

Chapter 1

Introduction

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Abstract In the process of modernization, China will have to face the challenges of ensuring energy security and of mitigating climate change over the long term. China is currently one of the fastest growing regions in the global automotive market and has become the world's largest nation of automobile consumers and producers. Automotive energy has therefore become a core energy and environmental issue for the country. China intends to establish a sustainable automotive energy system. However, there is as of yet no currently recognized standard definition of such a system anywhere in the world. The resource endowment, population and geography, economic and social development levels, infrastructure characteristics of energy and transportation, and technological innovation capability of energy and transportation vary by country. We believe there are six basic standards for estimating the sustainability of China's automotive energy system: the transportation economy, energy efficiency, greenhouse gas emissions, security of energy supply, supply and demand matching of fuel types, and automotive industry leadership.

Keywords Automotive energy • System analysis • China

Energy security and climate change have become major issues for current international economy and environment policy. In the process of modernization, China will have to face the challenges of ensuring energy security and of mitigating climate change over the long term. Future energy development will have a significant effect on global energy markets and on addressing climate change. China is currently one of the fastest growing regions in the global automotive market and

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has become the world's largest nation of automobile consumers and producers. Automotive energy has therefore become a core energy and environmental issue for the country.

1.1 Influences of Automotive Energy

There are four categories affecting development of the automotive industry: economic growth, population and geography, technological progress, and public policy.

1.1.1 Economic Growth

The demand for automotive transportation services determines car ownership and consumption of automotive energy in a country. Demand is also determined by macroeconomic characteristics such as total economic scale, economic structure, and industrial structure of the country. Over a certain period, economic scale, automotive transportation service demand, and consumption of automotive energy generally have strong positive correlations. One important example of this strong positive correlation is related to China's reform and opening up. By the middle of this century, China will achieve basic modernization and become a middle-income, developed country. In the future, the economy will remain in a growth stage, and the GDP growth rate will be a major driver of the country's automobile transportation services demand.

1.1.2 Population and Geography

In addition to economic scale and developmental level, the population and geography of a country are key influences on automobile transportation service demand and consumption of automotive energy. Characteristics of said population and geography include its size, demographic composition, land area, urbanization rate, urbanization patterns, and transportation infrastructure. In the United States, there are vast land areas, decentralized urban agglomerations, a highly developed highway network, and a high rate of car ownership at 785 cars per 1,000 people. In Japan, there is a small land area, high population density, dense urbanization, and a car ownership rate of 450 cars per 1,000 people less than America. The rate of car ownership in other countries such as Canada, the United Kingdom, Germany, and France lies between those of the aforementioned two countries. Therefore, population growth rate, population density, urbanization

rate, urbanization patterns, and transportation infrastructure will be major drivers of China's demand for automobile transportation services and consumption of automotive energy.

1.1.3 Technological Progress

Future progress of automotive and energy technologies will significantly affect the development of automotive energy. Innovation and promotion of energy-saving technologies will continually improve automotive fuel economy and reduce emission levels of pollutants, including carbon dioxide. Advancement of new vehicle energy technology such as pure battery electric vehicles (BEVs) and fuel cell vehicles (FCVs) will significantly enhance automotive fuel economy and lower pollutant emissions. This will also bring new innovations such as automotive energy conversion and storage technologies, automotive energy infrastructures, and profound changes in the automotive industry itself. In addition, advances in bio-based alternative energy technologies will modify China's automotive energy supply structure. However, future automotive energy technology progress and market penetration rates are very uncertain.

1.1.4 Public Policy

The goal of China's automotive energy development is to establish a sustainable automotive energy system. Because of certain inconsistencies between the country's overall interests and individual interests, the market mechanism fails to internalize externalities and information supply. Establishment of a national sustainable automotive energy system should be supported by public policy. Policy orientation largely determines technical automotive progress. Under the same circumstances and with consideration for macroeconomic, population, and geography factors, different policy orientations will play distinct roles in technological innovation and selection of the technological direction for future automotive energy.

1.2 Sustainable Automotive Energy System

As stated above, China intends to establish a sustainable automotive energy system. However, there is as of yet no currently recognized standard definition of such a system anywhere in the world. The resource endowment, population and geography, economic and social development levels, infrastructure characteristics of energy and transportation, and technological innovation capability of energy and transportation vary by country. Therefore, the explanation, definition, and requirements of a

sustainable automotive energy system also vary. China is a vast, developing country with a large population, relative lack of resources, and rapid economic development. Thus, the country's sustainable automotive energy system will have certain characteristics as follows:

1. Automotive traffic economy: social and economic development and the individual demands for automotive transport services should be satisfied by affordable (or as low as possible) cost. The sustainable automotive energy system will help reduce oil imports, which expend substantial foreign exchange reserves and economic resources. Consequently, the transition to a sustainable automotive energy system will significantly benefit the automotive traffic economy.
2. Efficiency of energy system: the future automotive energy system will expend minimum energy resources to satisfy social and economic development and individual demand for automotive transport services. The ideal sustainable automotive energy system should be one that achieves minimum or reduced energy consumption in the well-to-wheel (WTW) life cycle, under the same conditions as the automotive transport services demand.
3. Greenhouse gas emissions: carbon dioxide is the main greenhouse gas (GHG). According to the global CO₂ emission control target scenario, global average CO₂ emissions per capita in 2050 will be just greater than 1 t as presented by the fourth-version IPCC report. Controlling CO₂ emission has been a major impetus within automotive energy technology innovation. Automotive vehicles have become some of the most serious pollution contributors to air deterioration in cities. The ideal sustainable automotive energy system should be one in which CO₂ emissions of the WTW life cycle and motor vehicle pollutants are minimized or reduced, under similar conditions of automotive transport services demand satisfaction.
4. Security of energy supply: China's oil resources are relatively scarce. Its dependence on oil imports reached nearly 55 % in 2010 and will increase in the future. Because more than 95 % of automotive energy comes from petroleum-based fuels, an increase in the need for automotive energy is the main reason for the recent rise in dependence on oil imports. The sustainable automotive energy system should have the ability to respond to the risks of the international energy markets. From this standpoint, the automotive energy supply should be diversified and should reduce dependence on energy imports under feasible economic conditions.
5. Supply and demand matching of fuel type: the sustainable automotive energy system should not only ensure a supply and demand balance of automotive energy in quantity but also reasonably match automotive energy types. This is an attempt to avoid a surplus or deficiency of automotive energy types and ensure scientific use of automotive energy infrastructure in the processes of energy production, transport, and filling.
6. Competitiveness of automotive industry: although China's automotive industry began late and lacked competitiveness in traditional automotive and energy technologies, it has a greater possibility to excel in the area of new energy

vehicles. The country's new energy automotive market will provide the impetus for upgrading and introducing competition into the automotive industry once it reaches a certain scale.

The sustainable automotive energy system is an ideal policy target scenario. We believe there are six basic standards for estimating the sustainability of China's automotive energy system: the transportation economy, energy efficiency, greenhouse gas emissions, security of energy supply, supply and demand matching of fuel types, and automotive industry leadership.

1.3 Contents of This Book

China's automotive energy situations are very complex. They are related to energy, economy, environment, technology, society, industry leadership, and public policy. Systematic, in-depth multidisciplinary and comprehensive studies will provide a solution for the country's automotive energy challenges. Commissioned by the National Energy Administration, Ministry of Industry and Information Technology, Ministry of Science and Technology, and other government departments, Tsinghua University's China Automotive Energy Research Center (CAERC) has studied the sustainable development of the country's automotive energy industry. After studying influences such as energy, economy, environment, technology, society, industry leadership, and policy, plus the life cycle of automotive energy in several technology roadmaps, CAERC put forward five scenarios of automotive energy development in China. These are the Reference Scenario (RS), Electric Vehicles Development Scenario (EVDS), Fuel Cell Vehicles Development Scenario (FCVDS), Biofuels Development Scenario (BDS), and Integrated Policy Scenario (IPS). In scenario analyses, CAERC assessed automotive energy demand management, improvement of vehicle fuel economy, and technical specifications of BEVs, FCVs, and second-generation biofuels. CAERC made policy recommendations and institutional arrangements for promoting sustainable transformation of the national automotive energy system. The aforementioned research works and CAERC achievements are summarized in this 13-chapter book. Chapters 2 through 13 are described as follows.

Chapter 2 Motor Vehicle Development and Air Pollution Control illustrates environmental problems caused by the development of motor vehicles in China, focuses on the relationship between urban motor vehicles and air pollution, analyzes pollution control measures of motor vehicles, and summarizes relevant challenges and future prospects.

Chapter 3 Scenario Analyses of China's Vehicle Ownership and Vehicle Traffic Services focuses on future projections of vehicle ownership and vehicle traffic services; forecast of ownership of private passenger vehicles, public transport vehicles, and other vehicles, through creating predictive models related to population density, household income, and other factors; and also forecast of passenger and freight vehicle traffic services, combined with future projections of annual vehicle mileage and passenger/cargo rates.

Chapter 4 Vehicle Powertrain Technology: systematic assessment of the development status of China's motor vehicle power systems, which includes technologies of high-efficiency and clean vehicle power, hybrid and pure electric drive. Also, there is an introduction to RD&D of these technologies in the country.

Chapter 5 Petroleum-Derived Liquid Fuels: analysis of the country's oil supply chain around petroleum-based vehicle issues, as well as examination of oil production, imports, refining, and consumption. Strategic recommendations are provided for future development.

Chapter 6 Natural Gas: discussion of the future of China's natural gas supply and demand and technology development of natural gas vehicles. Also, there is the discussion of the potential for using natural gas in automotive energy.

Chapter 7 Coal-Derived Liquid Fuels: analysis of the supply chain of coal-based liquid fuel technology; comprehensive and objective assessment of technological developments of coal-based liquid fuel. Basic developmental recommendations are provided.

Chapter 8 Liquid Biofuels: assessment and commentary on various resources and technologies that would affect China's future biofuels. There is multi-scenario analysis of future automotive biofuels (fuel ethanol and biodiesel), combined with future key technological breakthrough points and policies.

Chapter 9 Energy for Electric Vehicles: analysis of electrical system development status and future development scenarios, with respect to development issues of automotive electrical energy. There is the discussion of key effects on electrical system development and assessment of the possible use of electricity as an automotive fossil-fuel alternative. An outlook for feasible directions is also provided.

Chapter 10 Hydrogen and Fuel Cell Vehicle Technology: analysis of China's hydrogen production and utilization, with respect to development issues of hydrogen and fuel cell vehicles. Exploration of sources of future automotive hydrogen, together with technological development of fuel cell vehicles, is also presented.

Chapter 11 Life-Cycle Energy Consumption and Greenhouse Gas Emissions of Automotive Energy Pathways: after introducing models and related parameters of different fuel and power technologies, the life cycle of the multi-fuel/vehicle line is comprehensively compared, based on the same computing platform as China's automotive energy pathways. There is also the forecast of energy consumption and carbon emissions under the life cycle of the key technical path.

Chapter 12 Scenario Analyses of Automotive Energy: five future development scenarios of China's automotive energy are provided, with respect to its sustainable transformation—the Reference Scenario (RS), Electric Vehicles Development Scenario (EVDS), Fuel Cell Vehicles Development Scenario (FCVDS), Biofuels Development Scenario (BDS), and Integrated Policy Scenario (IPS). Analysis and assessment of these five scenarios within the scope of energy, economy, environment, and technology, and industry leadership are also presented.

Chapter 13 Policy Recommendations Regarding Sustainable Development of China's Automotive Energy: quantitative analysis of sustainable transformation of the country's automotive energy system with policy recommendations.