Energy Policy 115 (2018) 92–97

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Critical issues of energy efficient and new energy vehicles development in China

Zongwei Liu[a,b], Han Hao[a,b,c], Xiang Cheng[a,b], Fuquan Zhao[a,b,*]

[a] State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China
[b] Tsinghua Automotive Strategy Research Institute, Tsinghua University, Beijing 100084, China
[c] China Automotive Energy Research Center, Tsinghua University, Beijing 100084, China

ARTICLE INFO

Keywords:
Energy efficient and new energy vehicles
Technology pathway
Vehicle manufacturers
China

ABSTRACT

Energy efficient and new energy vehicles are key measures in addressing China's energy and environment problems. In terms of the prospect of different technologies, the industrial and academic circles have not reached a consensus yet. In this study, the current situation and future development of main technology pathways in China are discussed. Specifically, internal combustion engines will be simpler in the future as a result of electric motor coupling. Battery electric vehicles are faced with a certain challenges currently and should be adopted in smaller vehicles at first. Hybrid technologies should be considered a significant development stage and should be applied before 2018. Plug-in hybrid electric vehicles and extended range electric vehicles are different in essence and should be applied based on their original intentions. Fuel cell vehicles are confronted with multiple challenges currently and will probably popularize after 2025.

1. Introduction

China's automotive industry has experienced rapid development over the past few decades. In 2016, the production and sales volume of automobiles in China exceeded 28 million units, continuing to be the world's first in eight consecutive years (State Council, 2016). Meanwhile, the rapid development poses enormous challenges for the energy consumption and environment in China. In terms of energy consumption, energy safety has become one of the top priorities for China's national security. The degree of foreign dependence on oil of China has reached 65% in 2016, much higher than the international safety line of 50% (National Bureau of Statistics, 2016). According to statistics, oil consumption of automotive industry accounts for nearly 40% in China's total consumption (Zhang et al., 2011). With the rapid growth of vehicle ownership, oil consumption of China's automotive industry will continue increasing. On the other hand, environment pollution issues are increasingly severe in China recently. The frequent hazy weather in big cities has gained widespread attention on air pollution (Huang et al., 2014). Among the urban air pollutions, vehicle exhaust emission is a significant source. Researches show that vehicles are one of the primary sources of particulate matters in large cities such as Beijing and Shanghai (Wang et al., 2014). Under such backgrounds, energy saving and emission reduction have become the key developing trends of China's automotive industry.

Among the energy saving and emission reduction measures, promoting “energy efficient and new energy vehicles” is a key measure. In order to promote energy efficient and new energy vehicles, Chinese government has introduced plenty of policies, including fuel consumption regulations, credit management policies and carbon quota policies. For the fuel consumption regulations, the government has restricted corporation's average fuel consumption (CAFC) of passenger vehicles (State Council, 2015). The average fuel consumption of passenger vehicle manufacturers should be reduced to 4 L/100 km by 2025. For new energy vehicle (NEV) credits, vehicle manufacturers are demanded to gain 10% and 12% of NEV credits in 2019 and 2020 (Ministry of industry and information, 2017). For carbon emissions, *Administrative Measures on Carbon Quota of New Energy Vehicles* has been issued to stipulate the carbon emission reduction quota of vehicle manufacturers (National Development and Reform Commission, 2016). Meanwhile, Chinese government is also considering the systematic integration of multiple credit systems. For instance, the *Measures on the Joint Management of CAFC and NEV Credits* has been released in order to achieve parallel management of CAFC and NEV credits in the future (Ministry of industry and information, 2017).

The development of energy efficient and new energy vehicles in China is supported by three main factors, namely the severe situation of energy and environment, the rapid development of technologies and supportive polices by the government. At present, the powertrain

* Corresponding author at: State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China.
E-mail address: zhaofuquan@tsinghua.edu.cn (F. Zhao).

https://doi.org/10.1016/j.enpol.2018.01.006
Received 13 September 2017; Received in revised form 27 November 2017; Accepted 4 January 2018

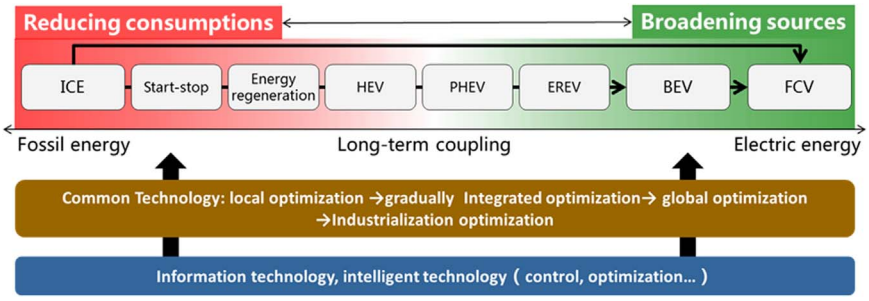

Fig. 1. Relationship between broadening sources and reducing consumptions.

transforming process from fossil energy to electric energy is continuously being deepened. However, the challenges and application scenarios of conventional vehicles, hybrid electric vehicles (HEV), battery electric vehicles (BEV) and fuel cell vehicles (FCV) are quite different. Currently, the industrial and academic circle have not reached a consensus in China yet. According to the literature review, most existing studies focused on a certain kind of technology (Kang et al., 2009; Plotkin et al., 2002). There are also many articles which compared technology pathways from the perspective of life-cycle emission or cost (Hawkins et al., 2013; Hao et al., 2017). However, few articles researched on the choice of technology pathways of enterprises systematically. Therefore, a systematic and clear judgment of different technologies is extremely necessary. In this study, based on plenty of surveys and deliberations, a systematic solution was illustrated.

It should be stressed that broadening sources and reducing consumptions are both indispensable in addressing China's energy and environment issues, as presented in Fig. 1. For the automotive industry, reducing consumptions means improving the current technologies, represented by improving the efficiency of internal combustion engines (ICE) and various hybrid technologies. These technologies are also called energy efficient technologies. Meanwhile, broadening sources means seeking new power sources, represented by BEVs and FCVs, which is also called NEV technology. The proportions of these two types of solutions are fluctuating. However, they do not contradict. On one hand, energy efficient vehicles will gain time for the gradual maturity of NEVs. On the other hand, the development of NEVs will extend the life of ICEs. Therefore, “broadening sources” and “reducing consumptions” should both be attached equal importance. This viewpoint should be regarded as the basic starting point for the development of energy efficient and new energy vehicles.

2. Technology pathway analysis

2.1. Engine powertrains

Although engine powertrain belongs to a traditional power type, it will also experience tremendous changes during this power transformation process. In the past, the engine and transmission combine to output power. Therefore, engines must be able to operate in a wide range to meet the intricate operating conditions. Accordingly, the optimum operating area of the engine must be as wide as possible, which is difficult to achieve (Kiencke and Nielsen, 2000). The demand of intricate operating conditions is met by mechanical structures such as variable valve timing (VVT), variable valve lift (VVL), variable compression ratio (VCR), multiple-speed transmission and continuously variable transmission (CVT) (Guzzella and Onder, 2009). If technology develops in line with this pathway, the engine powertrain will become more and more complex, which will make the control system increasingly complicated and expensive.

In the future, the output power will be provided by both the engine and electric motor, as shown in Fig. 2. Although the intricate operating conditions for the vehicles do not change, the engines can operate in a narrow optimum area (Moore, 2001-10-23). This is achieved by

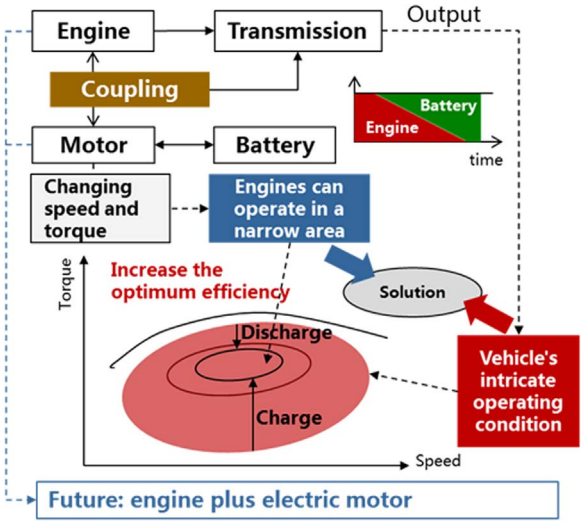

Fig. 2. Future's coupling structure of engine and electric motor.

changing the speed and torque of the electric motor. The essence of the structure is to achieve variable output from electromechanical coupling to meet the requirements of variable driving modes. Because of this structure, enterprises will merely need to increase the optimum efficiency of the engine within a small operating area, instead of adopting intricate variable units and control strategies. Therefore, this electromechanical coupling will simplify the technologies and lower the cost.

To sum up, engines will be simpler in the future. Effective combination of engine and electric motor will be achieved. Therefore, the efficiency optimization within a small operating area will be attached more importance. Meanwhile, the significance of transmission for energy saving will decrease. Effective coupling between engine and electric motor will be paid more attention than transmission efficiency. For technology decision makers, it should be stressed that under the same output, increasing the performance of electric motor will lead to simpler engine technology. Therefore, the cost increase of electric motors and cost reduction of engine should be weighed and balanced. The critical issue for enterprise decision-making lies in reasonably evaluating the balance point of cost.

2.2. Battery electric vehicles

Traction battery means the battery which drives the electric motor in BEVs. In general, the development of BEV industry is a function of time in regard to traction battery performance. Currently, the specific energy of battery system has reached 110 Wh/kg. And the cost of battery system is 2.2 yuan/Wh in 2016 in China (SAE-China, 2016a). Although there have been improvements in the performance and cost, great uncertainty still exists currently for traction battery technology. On one hand, current predictions on battery performance are mainly based on experience or historical data (Nykvist and Nilsson, 2015). On the other hand, future's development of new system battery is difficult