Angeles has already put forward a more active target of reducing emissions in 2015. Under the leadership of Mayor Eric Garcetti, who regards tackling climate change as the most important task in his administration, Los Angeles further launches a "Green New Deal"[9] in 2019 and sets more ambitious targets for mitigating climate change. Here are only the contents related to transportation and urban planning:

- By 2045, the power system will achieve 100% renewable energy supply;
- By 2035, 80% of passenger cars are powered by electricity or zero-emission fuels, while 80% of the electricity supply comes from renewable energy;
- By 2050, 100% of vehicles will be electric vehicles or zero-emission vehicles, and by 2030, public transportation including rails and buses will be 100% electrified;
- Port-related carbon emissions will be reduced by 80% against the level of 1990 by 2050;
- The number of public charging stations for electric vehicles will reach 28,000 by 2028;
- Vigorously developing public transport (by 2035, 50% of the trips will be made up of low carbon modes such as walking and cycling);
- Implementing public transport-oriented urban design and planning (by 2035, 75% of new residential buildings will be located within 1,500 feet of public transport stations);
- Using reverse incentives (charging higher road tolls in heavily congested areas), Los Angeles plans to reduce the average daily driving distance of residents from 15 miles around 2017 to 13 miles in 2025 and 9 miles in 2035.

Los Angeles has set an action targets full of opportunities and aspirations. Maybe by 2030, we can judge whether Los Angeles has realized its objectives and recreated a model of world-class city's low carbon development based on the facts and experiences.

Conclusion: What kind of cities do you want to live in?

From the macro point of view, sustainable transportation development requires us to rebuild the social development model and policy decision-making framework, and we need to balance thinking and making decisions about our future from the "Triple Bottom Line" of society, environment and economy; from a micro point of view, the realization of sustainable transportation depends on every citizen's action to answer the question: What kind of urban environment do you want to live in in the future? Responding to climate change is the most urgent and important issue in the field of sustainable development, as well as in the field of transportation. Under the Paris Agreement, most governments have been taking various actions to reduce greenhouse gas emissions under the constraints of their own capabilities and resources. However, the current trajectory of global mitigation efforts cannot achieve the goal, to keep the global average temperature rise no more than 2℃ . Therefore, more and more non-state (government) actors, from commercial enterprises, to community organizations, environmental groups and individual citizens, are taking part in the initiative to make changes from the bottom up. In the next ten years, these two currents, both top down and bottom up approaches will work together to bring sustainable development and low carbon development to the core of all parts of human activities, including the transport sector. The cities, where vast majority of population across the globe will live and work in the future, will become more socially inclusive, economically dynamic, technologically creative, environmentally healthy, and naturally sustainable for their citizens. This might be the ideal future city each of us would like to live in.

References

1. The so-called sustainability should involve environmental, economic and social sustainability. Specifically, it should refer to environmental sustainability (climate change), vitality of economic development and sharing of growth/values, social inclusion, multiple integration and mutual respect (avoiding the disparity between the rich and the poor and ethnic confrontation based on beliefs and values).
2. TRB is one of the six main branches of the National Research Council of the United States. It is managed by the United States National Academy of Sciences, the National Academy of Engineering and the National Academy of Medicine and has a history of nearly 100 years. This interdisciplinary and cross-disciplinary research institution is leading the way in promoting innovation and progress in the transportation field in the United States through research and information exchange.
3. NCHRP Report 750 Volume 4: Sustainability as an Organizing Principle for Transportation Agencies
4.“Critical Issues in Transportation 2019: Policy Snapshot” Link:http://onlinepubs.trb.org/onlinepubs/policystudies/criticalissuesbrochure.pdf
5. According to Stastata.com's data on GDP comparison.
6. Achieving a Lower Carbon and More Sustainable Transportation System, Pam O'Connor. Link:https://sustainabledevelopment.un.org/content/documents/3724oconnor.pdf
7. Same as footnote 6.
8. The data quoted in this paragraph is from an interview with the Mayor of Los Angeles in Los Angeles Times, published on April 29, 2019, entitled Los Angeles Mayor Proposes Ambitious Sustainability Plan. Linkage: https://www.govtech.com/fs/transportation/Los-Angeles-Mayor-Proposes-Ambitious-Sustainability-Plan.html
9. Links to "Green New Deal Plan": https://plan.lamayor.org/targets

Review of China's Low-emission Policy in Transport sector

Lin Jiaqiao

The transport sector involves both traditional pollutant emissions and greenhouse gas emissions, which makes it difficult to solve the challenge of air pollution and climate change at the same time. Although the two types pollutants are of the same source, their impacts and formation processes are quite different, which leads to the fact that the policies for the two are often separated when they are formulated, but actually they are partially overlapped at the implementation level, resulting in unsatisfactory policy implementation effect. This article will review the development of China's low-emission transportation policies from the perspectives of pollutant control and low carbon transportation policies, discuss specific issues and give policy recommendations.

1.Review of Transport Pollution Control Policy

In early 2013, Northern China encountered continuous smoggy days. In autumn 2013, the State Council promulgated the Air Pollution Prevention Action Plan[1], which put forward specific feasible suggestions on transportation, mainly focusing on traffic management, oil quality, scrapping of high-emission vehicles, environmental protection management of motor vehicles, promotion of new energy vehicles, etc. In the same year, some laws and regulations such as the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution and the Environmental Protection Law of the People's Republic of China were revised one after another, and air pollution policies at the regional, provincial and municipal levels were also promulgated one after another. As a basic law in the field of air pollution prevention and control, the Law on the Prevention and Control of Atmospheric Pollution was promulgated in 1987 and revised in 2000. The new edition (2016) [2] includes management of emission limits to control the vehicular pollutants. In terms of energy conservation, public transportation and driving behavior, the law is only at the level of encouragement and advocacy.

1.1 Motor vehicle emission limit

At present, the motor vehicle emission standard widely implemented in the whole country is Light Vehicle Emission Limits and Measurement Methods (CHINA 5) (GB 18352.5-2013), which is abbreviated as "CHINA 5 Standard". According to the relevant provisions of the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution, more developed regions such as Guangdong Province have already implemented the “CHINA 5” in advance from 2015[3].

At the end of 2016, the Ministry of Ecology and Environment issued Limits and Measurement Methods for Emissions from Light-duty Vehicles (CHINA 6) (GB18352.6-2016). The CHINA 6 standard will be implemented on July 1, 2020. The limits in this standard are far higher than those in EURO 6 emission standard and the Tier3 Standard in the United States, which is by far the strictest standard in the world for motor vehicle emission standards. At present, many provinces and cities across the country have begun to implement the "CHINA 6 standard". Compared with the “CHINA 5 standard”, the CHINA 6 standard has added the nitrous oxide limit requirement.

Table 1: Comparison of emission standards for motor vehicle pollutants

Pollutant	CHINA 5	CHINA 6a	CHINA 6b	EURO VI	U.S. Tier3*	(Unit)
CO (carbon monoxide)	1000	700	500	1000	4200-1000(2025)	mg/km
THC (hydrocarbons)	100	100	50	100	-	mg/km
NMHC (non-methane alkane)	68	68	35	68	-	mg/km
NO_x (nitrogen oxide)	60	60	35	60	-	mg/km
N_2O (nitrous oxide)	-	20	20	-	-	mg/km
PM (particulate matter concentration)	4.5	2.5	3	4.5	3	mg/km
PN (particulate matter quantity)	-	6.00E+11	6.00E+11	6.00E+11	-	Pcs/ km

*Tier3 emission standard specifies the total amount of NMOG (Non-methane organic gas) and NO_x and replaces them in seven levels.

1.2 Fuel standard

The 2013 Air Pollution Prevention Action Plan proposed to improve fuel quality. Strive to supply automobile gasoline conforming to the "CHINA 4" standard nationwide by the end of 2013, and supply automobile diesel conforming to the "CHINA 4" standard nationwide by the end of 2014 and supply automobile gasoline and diesel conforming to “CHINA 5” standard nationwide by the end of 2017."

In June 2018, the State Council's Notice on Issuing a Three-Year Action Plan on Air pollution Control required that "from January 1, 2019, supply the automobile gasoline and diesel conforming to 'CHINA 6 Standard' nationwide and stop selling gasoline and diesel below CHINA 6 Standard …”[4]. Compared with “CHINA 5” oil products, “CHINA 6” gasoline/diesel is mainly reduced in the content of olefin, aromatic hydrocarbon, benzene, etc. in automobile gasoline; in addition, polycyclic aromatic hydrocarbons in the index of vehicle diesel oil is reduced but the quantitative index requirement of total pollutant content is added, which is in line with the current European Union standard level of vehicle oil products, and even individual indexes exceed the European Union standard.

1.3 Traffic demand management: taking both administrative and economic measures

In addition to improving vehicle exhaust emission standards and upgrading the quality of oil products, there are also many policies and measures in traffic demand management that can reduce pollutant emissions. For example, traffic restrictions and license plates number restrictions are implemented in some areas to ease traffic congestion, which are currently common in large cities in China. Traffic demand is reduced by restricting the purchase and use of cars.

In addition, the emission standards mentioned above can also reduce the intensity of pollution emission by restricting and banning the use of vehicles. The CHINA 6 standard for motor vehicles is for new cars, and the impact on purchased and used cars is based on whether and how the regions implement the restrictions. However, after the promulgation of the CHINA 6 standard, in the future, more restriction will be imposed on vehicles that are lower than the standard. Some cities have even introduced measures to prohibit “CHINA 4” vehicles from entering the urban areas. For example, in Taiyuan, Shanxi, the latest control measures clearly specify that diesel trucks under CHINA 4 standard (inclusive) are prohibited from passing the key roads all day[5]. Therefore, it is another measure to reduce pollutant emission intensity due to the standard upgrade. As for how to implement it, the actual situation in various regions should be considered, and the policies of restriction and prohibition should be formulated.

Summary: China's pollution control mainly relies on legislation to guide the vehicle exhaust emission standards and the upgrading of oil standards. Currently, the CHINA 6 standard that have been implemented in some provinces and cities are at the international advanced level. Reducing pollutant emissions through the transition to strict emission standards and oil quality standards is the only way to control the total amount of pollutant emissions, the main reason is that the emission amount is very large due to huge number of motor vehicles in China even if the CHINA 6 standard is fully implemented across China. In addition, relevant policies such as encouraging the use of public transportation and new energy vehicles, total vehicle number control, and eco-friendly driving also play a role in reducing pollutant emissions, but the objectives of these policies are not completely focused on controlling pollutants or the driving force is very small, and are not analyzed as a key point.

2.Low carbon transportation policies

2.1Review of low carbon transportation policy

With regard to low carbon transportation, the national policy can refer to the National Climate Change Plan (2014-2020),[6] in which the low carbon development of transportation mainly focuses on the regulation of the total number of motor vehicles, fuel substitution, development of public transportation, low carbon standard system, and so on **(Table 2)**. It is worth pointing out that the plan proposes to study and establish carbon emission standards for new vehicles and encourages the development of **low-emission vehicles**.

Other policies at the national level include low carbon provinces and cities and key cities for air pollution prevention and control, which are also policies that directly or indirectly promote the reduction of carbon emissions. At present, the national ministries and commissions concerned with low carbon transportation are mainly the National Development and Reform Commission and the Ministry of Ecology and Environment. The Ministry of Transport has launched the pilot city of low carbon transportation in 2012, but did not continue after two batches of pilots.

From a technical point of view, there is a road map for the technology development of energy saving and new energy vehicle, which provides a detailed technical path for emission reduction[7]. In terms of national standards, the standard Fuel consumption limits for passenger cars actually indirectly restricts CO_2 emissions. At that time, the CO_2 emission limit will be around 120 g-CO_2/km, which is still a certain gap from the new car emission limit[8] of 95 g-CO_2/km introduced by the EU from 2020. At present, the CHINA 5 standard (2021-2025) is in the process of soliciting opinions[9]. The target is to reach an average fuel consumption of 4.0 L/100km for new passenger cars by 2025, when this standard is also close to the average level set by developed countries in the world.

Table 2: China’s low carbon transportation policies in recent years

Major policies	Low carbon transportation related
National level	

Energy-saving and New Energy Automobile Industry Development Plan (2012-2020)[10]	▪ It points out that pure electric drive is the main strategic orientation for the development of new energy vehicles and the transformation of the automobile industry and encourages the development of alternative fuel-driven passenger cars such as natural gas and biofuels; ▪ It requires to promote the continuous improvement of the fuel economy level of passenger cars and upgrade the standard of fuel consumption of passenger cars.
National Climate Change Plan (2014-2020)	▪ It regulates the control of vehicle possessing and actively promotes natural gas and pure electric vehicles; it encourages the development of low emission vehicles; ▪ Actively develop urban public transportation; ▪ Study and formulate a low carbon standard system for the transportation industry, and study and establish specific measures such as carbon emission standards for new cars.
The 13th Five-Year Plan for Controlling Greenhouse Gas Emissions[11]	▪ Put forward the construction of low carbon transportation system; ▪ Improve the urban transportation system that gives priority to public transportation and encourage the use of low carbon and clean means of transportation; ▪ Raise fuel consumption limit standards for passenger cars and heavy commercial vehicles, and study carbon emission standards for new vehicles; make in-depth implementation of low carbon transportation demonstration projects.
National low carbon pilot provinces and municipalities (National Development and Reform Commission)	▪ Guangdong: Promote the use of new energy, renewable energy utilization technologies and new technologies for energy conservation and emission reduction, promote comprehensive innovation of ideas, policies, institutional mechanisms and technologies, so as to provide scientific and technological support and policy guarantees for accelerating the construction of low carbon transportation systems; ▪ Hangzhou: Further improve the “five in one” low carbon transportation system, i.e. subway, bus, taxi, free bicycle and water bus.
Key areas for air pollution control (Ministry of Ecology and Environment)	▪ Beijing, Tianjin and Hebei: Give priority to policy and financial support, take the lead in replacing buses and taxis with new energy vehicles, and gradually improve the green transportation system by improving the charging infrastructure construction.
Technology Roadmap for Energy Saving and New Energy Vehicle[12]	▪ The development in the next 15 years will focus on new energy vehicles and intelligent connected vehicles, and the automobile industry will initially realize the transformation to electrification; ▪ At the same time, put forward the idea of energy-saving vehicle is to focus on the development of hybrid vehicles, increase the proportion of small vehicles, and give consideration to natural gas vehicles; Establish carbon emission targets.

Fuel consumption limits for passenger cars (GB 19578-2014) and Fuel consumption evaluation methods and targets for passenger cars (GB 27999-2014)[13]	▪ From January 1, 2016, the average fuel consumption standard for automobile manufacturers is required to meet 6.7 L/100km in 2016; ▪ By 2020, the average fuel consumption shall drop to 5.0 L/100km.
Provincial and municipal level	
Development Plan for Clean Energy Vehicle in Hainan Province[14]	▪ Put forward the general goal of achieving "a new Hainan in green and smart travel" by 2030, which is divided into three stages: 2020, 2025 and 2030. ▪ In the field of public services, efforts should be made to realize clean energy by 2020; in the social operation field, efforts shall be made to realize clean energy by 2025; in the field of private cars, efforts shall be made to add and replace 100% of new energy vehicles in the province by 2030.
City level	
Carbon emission peak target of low carbon pilot provinces (districts) and cities	▪ Accelerate the development of pure electric and hybrid vehicles; ▪ Promote the demonstration application of hydrogen fuel cell electric vehicle; ▪ Vigorously develop public transportation and rail transit; ▪ Establish a road rights system with priority for pedestrians, non-motor vehicles and transit; ▪ Encourage and support the orderly and rapid development of shared transportation; ▪ Increase the proportion of railway and waterway transportation; ▪ While developing logistics, seize the opportunity of emission reduction in the freight industry; ▪ Explore the innovation of transportation emission reduction mechanism and promote emission reduction through market means.
Enterprise level	
Automobile manufacturers and dealers	▪ Volvo: Since 2019, it has stopped production and sales of traditional internal combustion engine models, abandoned diesel engines, and listed new cars equipped with electric motors. ▪ Fiat-Chrysler Automobiles (FCA) Group: In 2022, the number of pure or hybrid vehicles under the FCA reached 50%. ▪ Volkswagen: The fuel vehicles will be gradually stopped selling within five years until the car is motorized.

2.2 Suggestions on current low carbon transportation policy

In the perspective of the national macro policy level, the current low carbon transportation policy has not been attached great importance to, and it is at the level of planning and implementation of the work plan. The set goals are mainly concentrated in the field of operational transportation, and there is still a lack of effective control policies for the fastest growing non-operational areas. The specific problems we have observed, and suggestions are as follows:

▪ Issuing special policies of transportation department to deal with climate change

Develop and organize the implementation of special plans or special action plans for the transportation industry to deal with climate change, and subdivide them into sub-sectors such as roads, railways, water transportation and aviation, according to China's National Climate Change Programme and China’s National Plan on Climate Change (2014-2020) and other documents.

▪ Expanding the target range of transportation emission peak

Although some cities have proposed to reach the peak of traffic carbon emissions at the city level, most cities have not set goals, so it is necessary to further expand the pilot of low carbon cities to increase the number and scale of cities committed to reach the peak, and expand it to the scope of province.

▪ Strengthening the low carbon policy and standard system for transportation

Vehicle carbon emission standards and their corresponding carbon emission reductions shall be linked to Nationally Determined Contribution (NDC) at the national macro level; just like the management of air pollutants, the specific air quality level corresponds to the total emission limit of pollutants in various industries, and the emission limit standards and corresponding policies are formulated accordingly.

▪ Making the low carbon technical route clearer

Increasing the proportion of low carbon fuels is an issue to be considered in different low carbon paths. How to reasonably evaluate the economy and feasibility of different low carbon fuels such as LNG (liquefied natural gas), CNG (compressed natural gas), electric power, hydrogen fuel and among others; at present, there are still large arbitrariness and industry judgment affecting the selection of reasonable technical routes.

▪ Coordinating economic development and social equity

Most urban transportation policies focus on the goal of achieving a low carbon city, while there are no corresponding supporting policies for achieving more macro goals such as sustainable and livable cities, such as promoting social and economic development and social equity on the basis of achieving a low carbon city. Moreover, the fairness of travel is not considered enough.

▪ Discussions on “no fuel vehicles” should be opened

At present, only Hainan Province has issued a policy on banning the sale of fuel vehicles. The European Union, the United States and other places have already expressed their positions on the “no fuel vehicles” policy. China’s future development plan and no-sale schedule for fuel vehicles should also be discussed on a larger scale, such as at the provincial and even national levels.

▪ National low carbon policy needs to increase synergy

The Ministry of Housing and Urban-Rural Development and the Ministry of Science and Technology have launched a national smart city pilot. Smart city construction can promote the development of low carbon transportation, but the specific policies may overlap with the national low carbon pilot provinces and cities led by the National Development and Reform Commission. Therefore, the policies for low carbon transportation adopted by different ministries should be properly coordinated in the process of formulation and implementation to avoid the policy effect to be reduced.

- Lack of carbon pricing

The small and disproportionate carbon emissions due to the mobile source characteristics of the transport sector make it challenging for market-based, cost-effective policy instruments such as carbon credit trading to control the carbon emissions of the transport sector. At present, Singapore has already implemented a carbon tax in all sectors, while China's choice of carbon pricing for the transport sector is still in discussion, and those who support the implementation of the carbon tax think it is simpler and easier.

Conclusion

Due to the homology between traditional pollutants and greenhouse gas emissions in the transport sector, many transportation low emission policies overlap. In general, there are four ways to achieve emission reduction in the transport sector: controlling the level of traffic activities, optimizing the composition of transportation modes, improving fuel efficiency and promoting clean energy applications.[15] At present, clean transportation and low carbon development in China still rely on fuel substitution and travel modal shift to reduce the consumption and reduction of fossil fuels, thus reducing the emission of traditional pollutants and greenhouse gases. A common problem faced by China's urban transport sector in reducing emissions is that the reductions in emissions and efficiency of existing technology measures to improve vehicle energy efficiency are not sufficient to offset the increase in emissions.

After the China-US trade war, China's preference for key consumer goods, such as automobiles[16], "it is strictly forbidden to introduce new regulations on automobile purchase restriction everywhere, and local governments that have implemented automobile purchase restriction should speed up the shift from purchase restriction to use guidance according to the control effect of urban traffic congestion, pollution control and traffic demand...", which brings uncertainty to the development of low emission transportation in the future. Under the current economic situation, more similar problems may be faced in the future. Therefore, it is one of the challenges of future transportation policies to replace administrative measures such as restriction of travel and purchase with market measures, and to manage the level of transportation activities and balance the development of the automobile industry through market-based mechanisms.

Developing low-emission transportation should be a slogan for the transport sector in the future. Finally, it is suggested that when formulating the low-emission transportation policy, not only the problems at the solution level should be discussed, but also the public health factors should be taken into account, and how to improve public awareness on green travel and change the existing driving behavior should be further discussed.

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More ambitious NDC: Low carbon development needs to be accelerated in the Chinese transportion sector

Lin Jiaqiao

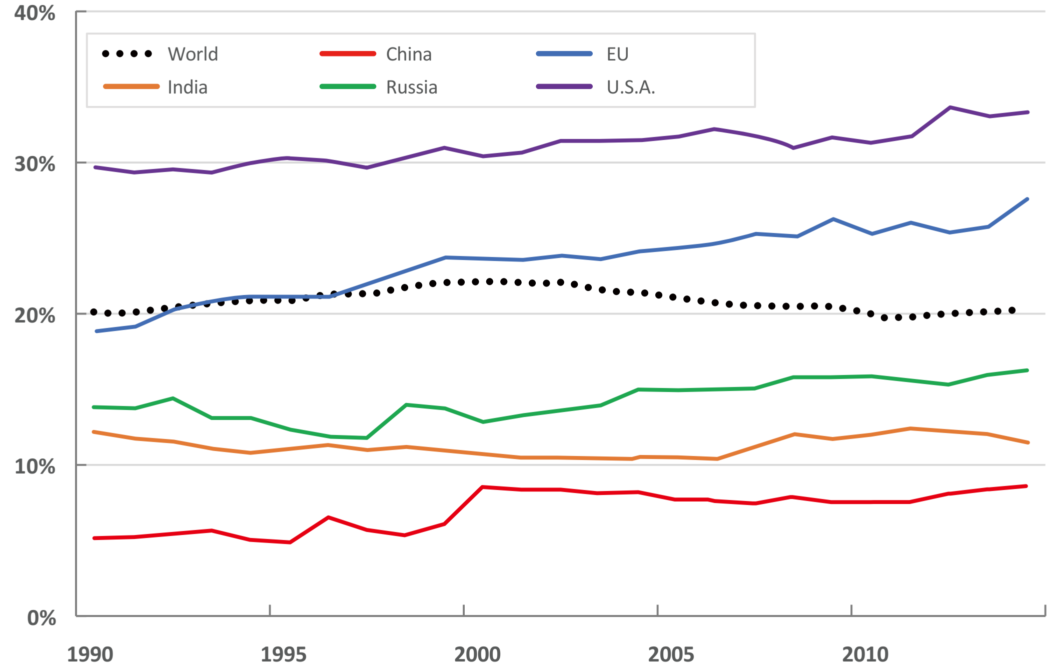
China's climate commitment under the Paris Agreement is ambitious through horizontal comparison among the emerging economies. The Nationally Determined Contributions (NDC) also mentions the goal of peaking emissions around 2030, but China is supposed to take more responsibilities in the context of global temperature rise of 2℃ or even 1.5℃ . In this case, as the world's largest emitter, China's NDC has been labeled as "highly insufficient"[1].

Therefore, it is necessary to carefully analyze the emission reduction potentials and future development trends of various sectors under the control of the total emission target, so as to provide necessary support for future NDC updates in China. According to the statistics on carbon emissions in China, the proportion of carbon emissions in the transport sector ranks third[2], and is now increasing year by year at a fast rate, especially in the road traffic sector. As the number of private cars grows rapidly due to urbanization, the resultant growth rate of emissions cannot be ignored, and has also become the main obstacle to low carbonization of the transport sector.

1.Carbon emission status of transport sector in China and horizontal comparison

According to the International Energy Agency (IEA), the carbon emission of the transport sector in China was 780 million tons of carbon dioxide in 2014, accounting for 8.6% of China's total energy-related emissions, which is still much lower than the world average of 20%. Among the world's five major emitters (regions), the United States and the European Union account for about 30% respectively; India is also slightly higher than China, accounting for 11.5% in 2014.

Figure 1: Proportion of carbon emissions in the total carbon emissions for the transport sector of the five major emitters



Source: World Bank DataBank CO2 emissions from transport (% of total fuel combustion). Link: https://data.worldbank.org/indicator/EN.CO2.TRAN.ZS

The specific trend in China is that there is a period of rapid growth after 1998, but it tends to be stable after 2000, accounting for about 8%. As the growth rate of China's total carbon emissions slows down and that of energy consumption in the transport sector maintains a high level, the proportion of transport emissions in the future will be closer to the world average.

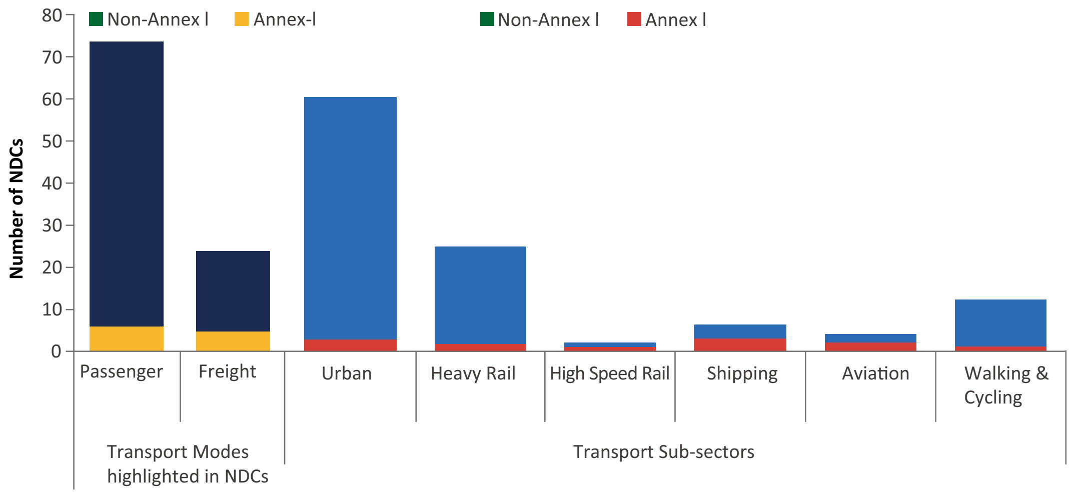
2.Commitments on the transport sector in NDCs of different countries

The IPCC Fifth Assessment Report (AR5) proposes a set of strategies for reducing the greenhouse gas emission intensity of the transport sector, including the implementation of "Avoid" and "Shift" strategies to complement the "Improve" measures[3]. For some countries, their NDCs can reflect how to balance these strategies, for example, Jordan's NDC, which includes both "Avoid" strategy (e.g. vehicle restrictions, congestion charges, etc.) and "Shift" strategy (e.g. improving public transport, encouraging cycling and walking, etc.) and "Improve" strategy (e.g. improving fuel efficiency, promoting fuel low carbonization, increasing electric travel ratio, etc.).

As urbanization and industrialization in different countries are in different stages, according to the emission inventories, the urban carbon emissions in developed countries are mainly from the construction sector, while those in the emerging countries are mainly from the transport sector, and those in the fast-growing developing countries are mainly from the industrial sector[4]. As a result, different countries have different priorities on their NDCs, and these factors need to be taken into account when making the commitments on the transport sector.

Nearly three-quarters of the countries that have submitted NDC or INDC have explicitly mentioned the emission reduction measures for the transport sector, and some organizations have analyzed these measures. In addition to distinguishing different transport modes, the country category (Annex-I vs. Non-Annex I) has also been indicated. In terms of transport modes, measures in the NDCs are obviously biased towards passenger transport, and there are insufficient considerations for freight transport, especially for Non-Annex I countries. Among other passenger transport measures, urban transport and heavy rail are more likely to be mentioned in the NDCs. In contrast, high speed rail, shipping and aviation receive far less attention, while the measures to reduce emissions by walking and cycling are mentioned by more than 10 countries.

Figure 2: Analysis of NDCs in covering transport sector



Source: Transport and Climate Change: How Nationally Determined Contributions can Accelerate Transport Decarbonization, By Cornie Huizenga, Secretary General and Karl Peet, Research Director, Partnership on Sustainable, Low Carbon Transport

Note: Annex I countries refer to the contracting states that have established a special commitment to reduce greenhouse gas emissions in the United Nations Framework Convention on Climate Change (UNFCCC) (1992) and the Kyoto Protocol, which are basically developed countries; the exceptions are Turkey and Belarus, which are listed in Annex I, but did not make emission reduction commitments under the Kyoto Protocol. Non-Annex I countries refer to all other contracting states other than Annex I countries.

3. Review of China's NDC and comparison with other major emitters

As China's international commitment on climate change, NDC reflects a country's ambitions for climate action, so it is necessary to analyze China's NDC and compare it with those of other major emitters, especially carbon emissions in the transport sector that this article focuses on, which will help us understand what aspects of China's transport sector need to be strengthened for future NDC updates.

China's climate commitment on the transport sector is mentioned in the NDC submitted[5], reflecting China's emphasis on the development of low carbon transport. Although the emission control measures mentioned in the NDC are broad, they are also consistent with domestic low carbon transport development policies. In other words, existing domestic low carbon transport planning, policies and measures are refined.

According to the latest emission data (2017), more than 70% of global carbon emissions are concentrated in 10 economies[6]. However, due to the inconsistent development levels of these countries and regions, the transport modes are quite different, so the proportion of traffic emissions in their respective total emissions is also different.

Table1: Summary of specific measures for the transport sector in the NDCs of the world's major emitters

Country (Sorted by total emissions from high to low)	Carbon emissions of transport sector* (CO_2e)	Transport sectors in NDCs (relevant sectors, emission reduction targets and measures)
China	780 million tons	▪ Build a green low carbon transport system, optimize transport modes, rationally allocate urban transport resources, give priority to the development of public transport, encourage the development and utilization of low carbon environmentally-friendly means of transport (e.g. new energy vehicles and ships, etc.), improve fuel quality, and promote new alternative fuels. By 2020, public transport in large and medium-sized cities will account for 30% of motorized travel. Promote the construction of urban pedestrian and bicycle transport systems and advocate green travel. Accelerate the construction of intelligent transport system and promote the development of green freight. ▪ Innovate low carbon development model, deepen low carbon provinces and regions, ..., low carbon transport pilots, explore different low carbon development models, and study effective ways to control carbon emissions in different types of regions and cities.
U.S.A.	1.73 billion tons	▪ Introduce fuel economy standards for light vehicles from 2012 to 2025 and heavy vehicles from 2014 to 2018.
EU (28 member states)**	870 million tons	▪ The EU's NDC represents the common goal of all EU member states and are legally binding; specifically, to reduce domestic greenhouse gas emissions by at least 40% by 2030 than that in 1990; transport, as a key component of the NDC, is under the broad category of energy use. But the transport sector does not have a separate emission reduction target.
India	230 million tons	▪ By 2030, the share of railway in land transport will increase from 36% to 45%; ▪ Speed up the manufacture and promotion of hybrid and electric vehicles; ▪ Formulate national policies on biofuels; ▪ Set fuel efficiency standards on passenger vehicles; ▪ Build over 1,100 km of metro lines; ▪ Approve the construction of 39 urban transport and public rapid transit projects; ▪ Build two dedicated freight corridors in the east and west of India, with a total length of over 3,300 km; ▪ Boost the growth of coastal transport and inland water transport; ▪ Build a highway network of about 5,000 km in coastal areas.

Russia	240 million tons	▪ The transport sector is not mentioned specially.
Japan	210 million tons	▪ By 2030, greenhouse gas emissions in the transport sector will drop by 27% (no more than 163 million tons of CO_2e) than 2013; ▪ Improve the energy efficiency of roads, railways, aviation and water transport; ▪ Promote the next generation of vehicles; ▪ Shorten the distance of land transport by choosing the nearest port, and fully realize low carbon transport in the ports; ▪ Promote Intelligent Transport System (ITS) (for example, control of traffic signals); ▪ Promote piloted driving, eco-driving and car sharing; ▪ Optimize truck transportation; Promote public transport and shift to a rail-based model.
South Korea	90 million tons	▪ Increase the average CO_2 emission standard from 140g-CO_2/km in 2015 to 97g-CO_2/km in 2020; ▪ Introduce low carbon standards related to automobile fuel efficiency and carbon emissions; ▪ Develop incentives for electric and hybrid vehicles, including tax reduction; ▪ Expand the infrastructure construction for green public transport.
Iran	140 million tons	▪ Strengthen the implementation of national fuel consumption and emission standards.
Saudi Arabia	130 million tons	▪ Introduce energy efficiency standards to the transport sector; ▪ Promote the development and usage of urban public transport by taking necessary actions to speed up the metro development in the capital and other two large cities.

*Data in 2014; ** Although Germany, which is not included in this table, is the seventh largest emitter, its NDC is consistent with that of the European Union.
Reference: Transport in Nationally Determined Contributions (NDCs) Lessons learnt from case studies of rapidly motorising countries by GIZ 2017.

Comparing the commitments in transport made by major emitters listed in the table above, the U.S.A. and Iran have only proposed one measure in fuel efficiency and standards, while Saudi Arabia has mentioned the development of public transport on this basis. Although the European Union has set emission reduction targets, there is no separate limit to the total emissions in the transport sector and the practical implementation is based on the actual situation of member states. In general, freight-related emission reduction measures need to be strengthened in the NDC.

In Japan and South Korea with a high proportion of public transport travel, emphasis is placed on “Improve” strategy, involving energy efficiency and emission standards. Japan has made a very comprehensive low carbon overall strategy for transport sector in the NDC, proposing the total emission control of the transport sector by 2030, with a special mention of sub-sectors such as aviation and shipping, and detailing the low carbon strategy for ports. It’s worth noting that Japan is the only country that has proposed in the NDC to encourage “eco-driving” based on the change in behavioral patterns. South Korea is the only country that has proposed to include the average CO_2 emission standard into the NDC and reach 97g-CO_2/km by 2020, which is close to

95 g-CO_2/km specified by the European Union.

As two major developing countries, China and India, due to their underdeveloped public transport, especially India, have also emphasized the “Shift” strategy in the NDC. India has also proposed many quantitative indicators, mainly for railways and roads. In China's NDC, “Avoid” strategy for the transport sector is not separately mentioned, while there is a mention of “giving priority to the development of public transport, encouraging the development and utilization of new energy vehicles and ships, promoting the construction of urban pedestrian and bicycle transport systems, etc.” in terms of the “Shift” strategy, and "improving fuel quality, promoting new alternative fuels, accelerating the construction of intelligent transport system, promoting the development of green freight, etc." in terms of the "Improve" strategy. It is worth noting that China has proposed a low carbon transport pilot project, which is also an exploration with Chinese characteristics and helps to develop a unique and easily replicable low carbon transport development model. The disadvantage is that it only mentions the “research on effective ways to control carbon emissions in different types of regions and cities”, instead of specific emission reduction target for the transport sector and longer-term commitment.

Conclusion: China shall strengthen the commitment on the transport sector when the NDC is updated.

2019 is an important year, because by the end of 2020, as agreed in the “Talanoa Dialogue”, the parties to the UNFCCC will have the opportunity to submit new or updated NDCs[7] before 2020, and countries will also need to submit low emission strategies by 2050. Based on the comparison of NDCs between China and other major emitters in the world, we hereby suggest that China strengthen the commitment on the transport sector before the NDC is updated by following means:

▪ Specifying the year of carbon emission peak in transport sector

At present, the carbon emission peak in the transport sector is not mentioned in China’s NDC. However, it is necessary for the transport sector where the emission growth rate is still relatively high and can at least guide the future development direction of low carbon transport in China and provide policy-level support for the "Shift" strategy by limiting total emissions. In addition, for the emission of non-commercial transport, when developing transport emission path and control policies, a fuller coverage of emitters shall be taken into consideration, because the national emission reduction plan neither covers this emission sector nor proposes any specific emission reduction target[8].

▪ Improving commitment on electric vehicle development

“As for electric vehicles, by 2020, public transport in large and medium-sized cities will account for 30%[9] of motorized travel” mentioned in the existing NDC shall be updated as appropriate. China shall not only limit the coverage to public transport vehicles, but also pay more attention to the electrification of private cars and focus on longer term, such as 2030 and 2035. In the exposure draft of New Energy Automobile Industry Development Plan (2021-2035)[10], the targets for the proportion of electric vehicles in the future are mentioned. In the formulation of these targets, climate change factors shall be taken into account and reflected in China's NDC as much as possible.

▪ Taking more account of aviation emissions

Although the policies related to carbon emissions in the aviation industry mainly depend on the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) implemented under the leadership of the International Civil

Aviation Organization, the system itself does not directly reduce carbon emissions, but neutralizes emissions exceeding the limit. Considering the rapid growth momentum of China's air travel, especially international air travel, China shall not only simply carry out carbon neutralization, but also present specific planning targets in aviation energy efficiency and aviation biofuel. For domestic aviation, it is also necessary to present specific plans and schedules when updating NDC to explain how to take the emissions of the aviation sector into account in China's carbon market in the future.

▪ Emphasizing the relationship between transport and health

Since lower carbon emissions from the transport sector will reduce the emissions of pollutants from car exhaust, some countries will also include the air pollution-oriented measures into NDC, because measures to reduce air pollution will often bring about direct or indirect carbon emission reduction. Therefore, it is also necessary for China to review the contribution of healthy exhaust control policies or congestion mitigation measures to carbon emission reduction. This will help to determine if a faster mode shift from automobiles to public transport or technological improvement from gasoline/diesel vehicles to electric vehicles is required.

▪ Coordination between government departments and between the central and local governments

In addition to the extensive coordination between relevant national government departments (energy, transport, planning, environment, industry, etc.), local governments can also participate in the formulation of NDC for the transport sector, because they all have the required professional knowledge and are directly affected by the implementation of these specific measures.

▪ Specifying fuel economy standard in the NDC

The improvement of energy efficiency in the transport sector requires the implementation of stricter vehicle fuel economy standards, which is not reflected in China's NDC. However, since January 1, 2016, China has already implemented the national standard of Fuel consumption limits for passenger cars and is expected to introduce stricter standards after 2020. Therefore, it is necessary to state this in the NDC.

▪ Strengthening the legal norms and standard system related to low carbon transport

If possible, a schedule for the issuance of carbon emission standards for passenger cars shall be provided, and the carbon emission reductions corresponding to the implementation of standards can be calculated accordingly, which will be conducive to setting the total amount control target of the transport sector in the NDC. The formulation of carbon emission standards requires policy makers to consider fuel economy standards from a macro perspective and to strengthen the integration of relevant legal norms and standard system for low carbon transport.

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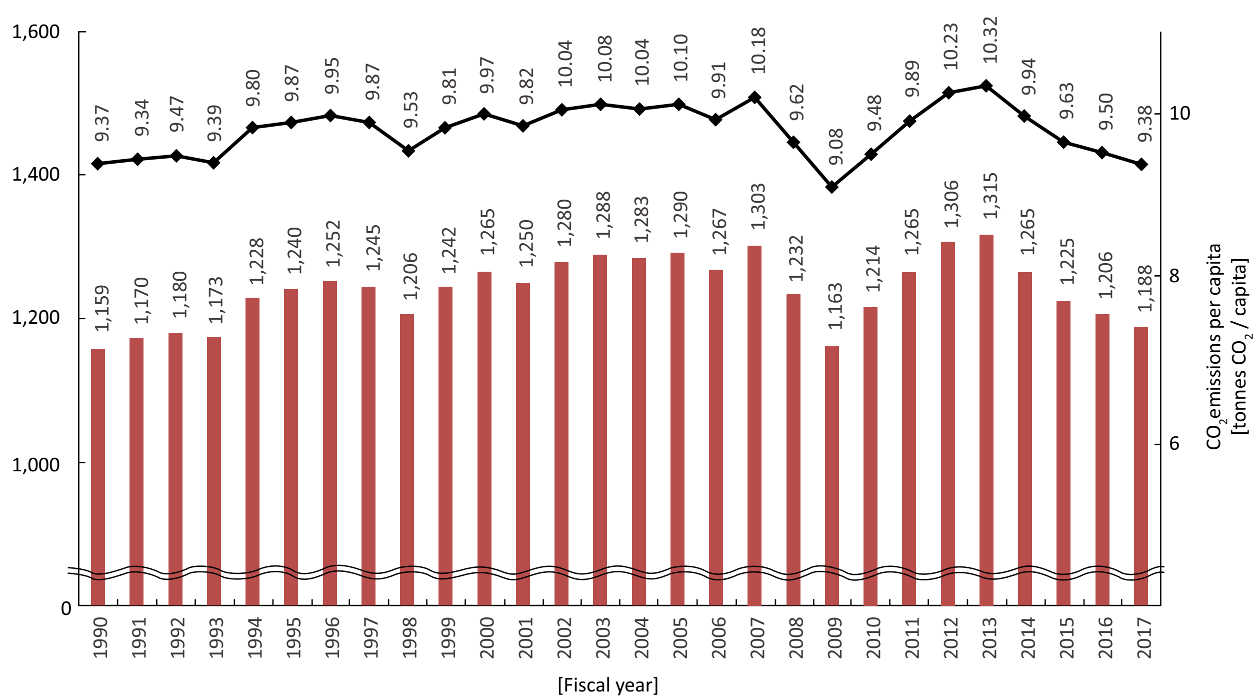
Sustainable Development of Urban Land Transportation: Japan's Experience

Zhao Ang, Yuan Yating

Japan, as the world's fifth largest producer of greenhouse gases, had a total carbon emission of 1.188 billion tons in 2017, accounting for 92.0% of its total greenhouse gas emissions. Since 1990, Japan's total carbon dioxide emissions have remained at almost the same level with per capita emissions, although the former rises and then falls from 1993 to 1998 and from 2009 to 2017. In the past 30 years, Japan's carbon emission trend is closely related to its features of low economic growth rate, small changes in energy structure and basically constant population size.

Figure 1: Trends in total CO_2 emissions and CO_2 emissions per capita



Source: National Greenhous Gas Inventory Report of Japan 2019

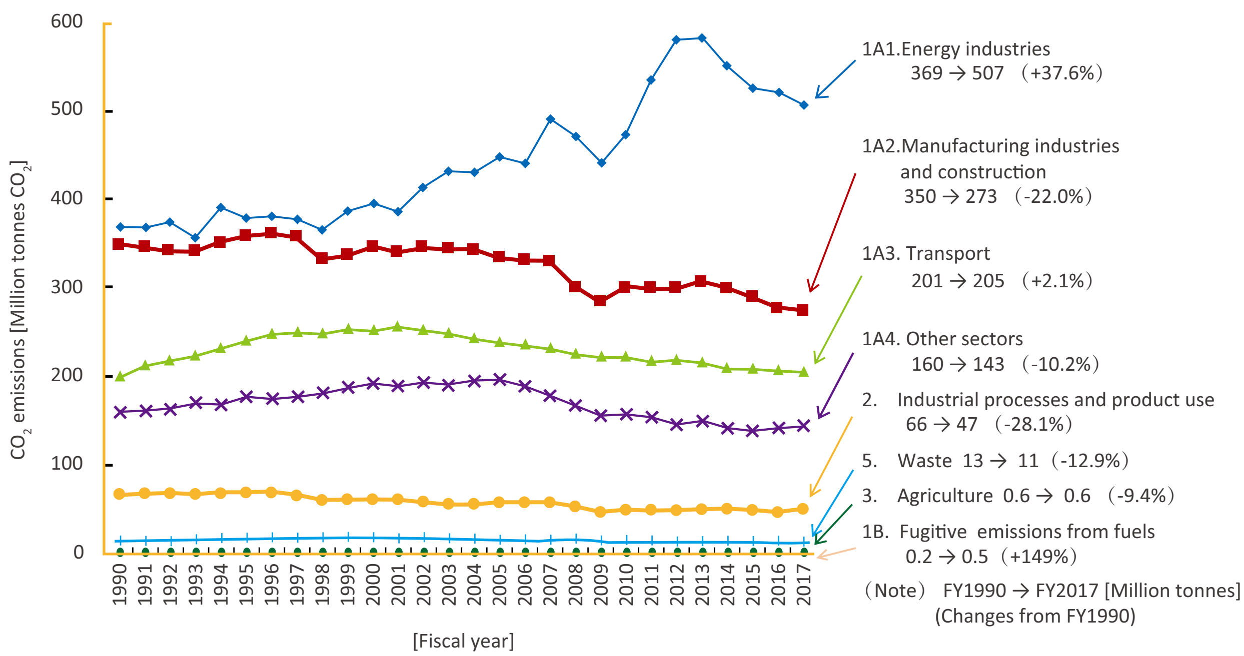
In the past 30 years, the distribution of carbon emissions from Japan's industries and sectors have undergone obvious changes. Carbon dioxide emissions from energy (mainly fossil fuel) consumption accounted for 95.0% of the total emissions. According to the data provided by Figure 2., the author initially calculated that emissions from the energy industry accounted for 42.7% in 2017, followed by the manufacturing and construction industry of 23.0%, and then the transport sector of 17.3%. Between 1990 and 2017, emissions from the energy industry rose by 37.6%; emissions from the manufacturing and construction industry fell by 22%; emissions from the transport sector increased slightly by 2.1%, which is similar to the increase rate of the total emissions over the same period. The carbon emissions of Japan's transport sector peaked at 267 million tons in 2001 and fell to 205 million tons in 2017, a decrease rate of 23% in 16 years.

1. Background of carbon emission reduction in Japan's transport sector

To discuss Japan's experience in carbon emission reduction in the transport sector in the past 30 years, it is necessary to state Japan's economic development and population growth trend during the same period, since the above two aspects are structural factors that affect carbon emission reduction in the transport sector. According to the data from the World Bank[1], calculated by the Constant Price in 2010 (US$), Japan's GDP increased from 4.704 trillion in 1990 to 6.141 trillion in 2017, an increase rate of 31% in 27 years. During the same period, Japan's total population rose from 123.5 million in 1990 to 126.8 million in 2017, an increase rate of only 2.67%. More importantly, Japan's population peaked at 128.1 million in 2010, which kept falling year by year from then on. Japan might be the only country in the developed economies that faces a huge challenge of demographic decline.

Under such a background, we will see what we could learn from Japan's transport sector in reducing carbon emissions and improving efficiency. Since the carbon dioxide emissions from road traffic account for the largest proportion of the total emissions from the transport sector, this article will introduce Japan's measures of emission reduction for the road traffic to achieve the carbon dioxide emission reduction target, including some cases of sustainable transport policies in some Japanese cities, for China's reference in establishing a low-emission transport system.

Figure 2: Trends in CO_2 emissions in each sector



Source: National Greenhous Gas Inventory Report of Japan 2019

2. Policies of the transport sector to combat climate change

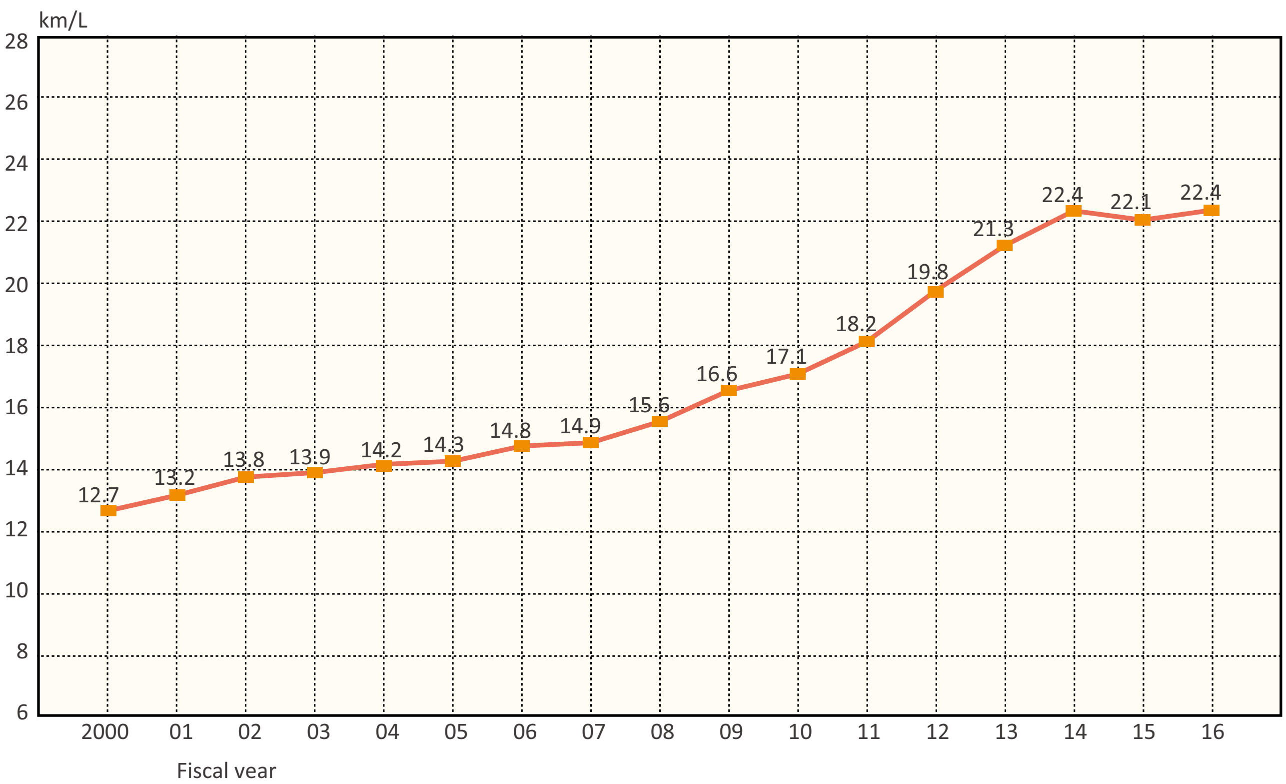
In order to achieve Japan's commitment under the Kyoto Protocol, Japan's Ministry of Land, Infrastructure, Transport and Tourism proposed countermeasures to combat climate change for the first time in 2002, under the guidance of which, Japan fulfills its commitments. In 2016, Japan announced the latest countermeasures, and revealed the greenhouse gas reduction targets throughout the country and for various sectors, among which, the carbon emission of the transport sector in 2030 will be 28% lower than that in 2013[2]. Therefore, a sustainable transport system is the only way to achieve this target. The countermeasures proposed by Japan's transport sector mainly cover the following two aspects: the popularization and application of eco-friendly vehicles and the shift to a traffic system dominated by public transport with less environmental loads.

2.1. Popularization and application of eco-friendly vehicles

(1) Improvement of fuel economy

Automobile manufacturers are targeted to promote technological innovations for improvement of fuel economy. For passenger cars, trucks and buses, the fuel economy targets are set according to the "Top Runner" standard, i.e. the fuel economy target value for a given vehicle weight category is set based on the world's leading fuel economy performance for that weight category so far. From 2000 to 2016, Japan saw significant improvement in the average fuel economy of new gasoline-powered cars.

Figure 3: Average fuel efficiency of domestic new gasoline-powered passenger cars

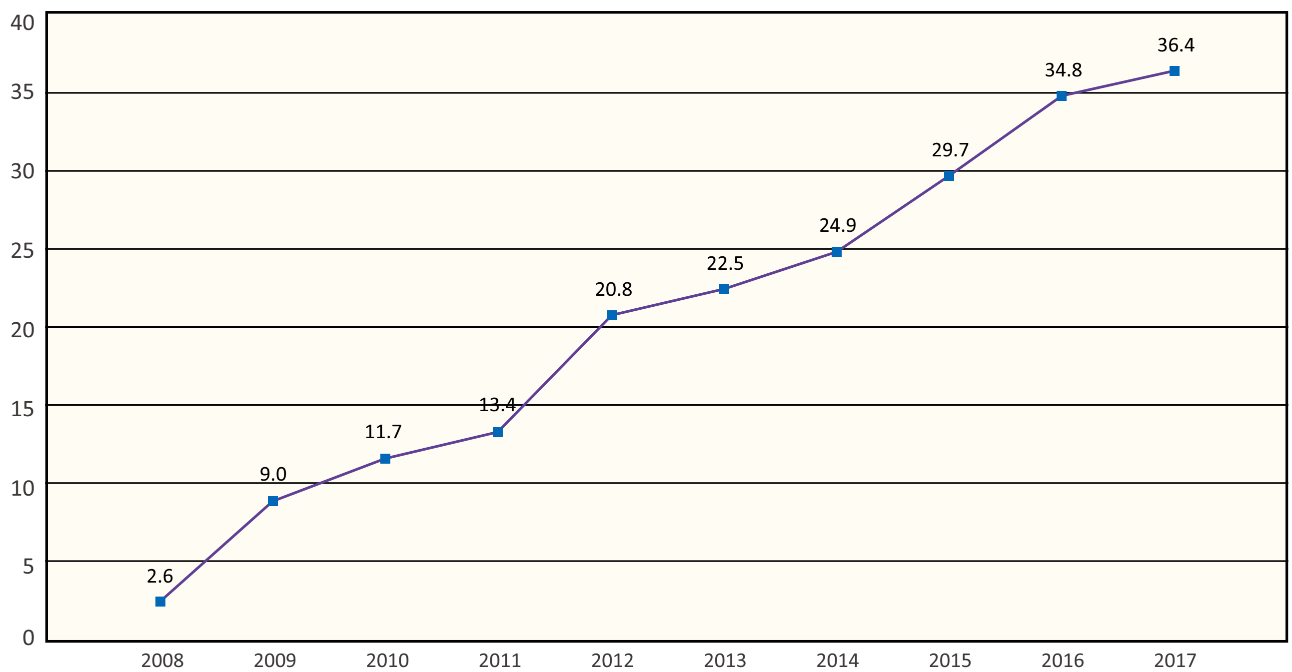


Source: Japan Automobile Manufacturers Association

(2) Promotion of eco-friendly vehicles

The government funded procurement program of eco-friendly vehicles and encourages the popularization and application of eco-friendly vehicles. For example, from April 1, 2017 to March 31, 2019, buyers of new energy vehicles (including hybrid electric vehicles, plug-in hybrid electric vehicles, electric vehicles, fuel cell electric vehicles, etc.) were exempted from purchase tax, and buyers of second-hand new energy vehicles enjoyed a reduction of the purchase tax of US$ 4,200.[3] From 2009 when the government first launched tax incentive and subsidy plans for the purchase of eco-friendly vehicles, Japan's sales of new energy vehicles have risen sharply in the total sales of passenger cars. In 2017, the number of new energy vehicles registered accounted for more than 36% of the total number of new passenger car registered (Figure 4), gradually approaching the target set by the Japanese government that, by 2030, the share of new energy vehicle sales accounts for 50%-70% of the total sales of new vehicles.[4]

Figure 4: Trends in next-generation vehicle share in new passenger car registrations



Source: Japan Automobile Manufacturers Association

(3) Promotion of eco-driving

Eco-driving is promoted for the main purpose of improving daily driving skills to reduce fuel consumption and carbon emissions. The Japanese government has been promoting eco-driving for many years. The Promotion Committee set up by the Ministry of Land, Infrastructure, Transport and Tourism has formulated "Ten Tips for Eco-driving", including pre-trip, on-the-road and daily vehicle maintenance that are promoted in the international conferences and exchanges. Regarding the effectiveness of eco-driving for energy-saving and emission reduction, Japanese scholars have proved through effect evaluation that eco-driving reduces the fuel consumption of Japanese vehicles by 10%-20%, which is proportional to carbon dioxide emissions[5]. For details in Eco-driving, please refer to ‘Changes in driving behavior and carbon emission reduction in transport sector: experience from Seoul and Tokyo' in the "Energy Review 2018".

(4) Measures to improve traffic flow and promotion of low carbon road facilities

Vehicles running at faster speeds will produce less carbon dioxide. For example, vehicles with an average speed of 60-70km/h emit about 1/2 of the carbon dioxide emitted by vehicles with an average speed of 10km/h. So it is very effective for reducing the carbon emissions from fuel consumption by improving the smoothness of traffic roads.

• Traffic signal measures. More efficient traffic signal operation and centralized signal control contribute to more stable traffic flow.

• Congestion mitigation based on the Intelligent Traffic System (ITS). Traffic congestion will be alleviated through the use of ITS that will provide real-time congestion information and plan the optimal route.

• Promotion of ETC (Electronic Toll Collection). Promotion of ETC on toll roads will reduce slow flow and road congestion caused by manual toll collection;

• Improvement of the cycling environment. Bicycles will replace some automobiles by redistributing road space, and rectifying cycling space and facilities in bicycle parking lots;

• Improvement of road network. The main road network is connected through loop roads and the like, and traffic flow is expanded by improving intersections;

• Installation of LED road lighting. During arrangement and change of road lighting, it is required to promote the energy-saving LED road lighting.

2.2. Shift to the public transport with less environmental loads

(1) Facilitating the convenience of public transport such as bus and railway

For the purposes of maintaining the traffic system, promoting tourism and coping with environmental problems, the Japanese government has established and implemented a Coordinative Plan to rearrange the public transport network for different regions to promote public transport.

• Promotion of buses based on bus positioning system. Bus location and transfer information is provided at all bus transfer stops to improve bus convenience and make the residents less opposed to transfer;

• Accessibility of railway stations. In a severe aging society, the barrier-free railway stations are promoted for security and convenience of the elderly, physically handicapped, etc.

• Development of Light Rail Transit (LRT). More light rails are connected with buses for the convenience of transfer so as to improve the overall convenience of public transport;

• Improvement of station square traffic node. In order to improve railway station transfer and the barrier-free walking space, the station square, traffic aisle, public parking lot and the like are optimized.

(2) Promotion of Mobility Management

Mobility management is a communication-oriented transport policy, which promotes change of commuters' commuting attitude and behavior, e.g., appropriately using public transport and bicycles more often to avoid excessive use of private cars, for the purpose of creating a good traffic environment for society and individuals.

Eco-Commuting, a kind of mobility management, aims at facilitating the transformation from private cars to public transport. An employee is specially assigned in each company office to be responsible for studying the ideal commuting means, providing timetables and road maps of buses, subways and trains, and checking commuting allowances. Toyota, a famous automobile city with the highest car parc and usage in Japan, has set up the "Toyota Eco-traffic Promotion Association" that proposed Eco-Commuting to solve the traffic congestion during commuter time. In addition to changing the means of transport dominated by cars, other environmental-friendly measures encouraged include commuting with shared vehicles and at off-peak hours.

3. Example: Sustainable transport strategy in Toyama

Toyama, one of Japan's Eco Model Cities, has introduced a bicycle sharing system and incorporated LRT into a compact city, in addition to the basic public transport system. Before that, Toyama had the lowest population density among all the densely populated counties in Japan. Residents there bought a large number of private cars and suburban houses, leaving the downtown area "empty". For this, train and bus companies began to cut routes to cope with the decrease in demand, making it more inconvenient to travel by train and bus, in particular for children and the elderly. Therefore, in 2003, Toyama set up the Compact City Development Group that was committed to the development of a compact city through cooperation with residents, enterprises and local governments. The core of the plan is to introduce a new LRT network. Toyama adopted a multi-center method rather than a single-center method to connect the existing facilities with the light rail, and introduced low-floor light rail and barrier-free platforms to provide more convenience. From then on, people anywhere can walk to the public transport stations in Toyama. In addition, Toyama has also launched the Cyclocity. There are more than 150 special bicycles at 15 bicycle shares throughout the city center. Users can rent and return bicycles at any bicycle share at any time.

4. Policy recommendations

In order to remain committed to its Nationally Determined Contributions proposed in the Paris Agreement (compared with 2013 level, a reduction in greenhouse gas emissions of 26% in 2030), Japan has developed a series of policies and plans and kept working for them to create an energy-efficient transport system by multiple means such as efficiency improvement, fuel substitution, and system reengineering, thereby reducing the carbon dioxide emissions of the transport sector.

China, as a large energy resource consumer, is challenged with energy saving and emission reduction during its rapid economic development. In the past 20 years, the increase in the number and usage of private cars in China mainly contributed to the increase in carbon dioxide emissions in the transport sector. In order to develop sustainable transport, China could learn from Japan's advanced experience, start from changing the way residents travel, and focus on the development of urban public transport network and service capacity, which constitutes one of the long-term key plans for the transport sector to mitigate climate change. Japan's experience shows that any action should start with details and small changes. Carbon emissions will be reduced with the gradual improvement of the operating efficiency of the traffic system. This paper puts forward the following suggestions:

1) Invest more in the construction of bicycle lane and public transport (including buses and light rails, etc.) systems to lay foundations for a complete transformation of traffic system infrastructure;
2) Facilitate the popularization of new energy vehicles while controlling the number of private cars, set up charging piles or stations of reasonable network layout, and realize the low carbon development goal of the transport sector by replacing traditional fuel vehicles;
3) Promote the popularization of intelligent transport systems, provide more accurate and faster road congestion information and shortest route suggestions, and adjust the operation of traffic signal systems according to the traffic

flow, thus improving efficiency;

4) Establish organizations to promote low carbon behaviors such as eco-driving and eco-commuting, and call for low carbon and energy-saving driving behaviors with government agencies, major universities, enterprises and public institutions, etc.

Conclusion

In the long run, the establishment of a low carbon and sustainable traffic policy system in response to combat climate change set a model for other countries and economies, while Japan may also learn from other countries. For example, for coping with climate change, it is necessary to support the development of electric transport system through low carbon transformation of electric system. Therefore, more international exchanges and cooperation will promote countries to cope with low carbon development in the transport sector and mitigate climate change more effectively.

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Analysis on Health Hazards of Traffic Pollution and Prevention & Control Benefits

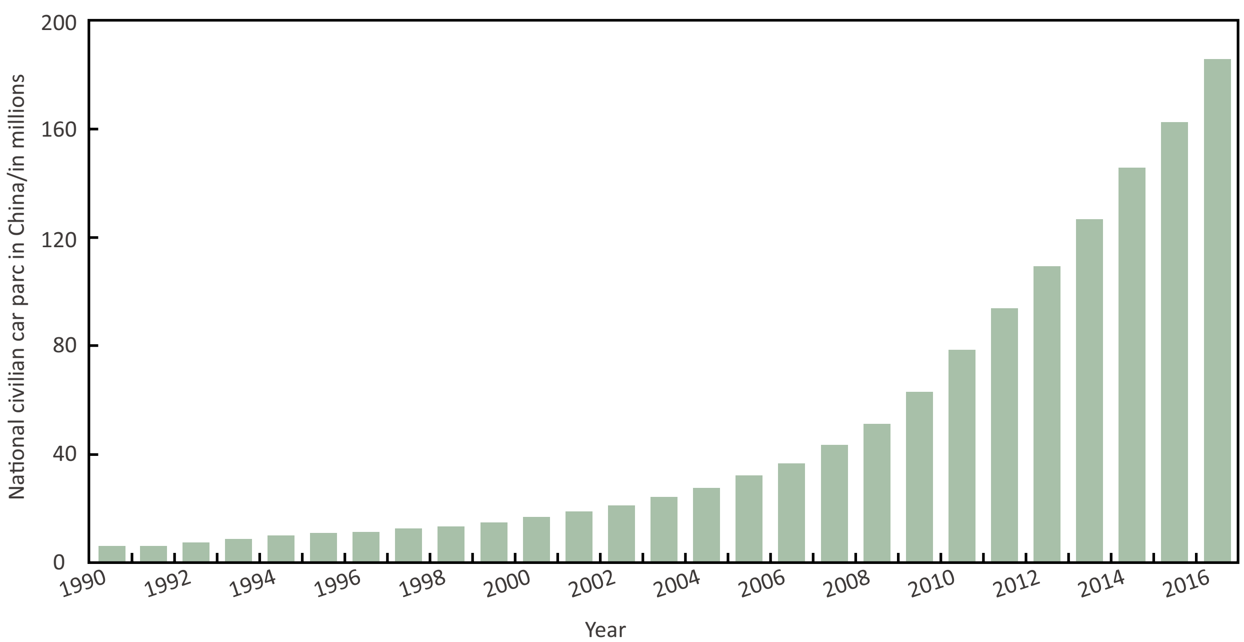
Pan Xiaochuan

With the rapid development of China's industrialization and urbanization, the increasing energy demand has led to a significant increase in fossil fuel consumption in recent years. Air pollution caused by pollutant emissions has become one of the most serious environmental problems in China at the present stage. With the rapid growth of vehicle parc, motor vehicle pollutant emissions remain high, seriously impeding the continuous improvement of atmospheric environment quality. This is becoming an important environmental issue in China's urban economic and social development, to which relevant departments and the public have attached great attention and importance. Effective control of traffic pollution has become one of the key influencing factors to improve urban ambient air quality and protect public health. In recent years, identifying and controlling the impact and contribution of traffic pollution on urban air quality so as to cost-effectively control and reduce vehicle pollutant emissions and further improve urban air quality has become one of the pressing issues that need to be resolved by relevant departments and scholars of China. The study on traffic pollution characteristics and population health effects is of great public health significance for preventing and reducing the harm of air pollutants to public health.

1.Status quo of traffic-related air pollution

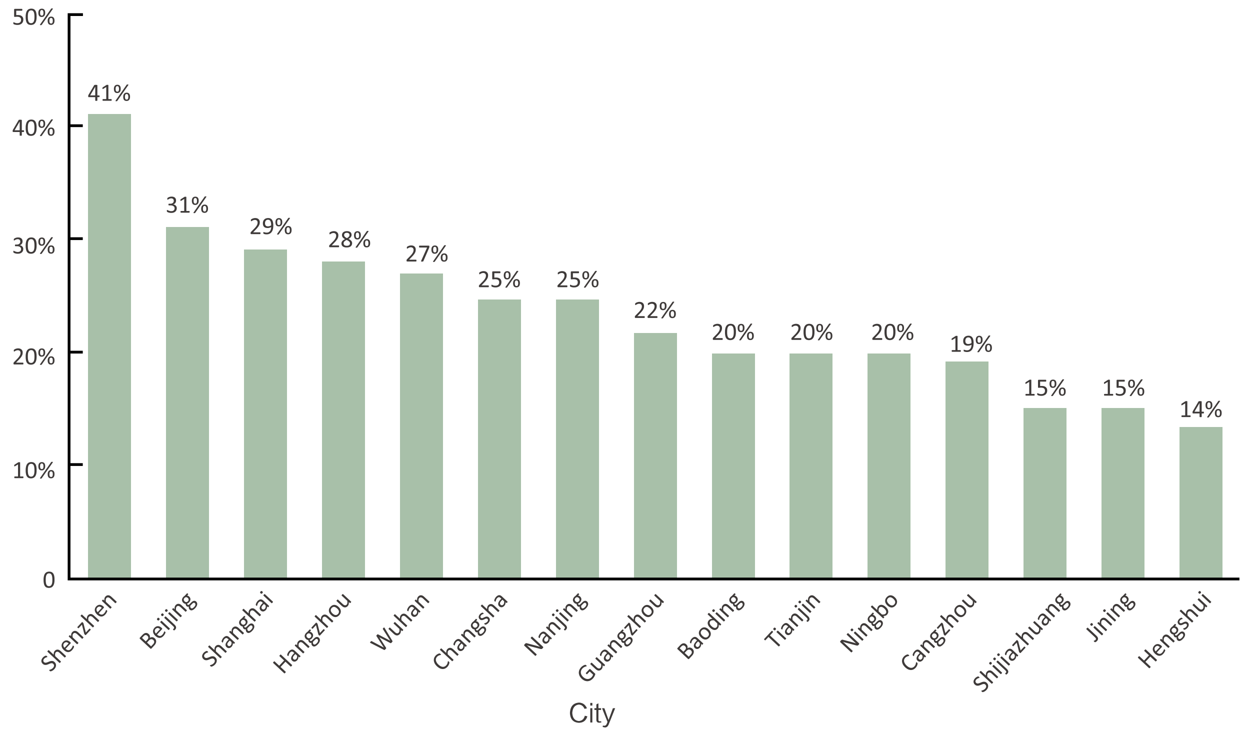
From 1990 to 2016, the national civilian car parc increased from 5.514 million to 185.755 million (Figure 1), an increase of 33 times in 27 years.

Figure 1: National civilian car parc from 1990 to 2016[1]



With the rapid growth of motor vehicle parc, the emission of pollutants from motor vehicles remains high, and its impact on the urban ambient air quality is increasing. The gaseous pollutants emitted by motor vehicle exhaust, in addition to conventional pollutants, such as CO, HC, NOx and PM, generate a highly oxidative photochemical smog (secondary pollutants), including ozone (O_3), secondary $PM_{2.5}$, etc. through a series of complex photochemical reactions in the atmosphere. More and more China's urban air quality being transformed from traditional coal-fired pollution to composite pollution combining coal-burning, vehicle exhaust and secondary pollutants[2], which seriously affects the health and life quality of the exposed population.

Figure 2: Contribution of motor vehicles to $PM_{2.5}$ concentration in urban atmospheric environment (%)



Although the contribution of $PM_{2.5}$ concentration in most cities is still dominated by coal-fired emissions, the contribution of mobile sources to atmospheric $PM_{2.5}$ in first-tier cities such as Beijing and Shanghai and densely populated areas in the central and eastern regions has reached 20% to 45%. As shown in Figure 2, the local pollution contribution of Beijing and Shanghai is about 30%, which exceeds that of coal and industrial production and becomes the largest $PM_{2.5}$ contributor in the local atmospheric environment. Moreover, since most of motor vehicles are driven in densely populated areas of the city, the pollutants emitted from the exhaust are mainly spread by mechanical diffusion and hot turbulent diffusion in the vicinity of the human respiratory zone, so that the concentration of pollutants in traffic micro-environment, e.g. in the vehicles and on both sides of the road, is much higher than the environmental background concentration. This significantly increases the actual exposure level of pollutants to the population, and also the health risks of the exposed population. In this case, the control of traffic-sourced pollution is becoming the most prominent and urgent problem in the urban air pollution control and disease prevention & control in China.

2.Main health effects of traffic-related air pollutants

As mentioned above, traffic-related air pollutants include conventional pollutants, such as CO, HC, NOx, and PM, and secondary pollutants, such as ozone (O_3) and secondary $PM_{2.5}$. Their pollution and health hazards are characterized as follows: I. The pollutants are diffused in a way of linear source emission, that is, the level of pollutants is high on both sides of urban and rural traffic trunks or highways, and gradually decreases along their peripheries; II. The pollution involves complicated composition, i.e. there are not only direct pollutants, but also a large number of secondary pollutants which are gradually formed in the atmosphere; III. The pollutants are discharged close to the human respiratory zone, resulting in more direct and rapid health hazards to the exposed population. Its main health effects include:

2.1 Effect on the respiratory system

Because the emission of traffic-related air pollutants is highly close to the human respiratory zone, it is more straightly harmful to the human respiratory system. The exposed population is generally occupational groups closely related to transport, such as traffic police, bus drivers and sales staff, highway toll collectors, field station guards and attendants. These groups are subject to long-time exposure to the traffic environment due to occupational characteristics. The health effects on their respiratory systems cannot be ignored. Researches in Shanghai, Hong Kong and other places in China have shown that the incidence of respiratory symptoms such as cough, sore throat and pharyngitis in motorists has increased significantly[3,4], indicating that long-term exposure to traffic pollutants reduces the respiratory resistance and functionality of occupationally exposed people. Children are susceptible to traffic exposure. Many studies have shown that traffic pollution exposure may have many adverse effects on children's respiratory system, causing increased incidence of respiratory symptoms such as asthma, wheezing, and increased airway responsiveness in children living near high traffic flow[5, 6].

2.2 Effect on cardiovascular system

The cardiovascular diseases associated with traffic-related air pollution mainly include myocardial infarction, coronary heart disease, hypertension and ischemic heart diseases[7-9]. A cohort study in Vancouver, Canada, conducted a four-year follow-up of 452,735 residents aged 45 to 85 years without coronary heart disease to assess the exposure concentrations of traffic-related pollutants, such as $PM_{2.5}$, black carbon (BC), and NO_2, and the coronary heart disease-related admission and mortality of the subjects during the follow-up period. It showed that for every 0.8 μg/m^3 increase in BC concentration, the admission rate of coronary heart disease increased by 3% and the mortality rate increased by 6%, demonstrating statistical significance and a linear exposure-response relationship. A group study conducted in Beijing taken a group of healthy young students as subjects to follow up and observe changes in exposure levels of air pollutants before and after their relocation from suburban campuses to urban campuses and the impact of such changes on the cardiovascular system. The monitoring data showed that the $PM_{2.5}$ concentration of urban areas was lower than that of the suburbs, while the levels of carbon components and gaseous pollutants in urban $PM_{2.5}$ were significantly higher than those in the suburbs, indicating that traffic emissions have a greater impact on the composition of urban air pollutants. After the population moved from the suburbs to the urban areas, the inflammatory biomarkers and homocysteine levels in blood generally showed a rising trend, and coagulation biomarkers tended to decrease in general. These suggest that traffic sourced components of $PM_{2.5}$ may be an important factor leading to the above changes[10].

2.3 Effect on the nervous system

In recent years, the impact of traffic pollution on the neurobehavior of exposed population has gradually attracted the attention of researchers. Current researches suggest that exposure to traffic-related air pollutants can cause neurological function impairment in children such as cognitive impairment. Studies have shown that traffic-related air pollution exposure is significantly proportional associated with decreased neurobehavioral function. A study of the correlation between exposure to traffic pollution and children's neurobehavioral functions[11] carried out in Quanzhou determined the neurobehavioral functions of pupils from schools in traffic-contaminated area and clean control area, the average concentrations of NO_2 in which are 36μg/m^3 and 7μg/m^3 respectively. The analysis results showed that all neurobehavioral function indexes of the pupils from the traffic-contaminated area are lower than those from the clean control area. In addition, a study conducted in Germany analyzed the association between cognitive dysfunction of 399 elderly women living at the same address for more than 20 years and the concentration of traffic-related particulate matter in their living environment. The results showed significant association and an exposure-response relationship between traffic-related particulate matter exposure and the cognitive dysfunction of the subjects. Since cognitive dysfunction is a high risk factor for the progression of Alzheimer's disease, this study suggests that long-term exposure to traffic-related particulate matter may also be one of the causative factors of senile Alzheimer's disease[12].

2.4 Carcinogenic effect

A large number of studies have confirmed that traffic-related air pollutants contain many carcinogens and mutagens, such as PM, polycyclic aromatic hydrocarbons (PAHs) and benzene, which can damage the body's genetic material and interfere with the normal division of cells, while destroy immune surveillance function of the body and cause mutations and cancers in human[13]. Reacting with the body, PM in the exhaust of motor vehicles can produce reactive oxygen species, leading to oxidative stress, inflammatory reaction and DNA damage, while the mutagenic effect of PAHs is related to the formation of PAH-DNA adducts in the body and the DNA strand breakage. In 2012, the International Agency for Research on Cancer (IARC) listed diesel exhaust as a definite human carcinogen, pointing out that diesel exhaust exposure can cause lung cancer and is also proportionally associated with the risk of bladder cancer.

2.5 Disease burden attributable to traffic-related pollutants

In recent years, domestic researches on the disease burden of the population exposed to traffic-related pollutants showed that [14] $PM_{2.5}$ pollution caused by traffic-sourced emissions in 2010 may cause premature deaths of about 116,900, accounting for 9.31% of the overall health burden of $PM_{2.5}$ (1,255,400 premature deaths). To this extent, the number of deaths from stroke was 63,100, 13,200 from chronic obstructive pulmonary disease, 9,800 from lung cancer, and 30,800 from ischemic heart disease, respectively accounting for 53.9%, 11.4%, 8.3%, and 26.4% of the national total number of premature deaths from the four traffic-sourced health outcomes of the year. Another study also showed that, as China's pollution caused by motor vehicle emissions shows an obvious regional characteristic, traffic-sourced health burden is not only associated with traffic pollution intensity, but also widely distributed in densely populated areas[15]. For example, in Shandong and Henan, the health burden of air pollution related to traffic-sourced emissions is heavier, mainly because the populations in Shandong and Henan are quite dense, resulting heavier health burden even though the contribution of traffic-sourced pollution does not take a large share.

3.Health benefits to people from controlling traffic-related pollution

In recent years, whether controlling the level of traffic pollution can improve people's health has received widespread attention from researchers. For example, during the Beijing 2008 Olympic Games, the Beijing Municipal Government took a series of traffic pollution control measures, including the introduction of new energy (natural gas) to replace coal, the development of public transport, the implementation of motor vehicle restrictions, and the prohibition of heavy trucks on the road during the day, the implementation of new motor vehicle emission standards, the elimination of old high-emission motor vehicles in Beijing, and controlling industrial and traffic pollution emissions from neighboring provinces and cities. These strict traffic control measures and policies produced obvious effects, making the concentration of traffic pollutants in Beijing, as well as the $PM_{2.5}$ and BC concentrations of the 12 traffic arteries, during the Olympic Games significantly lower than that before the Olympic Game[16]. Taking this as an opportunity, researchers in China have discussed the health benefits to people from traffic pollution control in terms of health impact, health economic loss and cancer risk. A study with taxi drivers as the subjects[17] discussed the relationship between the $PM_{2.5}$ concentration change before, during and after the Olympic Games and the subjects' HRV level. The result shows that increased traffic-sourced $PM_{2.5}$ exposure concentration is significantly related to reduction in HRV levels. Since HRV level reflects the regulation function of the cardiac autonomic nervous system, the HRV level increased significantly during the Olympic Games is considered to be a manifestation of a reduction in the risk of cardiovascular disease. In this regard, the result suggests that decrease in the traffic-sourced $PM_{2.5}$ concentration can reduce the risk of cardiovascular disease in a certain extent. In the same period, studies combined the methods of atmospheric diffusion model, epidemiology and environmental economics to evaluate the health effects and related economic losses caused by traffic pollution in Beijing from 2004 to 2008. The results showed that the traffic pollution-related incidence and related economic losses, e.g. acute and chronic bronchus, respiratory diseases and asthma attacks, increased to varying degrees between 2004 and 2007, but there was a certain degree of reduction in the 2008 Olympic Games, suggesting that the implementation of traffic pollution control policies has a positive effect on health improvement and can reduce economic losses due to health impact[18]. There is also a research showed that during the Olympic Games, the PAHs content in the atmosphere of Beijing was significantly lower than that during non-Olympic period, and the excess cancer risk corresponding to the PAHs content was significantly lower than that during non-Olympic period, suggesting taking effective measures to control traffic pollution sources can significantly reduce the cancer risk to people[19]. The above research results provide direct evidence for the improvement of the health of exposed population through the implementation of relevant policies and measures for traffic pollution control, and provide an important scientific basis for further implementation of traffic pollution control policies and measures for health protection.

Conclusion

China's traffic-related air pollution and its population health impact are increasingly prominent and are becoming pressing issues that need to be resolved by relevant departments and scholars of China. So far, considerable research experience and outcomes pertaining to health hazards of traffic pollution have accumulated domestically in terms of its diffusion mechanism, population health epidemiology, economic loss assessment and related technical measures for prevention and control. However, for the comparative study and investigation before and after the implementation of traffic pollution control policies and measures, there has not been systematic and comprehensive empirical research.

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The Role of Electric Vehicles in Sustainable Transportation Development: A Perspective of Life Cycle Assessment

Zhao Ang

Since conventional internal combustion engine vehicles (hereinafter referred to as ICEs), currently the mainstream vehicles, constitute one of the main factors contributing to climate change and urban air pollution. In the development of sustainable transportation, battery electric vehicles (hereinafter referred to as EVs) are highly expected. The replacement of ICEs by EVs is considered as one of the key pathways for the transport system to achieve a low carbon transition. However, in recent years, the debates on whether EVs are truly environmentally friendly and low carbon has been going on. Relevant studies considering important influencing factors such as different incentive policies, industrial manufacturing technologies, power system mix, battery life and battery recycling technology, have brought light to discussion. Most of these studies use Life Cycle Assessment (LCA) to compare the advantages and disadvantages of EVs, ICEs and vehicles using other technologies in terms of carbon emissions, public health impacts and ecological impacts. Based on a review of recent studies, this paper considers China's fast-developing EV market in recent years and proposes relevant policy recommendations related to sustainable transportation development in China.

1. Are EVs really green? A process of continuous knowledge gaining

Studies on whether EVs meet sustainable development goals are mainly focused on the following influencing factors: impacts on climate change, impacts on human health, and impacts on environmental ecosystems. To compare the advantages and disadvantages of EVs and ICEs based on LCA, studies not only need to calculate the emissions of pollutants and greenhouse gases in the collection process (such as mining) of automotive raw materials and battery raw materials, and those in the automotive production process, but also the various impacts generated in automotive recycling and battery recycling and disposal, as well as the carbon emissions and pollutant emissions of the power system in the whole process. Such studies will include new factors as people's knowledge increases. Therefore, it is a dynamic process to assess whether EVs are truly green, one that varies with different policy, technological, environmental, social and economic factors. However, existing studies show that replacing ICEs with EVs is in line with sustainable transportation development in general.

A report published by Norwegian researchers in 2013[1] compared the environmental impacts of EVs and ICEs based on LCA (production, use and scrapping of automobiles). For the production phase, the research team built a unified non-powertrain system framework to compare the environmental impacts of the main components of EVs and ICEs. The EVs which are chosen in the research project are those with LNCM battery (214 kg) and LiFePO4 battery (273 kg); for the use phase, the team adopt the industrial performance test specifications required under the EU driving cycle rules, taking into account factors such as vehicle size, performance, tires and transportation losses; for the scrapping phase, the team use the transport model built by the Argonne National Laboratory of the United States to assess the environmental impacts of automotive recycling and disposal. Battery scrapping of EVs include the environmental impacts of battery dismantling and cryogenic grinding.

The environmental impacts analyzed in this study included ten aspects: climate change potential, land acidification potential, particulate matter emission/forming potential, photochemical oxidation potential, human toxicity potential, freshwater ecotoxicity potential, land ecotoxicity potential, freshwater eutrophication potential, mineral resources depletion potential, and fossil fuels depletion potential. The main findings of the study indicate that the environmental impacts of EVs are primarily determined by the carbon intensity of the electricity consumed during their production and use. The study points out that extending the life of vehicles and batteries and making the power system cleaner and more low carbon is an important way to reduce the environmental impacts of EVs.[2]

It requires deeper studies from comparing environmental impacts to understanding health impacts based on LCA. To some extent, assessing public health impacts is more complicated, which not only needs to classify the specific health impacts (from various physical health problems to and mental health ones), but also figure out how to quantify health impacts so as to compare which type of vehicles causes greater health burden or risks. Thanks to plenty of quality studies in assessing the health impacts of air pollution, debating the air pollution impacts of EVs and ICEs based on LCA are more relevant and targeted. The research findings can provide direct support for policy options. A study published by the National Academy of Sciences in 2014[3] is just a response to such needs.

The study was conducted in the context of automotive technology, automotive production and use in the transport and energy systems of the United States. It mainly discusses the differences of different types of vehicles in the emissions of inhalable fine particulate matters and ozone (the two types of pollutants are the most important factors causing health issues), and focused on emissions from the use of vehicles. It also analyze the generation of the two types of pollutants in the production of the “fuels” (such as electricity, fossil fuel and biomass fuel) used by automobiles. Because automotive scrapping (recycling and disposal) generates pollutants much less than those from manufacturing and use on road, it was not analyzed in the study. The study conclude that EVs solely using coal power cause the largest and most serious air pollution, followed by ICEs (including gasoline and diesel vehicles) and EVs solely using natural gas power and hybrid EVs (with both conventional internal combustion engine and rechargeable batteries), respectively. EVs solely using renewable energy power cause the smallest air pollution. The study points out that when the power system still relies mainly on coal power, the development of EVs actually makes more contributions to air pollution.[4]

2. The future of EVs: In a context of broader social, economic and technological conditions

When comparing the environmental, health and social impacts of EVs and ICEs based on LCA, one cannot ignore two points: first, as mentioned in the first piece on sustainable transportation decision-making framework in this review report, the development of the transport system is closely tied with all aspects of society and economy. For example, as people pay more attention to climate change and air pollution control, EVs will be more popular. Or, with more people-oriented urban planning and design, people will have shorter travel distances and better mobility services, and accordingly, will be more inclined to choose electric public buses; second, technological innovation and application will also influence the role of EVs in the development of sustainable transportation. When technologies for the design, performance, recycling and disposal of EV batteries become more cost-effective and environmentally friendly, in addition to existing advantages over ICEs in terms of carbon emission reduction and urban air quality improvement, EVs will also fill the gap in public health and environmental health impacts. A new study discusses this issue and demonstrates how to make EVs more competitive in the transition to a sustainable transport system in the context of a circular economy.[5] The report specifically mentions that EV development needs to focus on the following aspects: vehicle design, use, battery reuse, recycling and the power system mix. In addition, there are studies and experiments exploring the second life-energy storage application of decommissioned EV batteries, because these batteries still have considerable energy capacity, which, according to relevant data, can reach 60% or higher of the capacity of a new battery.[6] If significant technological progress is made in extending the battery life, this will significantly reduce the carbon emissions of EVs in their life cycle. A study reviews the existing new developments in EVs battery technologies and estimates the emission reduction potential of new technologies, as shown in Table 1.

Table 1: Potential for carbon emission changes from technological progress in the production and use of EV batteries

Technological progress	Changes of proportion of carbon emissions during battery production	Changes of proportion of carbon emissions during the life cycle (gCO_2e/km)
Battery with a larger size	33%~66%	18%
Use of used battery	Unknown	-22%
Battery recycling and disposal	-7% ~ -17%	-4%
More energy-intensive battery	-10% ~ -15%	-6%

Note: A negative number denotes the potential for emission reduction, and a positive number denotes the potential for increasing emissions.

Source: Effects of Battery Manufacturing on Electric Vehicle Life-cycle Greenhouse Gas Emissions, Dale Hall and Nic Lutsey. The International Council on Clean Transportation, 2018. p 10. Link: https://theicct.org/sites/default/files/publications/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf

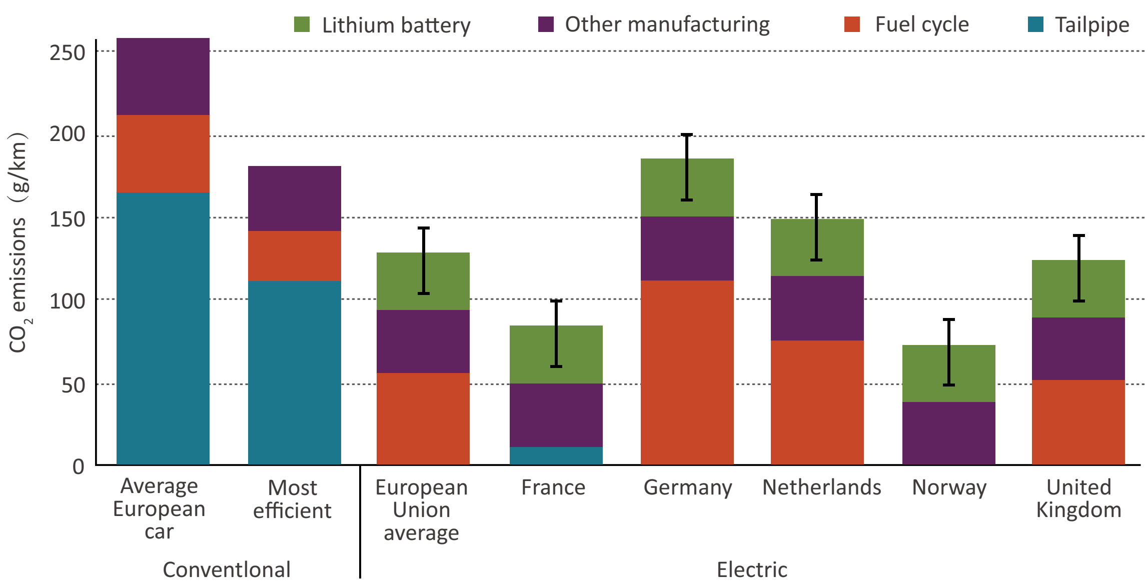
Therefore, we need to constantly pay attention to studies on the various life cycle impacts of EVs. However, according to most of the existing research findings,[7] EVs have definite advantages in reducing carbon emissions and air pollution in sustainable transportation development. Of course, the key conditions of the grid power structure mentioned above are indispensable.

From the perspective of effective pollution control, EVs have certain advantages over conventional ICEs. Most of the pollutant emissions of conventional vehicles occur during the use of the vehicles, which is a typical mobile source pollution and relatively hard to control. The pollutant emissions of EVs mainly occur during the production and recycling of the vehicles and their batteries, as well as during the energy resource exploitation and power generation for the electricity used. EVs do not emit pollutants during driving. The pollution of EVs mainly come from manufacturing and recycling, which are point sources pollution and are relatively easy to control. Therefore, as long as the power system is transformed into a renewable energy-dominated power system, the environmental and public health benefits of EVs will be very significant. However, no matter how much oil refining technology and fuel efficiency are improved, large-scale mobile source pollution is unavoidable from the operation of ICEs. Once pollutants are discharged into the air, they will undergo complex photochemical reactions and generate photochemical smog (secondary pollutant), including ozone and secondary particulate matter ($PM_{2.5}$), which obviously increases the difficulty of control.

3. Developing EVs: the challenge for China is to achieve low carbon development of power system as soon as possible

As mentioned earlier, the largest share of the life cycle carbon emissions of EVs comes from electricity consumption, so, the carbon intensity of the power system is the biggest factor influencing the carbon emission level of EVs. A study shows that with other conditions unchanged, and putting EVs used in the power systems of different countries in the life cycle, which means the proportions of renewable energy power and fossil energy power in the power systems of these countries are different, the carbon emission levels of EVs are also quite varied in these countries, as shown in Figure 1. Seen from the average carbon intensity of the power grids in the EU, EVs life cycle carbon emissions are significantly lower than those of the most energy-efficient conventional vehicles. However, if EVs were used in individual countries, their carbon emission levels are quite different. Since France is dominated by nuclear power and Norway by hydropower, the use of EVs in these two countries can bring the biggest carbon emission reduction compared to ICEs. In Germany, the use of EVs had the same climate change impact as the most energy-efficient ICEs. In other words, given the power mix of Germany in 2015, the replacement of the most energy-efficient ICEs by EVs had no carbon emission reduction effect.

Figure 1: Comparison of life cycle (over 150,000 km of mileage) carbon emissions of EVs and conventional vehicles in Europe in 2015



Source: Effects of Battery Manufacturing on Electric Vehicle Life-cycle Greenhouse Gas Emissions., Dale Hall and Nic Lutsey. The International Council on Clean Transportation, 2018. Figure 1. p 5. Link: https://theicct.org/sites/default/files/publications/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf

The power mix directly influences the carbon emission reduction effect of the replacement of ICEs by EVs. Compared with Germany, China homes a power mix heavily dependent on coal. According to the BP Energy Statistics Yearbook (2018), there was a significant gap between the power generation structures of Germany and China in 2017 (shown in Table 2). Low carbon power sources, including nuclear, hydro, and renewable energy, were as high as 45%

in Germany, while in China, the proportion was 29%. The power source with the highest carbon intensity is coal. Due to the high dependence on coal in its history, 37% of the electricity generated in Germany was still based on coal by 2017. The proportion in China was as high as 67%. From this point of view, at present, there is no carbon emission reduction effect from replacing ICEs with EVs in China. Of course, China's rapidly developing EV market in recent years may stimulate the economy, increase employment, enhance technological innovation and reduce the growth rate of urban air pollutant emissions from the road transport sector.

Table 2: Comparison of power generation structures in Germany and China (2017)

	Oil	Natural gas	Coal	Nuclear energy	Hydropower	Renewable energy	Others	Total
Germany	0.9%	13.1%	37.0%	11.6%	3.0%	30.3%	4.1%	100%
China	0.2%	3.0%	67.2%	3.8%	17.8%	7.3%	0.7%	100%

Source: 2018 BP Energy Statistics Yearbook

Conclusions

As climate change becomes increasingly urgent, we see more and more countries and policy makers setting the rapid development of EVs as a way to deal with climate change in the transport sector. Seen from the intrinsic requirement of the energy system to go low carbon (that is, quitting fossil energy and using renewable energy), such a strategy is reasonable. Particularly, in the long term, a lot of LCAs on the impacts of EVs on climate change, ecological environment and public health show that the development of EVs is the best available way to achieve sustainable transportation in the future. However, in order to effectively realize the carbon emission reduction effect from replacing ICVs with EVs, those countries whose power systems are heavily dependent on coal should decarbonize the power systems in priority or in the first place. On top of that, it may make sense to realize the role of ECs in sustainable transportation development.

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