# Sustainable Transport Systems in China

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## Introduction

The campus of Tsinghua University is situated in northwest Beijing on the site of the former imperial gardens of the Qing Dynasty, and surrounded by a number of historical sites. Tsinghua University was established in 1911, originally under the name "Tsinghua Xuetang". With the motto of "Self-Discipline and Social Commitment" and the spirit of "Actions Speak Louder than Words", Tsinghua University is dedicated to the well-being of Chinese society and to world development. As one of China's most prestigious and influential universities, Tsinghua is committed to cultivating global citizens who will thrive in today's world and become tomorrow's leaders.

The Department of Earth System Science starts since 1929. We strive to increase the success of existing programs at Tsinghua by playing a central role at the university as an integrator of the physical and social sciences, engineering and management toward a more comprehensive and systematic study of the Earth sciences to better meet the challenges of global environmental change and sustainable development. To achieve the overall goal of building a world-class comprehensive research university, Tsinghua University has recently decided to re-establish its earth science programs by initially developing the earth system science discipline with a focus on global and regional change issues. The College for Global Change Studies will initially concentrate on four broad academic fields:

1. Earth system science
2. Earth system modeling
3. Earth observation technology
4. Global change economics

Among those research fields, earth system model development is one major goal for the Department of Earth System Science, Tsinghua University. Apart from the conventional climate model components such as atmosphere, land, ocean and sea ice models, we are also planning to develop our own biogeochemical models, disease transmission models, socio-economic models and couple them to the current earth system modeling. To achieve this goal, we explore the key climate and environmental issues that severely influence the earth system and societies, which will further enhance our knowledge on both ecosystems and socioeconomic system. The goal of our department is to achieve the sustainable development of earth systems, which is closely related to the targets of SDG11. To better understand future sustainable development, one of the key global challenges is to estimate and mitigate the impacts of Air pollution, Energy and Climate Change. Energy consumption driven by human activities is the largest contributor that accelerates global climate change and air pollution. Current energy system induced an increase of 57%

of GHGs emissions between 1990-2015 [1]. The climate change induced by GHGs has had enormous impacts on human society and ecosystem on a global scale. Meanwhile the climate change is a great concern, energy use is the largest anthropogenic source of air pollution. WHO report shows that ambient air pollution inflicts 4.2 million premature deaths each year in the worldwide [2]. To ensure healthy lives and well-being for whole society, studies on different sectors, industries in different scales and different ecosystems are analyzed. These are some interesting initiatives closely related to sustainable transport systems for the society.

## Initiative 1 Green Transportation Mode for Urban Passengers in China

Unprecedented urbanization is happening in China. Traffic congestion is one of the major problems caused by urbanization. The increasing affluence of citizens and the inflow of residents from rural areas together with the growing household wealth results in the explosive increase of private cars. The traffic issue is also closely related with energy consumption, air pollution and climate change. For instance, the transportation consumes 8% of the total energy and contributes 20%-40% of total air pollution emissions [3] and 7%-9% of total $CO_2$ emissions in China [4]. China has implemented some policies and measures to address those ramifications. China invests about $29 billion to upgrade the standards for gasoline and diesel nationwide to cut emissions of air pollutants. The government also promotes the use of new-energy vehicles (NEVs) or zero-emission vehicles (ZEVs). The Chinese target of fuel economy standards is 20km/L in 2020, even lower than the fuel economy standard in the US in 2025 (21.8km/L). Those measures contribute to a substantial reduction of air pollution emissions. Local governments encourage residents to take public transit. One effective solution for alleviating urban traffic congestion is to build underground rail systems. In 2010, Shanghai, China, has taken over London as the city with the world's longest underground rail system. It plans to continue extending the network to a track length of 880 kilometers by 2020. In addition, megacities like Beijing and Shanghai adopt stringent traffic demand management policies which limit the number of car plates registered every year. However, those policies still cannot fully solve current traffic congestion and pollution emissions. Long-term transportation systems and patterns are not designed. This initiative applies a systematic approach to quantify the energy use and emission of transport sector under various patterns of urban development. To achieve this goal, this project investigates the choice of passengers' transport modes and designs mitigation scenarios based on those choices.

This project indicates the travel patterns of passengers in China. The $CO_2$ emissions and energy consumptions are estimated by classifying the travelling patterns into three choices- private vehicles (including private car, taxi, and business cars), public transit (including metro, light rail, BRT, and conventional bus), and Non-Motorized Transport (NMT, including e-bike, bike and walk). The scenario analysis gives potential pathways for cities in China to plan their future transport system. This initiative illustrates an overall picture of current and future transport system in China, while there are some other

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[1] Fatih Birol, "CO2 Emissions from Fuel Combustion 2017 - Highlights," *International Energy Agency* 1 (2017): 1–162, https://doi.org/10.1787/co2_fuel-2017-en.

[2] World Health Organization, "Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease," *World Health Organization*, 2016, 1–131, https://doi.org/9789241511353.

[3] Dongquan He et al., "Energy Use of, and CO2 Emissions from China's Urban Passenger Transportation Sector – Carbon Mitigation Scenarios upon the Transportation Mode Choices," *Transportation Research Part A: Policy and Practice* 53 (2013): 53–67, https://doi.org/https://doi.org/10.1016/j.tra.2013.06.004.

[4] He et al.

issues have not been considered. First, the travelling modes did not include electric vehicles. Thus, the future transport patterns could have more varieties and impacts. Second, the choice of travelling modes is evaluated while the reasons of those choices have not been analyzed. Understanding of the reason behind those choices can enable decision makers to learn the elasticity of passengers' choices. The transport planning based on their willingness can improve residents social well-being.

**Initiative 2 Impacts of Shipping Emissions on PM2.5 Pollution**

The fast development of seaborne trade contributes an increasing proportion of air pollution in China. The shipping emissions not only impairs the air quality of the coastal cities but also inland regions hundreds of kilometers away from the sea. The air pollutants emitted from shipping include carbon dioxide, sulfur oxides, nitrogen oxides and particulate matter. In addition to air pollution, the global shipping business is expected to contribute 17% of global $CO_2$ emissions in 2050 [5]. Liu et al. (2016) shows that shipping emissions can contribute to 14,500 to 37,500 premature deaths as of2013 [6]. The emissions of ship traffic vary significantly depending on the meteorological conditions, emission intensities and sources from inland regions. The air pollution of inland area can be controlled by provincial and regional policies, while the pollution emitted from international shipping is a big challenge for policymaking. The International Maritime Organization (IMO) designated four regions as Emission Control Areas (ECAs), where only low-sulfur-content fuel can be used. In addition to those areas, $SO_2$ and $NO_x$ are controlled within 200 nautical miles away from the coastline of North America and within 50 nautical miles of the islands in United States Caribbean Sea. In comparison, China designated 12 nautical miles as domestic emission control areas (DECAs). For a long time, there has been no study on the effectiveness of current DECA policy. This initiative is designed to explore the impacts of different DECA policy settings on the inland $PM_{2.5}$ pollution in China [7]. The initiative analyzed the PM2.5 concentration attributable to shipping emissions based on the shipping emission inventory. The results can provide scientific support for the design of DECA and shipping emission control.

This project combined high resolution shipping emission inventory with chemical transport model to simulate the $PM_{2.5}$ concentration and its health impacts. Then different DECAs are designed to evaluate corresponding impacts of $PM_{2.5}$ pollution due to the shipping. The study shows that the emission within 12 nautical miles contributes 51%-56% of total emissions. Thus, the 12 nautical miles DECA is not enough for pollution control. This initiative aims at providing scientific support for the domestic policymaking to avoid impacts of shipping emissions. However, air pollutants emitted from shipping expand to much larger areas instead of inland regions alone. Therefore, the impacts of pollution emitted around coastline of China will also influence the air quality of other countries. Further studies should investigate the whole pollution expansion regions due to shipping. Another challenging question is who is responsible for the emissions from one region that influence other regions and how should we internalize the externalities due to international shipping.

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[5] Martin Cames et al., "Greenhouse Gas Emission Reduction Targets for International Shipping," *Environmental Research of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety* 19 (2015).

[6] Huan Liu et al., "Health and Climate Impacts of Ocean-Going Vessels in East Asia," *Nature Climate Change* 6, no. 11 (2016): 1037.

[7] Zhaofeng Lv et al., "Impacts of Shipping Emissions on PM 2.5 Pollution in China," *Atmospheric Chemistry and Physics* 18, no. 21 (2018): 15811–24.

**Initiative 3 Climate Benefits of a 100% renewable energy system**

China is the largest energy consumer and greenhouse gas emitter in the world. Moreover, the air pollution related to the fossil fuel combustion challenges national environmental protection over the last three decades. Faced with limited fossil fuel resources and challenging environmental issues, China is actively increasing its installation of renewable energy, especially wind and solar power. China contributes more than 45% of global investment in renewable energy in 2017. The government aims to increase its use of renewable energy from 10% of total energy consumption now, to 15% by 2020 and 20% by 2030. Even though China's installed capacity is the largest in the world, its wind and solar energy only contribute 4% and 1% of its total electricity generation respectively. One of the main reasons for the substantial waste in renewable energy is the lack of efficient energy planning. This research aims to identify a least-cost pathway to build a 100% renewable energy supply, taking into consideration of renewable energy's fluctuation and construction cost. We model energy production and $CO_2$ emissions in China under the scenario of a 100% renewable energy system. In order to simulate a stable energy production process, we incorporate a smart energy system into our model. Depending on the advanced technology on energy storage, electric vehicles and biofuels, our model connects sectors and integrates technologies to simulate the various time scales from intra-hour to yearly electricity production with 100% renewable energy. The model is developed with the integration of smart electricity grids, smart thermal grids and smart gas grids, connected by appropriate infrastructure. To solve the problem of fluctuating output of renewable energy, we import solid, gaseous and liquid fuel storage technology into the smart energy system. In addition, we estimate the reductions in $CO_2$ emissions under a 100% renewable energy scenario and the cost of building this smart energy system. The results show that with proper planning and regulation, a 100% renewable energy system can be built with low cost and substantial environmental benefits. Our work can provide a potential pathway for national and global energy planning to achieve the goal of two-degrees temperature increase. On the other hand, this initiative can also support the sustainable energy use for transport sector in China.

This project provides state-of-the-science technique to simulate the renewable energy demand-supply system. The system can further lead us develop an effective energy roadmap for China. The challenge in this project is that the EnergyPlan model requires detail energy consumption distribution in a high-resolution time-series. The higher quality of the input data, the better performance of the simulation will be in the model. On the other hand, the energy model only simulates the energy demand-supply under current market design. A Computatable General Equilibrium model might be a useful tool to project future energy consumption under a dynamic market.

**Conclusion**

The primary goal of Center of Earth System Science at Tsinghua University is to study the earth system with an emphasis on observing, understanding and predicting the global and regional environment. We are looking for solutions to current urgent environmental and ecological ramifications due to economic activities. Our goal of research fits the targets of SDG 11, such as sustainable transport system, air pollution mitigation and other environmental and climate impacts on human health. We are especially interested in the less developed countries and under-representative population, who are suffering the most from the environmental degradation and global climate change.