Energy Policy 108 (2017) 355–358

Contents lists available at ScienceDirect

Energy Policy

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

China's traction battery technology roadmap: Targets, impacts and concerns

Han Hao, Xiang Cheng, Zongwei Liu, Fuquan Zhao*

State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China

ARTICLE INFO

Keywords:
Technology roadmap
Traction battery
Electric vehicle
China

ABSTRACT

In Oct 2016, China released its most up-to-date traction battery technology roadmap, which reflects the Chinese perspective, or even the global perspective to some extent, on the future technology development of traction batteries. In this paper, the technology targets specified in the technology roadmap, including the energy density, cost, power density, and durability, are reviewed and compared with previous projections from other countries. It is found that China's pre-2020 targets are generally in line with previous projections. The 2020–2030 targets are quite ambitious and aggressive. If the battery technologies evolve as projected, electric vehicles will have similar market competitiveness with conventional vehicles by around 2020, implying a mass market penetration of electric vehicles. This will impose very broad impacts on China's urban environment, oil security, rare metal security, climate change mitigation and charging infrastructure deployment. On the other hand, it should be fully noted that the technology roadmap is more market demand-oriented than technology capacity-oriented. The technology uncertainty issues did not receive adequate emphasis in the technology roadmap, which might result in over-optimism in the future of battery technologies and electric vehicle market penetration.

1. Introduction

China experienced rapid economic development over the past decades. The fast social wealth creation was accompanied by significant negative energy and environmental impacts, including air pollution, energy depletion and Greenhouse Gas (GHG) emissions. Such concern is especially outstanding in China's transport sector, where over twenty million of new vehicles join the fleet each year. As estimated by International Energy Agency (IEA), the transport sector was responsible for 23.3% of global anthropogenic CO_2 emissions in 2014, and 8.6% in China's context (IEA, 2016). Driven by the rapid vehicle ownership increase in some megacities like Beijing and Shanghai, these cities have suffered from severe hazy weather and traffic congestion.

Electric vehicles (EV) are considered as a promising solution to address these issues. EVs offer the benefit of zero tailpipe emissions, which contributes to reducing air pollutants in the urban area. Besides, EVs can also contribute to reducing CO_2 emissions with clean electricity. In this regard, China has put great efforts in promoting the market penetration of EVs. Generous subsidies for EV purchase are available from both the central and local governments. Besides, EVs typically receive preferential treatments under the local vehicle purchase and driving restriction schemes. As a further step, China is considering to establish a California Zero Emission Vehicle (ZEV) scheme-like framework to promote the sustainable development of the EV market. Under such a circumstance, China's EV market experienced a major surge in the year of 2016, having a total sales of 0.51 million, 53% higher than the previous year (CAAM, 2017).

To establish technology roadmap is an essential measure from the government to guide and promote EV technology development. In the 'Made in China 2025′ initiative launched in 2015, the automotive industry is listed as one of the ten key industries that China will develop with priority in the next decade (State council, 2015). Correspondingly, three automotive industry-related technology roadmaps, i.e., the technology roadmaps for energy-saving vehicles, new energy vehicles, and intelligent and connected vehicles, were released. These technology roadmaps outline the key technology targets that the industry expects to achieve in the timeframe of 2020–2030. As a further response to the 'Made in China 2025′ initiative, Chinese Society of Automotive Engineers (SAE-China) coordinated China's major automotive manufacturers, research institutes and universities, with more than five hundred top experts included, spending one year establishing an updated and detailed version of the technology roadmaps for China's automotive industry (SAE-China, 2016). The new release consists of seven technology roadmaps, including the technology roadmaps for energy-saving vehicles, EVs, plug-in hybrid electric vehicles (PHEV), fuel cell electric vehicles, intelligent and connected vehicles, traction batteries, vehicle lightweighting, and vehicle manufacturing. The new release of technology roadmaps reflects China's most up-to-date

* Corresponding author.
E-mail address: zhaofuquan@tsinghua.edu.cn (F. Zhao).

http://dx.doi.org/10.1016/j.enpol.2017.06.011
Received 6 December 2016; Received in revised form 23 May 2017; Accepted 6 June 2017
0301-4215/

perspectives on the key automotive technologies.

Traction battery refers to the battery which provides traction power for EVs. It is EV's most essential component, which substantially affects EV's performances such as range capacity, curb weight and manufacturing cost. Taking the 'Tesla Model S 85′ for example, the traction battery is responsible for approximately 30% of total vehicle weight and over 40% of vehicle cost. Each kWh of energy in the traction battery offers about 6 km of range capacity. What is more important, unlike the conventional vehicle components that have been maturely developed for decades and expect only incremental improvements, traction batteries are currently undergoing very fast and disruptive technology changes. Under such a circumstance, the technology roadmap for traction batteries has attracted the highest attention from the industry, government and research community. In this paper, China's technology roadmap for traction batteries is presented. The technology roadmaps from the U.S. (DOE, 2013), Japan (NEDO, 2013) and Germany (Fraunhofer ISI, 2012; NPE, 2012) are also incorporated as a comparison. Intensive researches have been conducted to project the future development of traction batteries. However, existing estimations vary a lot. In consideration of comparability of different countries, we didn't take these estimations into consideration. Afterwards, based on the technology roadmap, the possible impacts and concerns are discussed.

2. Technology roadmap

The key performance indicators of traction batteries are energy density, cost, power density and durability. All these indicators are covered in China's new technology roadmap. The targets specified in the technology roadmap are based on the expectation that a 400 km-range-capacity EV in 2020 has a similar lifecycle ownership cost with its counterpart conventional internal combustion engine-based vehicle. Battery chemistry evolvement, as the essential driver behind the technology improvement, is projected to undergo a major transition from the current 'aggressive Li-ion' chemistries to the 'beyond Li-ion' chemistries, such as lithium-sulfur, zinc-air batteries.

2.1. Energy density

Energy density (Wh/L or Wh/kg) refers to the amount of energy stored per unit volume or mass. Considering the comparability of different countries, only the mass energy density is discussed in the study. Two levels of energy densities are discussed in the study, which are the pack-level energy density and the cell-level energy density. The pack-level energy density refers to the energy density of the battery pack, while the cell-level energy density is the energy density of the battery cell. Fig. 1 shows the energy density targets from China's technology roadmap as well as roadmaps from other countries. Currently in China, the pack-level energy density is around 110 Wh/kg and the cell-level energy density is around 180 Wh/kg. Under China's new technology roadmap, the pack-level energy density is projected to increase from the current level of 110 Wh/kg to 250 Wh/kg, 280 Wh/kg, and 350 Wh/kg by 2020, 2025 and 2030, respectively. The changes are assumed to be driven by the improvement of current battery chemistries in the short term, and the application of next-generation battery chemistries in the long term. Compared with the previous targets under the 'Made in China 2025′ initiative, the new targets have a significant increase in the short term, with the cell-level energy density target in 2020 increasing from 300 Wh/kg to 350 Wh/kg. This reflects higher confidence of China's automotive industry in the improvement of traction battery technologies. As a comparison, the Japan target for 2020 and U.S. target for 2022 are both 250 Wh/kg, which is completely the same with the China target for 2020. The Germany target is significantly lower than other countries. Overall, the major countries have a general consensus in the projection of battery energy density. Although China's targets for the battery energy density are quite ambitious, they are aligned with US and Japan targets for the same period.

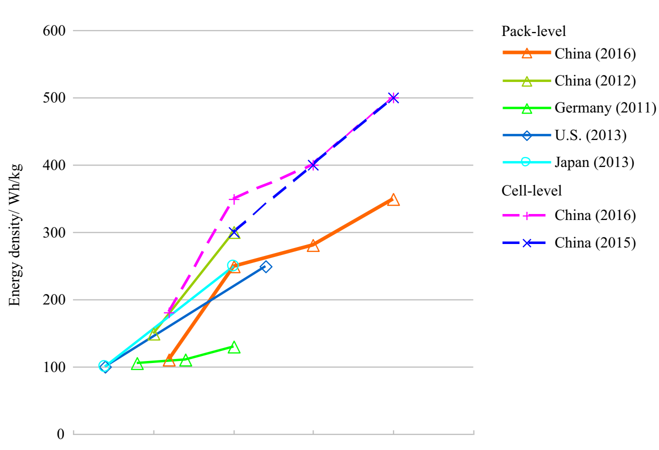

Fig. 1. Energy density targets from global technology roadmaps.

2.2. Cost

Similar to energy density, the cost of battery is also estimated from the perspectives of pack-level and cell-level, respectively. Fig. 2 shows the battery cost targets from the technology roadmaps of major countries. Again, China's new targets on battery cost are much more aggressive than its previous targets. Under the current situation, the pack-level cost is approximately $319/kWh in China while the cell-level cost is about $203/kWh. Under the new technology roadmap, the pack-level cost is projected to decrease to $145/kWh, $131/kWh, and $116/kWh by 2020, 2025 and 2030, respectively. It can be found that the decrease of battery cost before 2020 is quite substantial. This improvement relies on both the optimization of the current manufacturing system and the introduction of the next-generation battery chemistries. On the other hand, the cost reduction beyond 2020 is quite moderate. As a comparison, the Japan target on pack-level battery cost for 2020 is $181/kWh, and U.S. target for 2022 is $125/kWh. These targets are generally in line with the China's ambitious targets. The Germany targets are quite conservative, mostly due to the fact that the Germany technology roadmap was established in as early as 2011, when the battery technology was not evolving in such a rapid pace as nowadays.

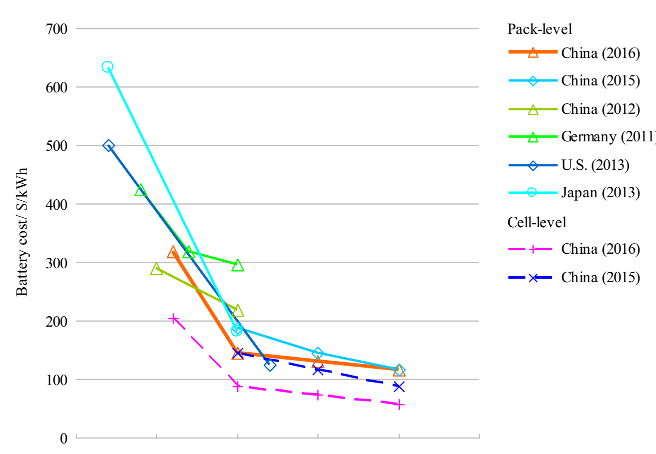

Fig. 2. Battery cost targets from global technology roadmaps.

2.3. Power density

Power density (W/L or W/kg) refers to the amount of power per unit volume or mass. In this study, only mass power density (W/kg) is considered because of data availability. In China's new technology roadmap, the indicator of power density is covered for the first time. The battery power density is projected to increase from the current level of 420 W/kg to 700 W/kg by 2020 and keep constant after that. As a comparison, the U.S. target is 2000 W/kg by 2022, and Japan target is 1500 W/kg by 2020. Compared with these targets, the China targets are a bit conservative.

2.4. Durability

Under China's new technology roadmap, the calendar life of traction batteries is projected to reach 10 years, 12 years and 15 years by 2020, 2025 and 2030, respectively. A general implication from this projection is that durability-induced battery replacement can be gradually avoided during the life time of EVs. The targets from other countries are generally similar. For example, under the Japan technology roadmap, the calendar life of traction batteries is projected to reach 10–15 years by 2020.

2.5. Traction batteries for PHEVs

Traction batteries function as auxiliary power unit on PHEVs, for which the power density is the most important indicator for such batteries. Under China's new technology roadmap, the pack-level power density of PHEV traction batteries is projected to increase from the current level of 800 W/kg to 900 W/kg by 2020 and 1000 W/kg by 2025. These are very conservative targets compared to other countries. For example, under the Japan technology roadmap, the power density is projected to reach the level of 2500 W/kg by 2020. Other key factors of PHEV traction batteries include energy density and cost. According to the technology roadmap, the pack-level energy density of PHEV traction batteries is 70 Wh/kg currently and is projected to increase to 120 Wh/kg in 2020 and 150 Wh/kg in 2025. The pack-level cost of PHEV traction batteries is projected to decrease from the current level of $435/kWh to $218/kWh in 2020 and $188/kWh in 2025.

3. Discussions

3.1. Possible impacts

If the targets specified in China's new technology roadmap are achieved, the expectation that a 400 km-range-capacity EV in 2020 has a similar lifecycle ownership cost with its counterpart conventional vehicle will be realized (SAE-China, 2016). Under such a circumstance, the market competitiveness of EVs will be substantially enhanced. China is quite likely to fulfill or even over-fulfill its ambitious target that EV and PHEV sales penetration rate reaches 7% by 2020 (around 2 million), 15% by 2025 (around 5 million) and 40% by 2030 (around 15 million) (SAE-China, 2016). This has very broad implications for the Chinese and even global policy makers.

One major opportunity is that the air pollution pressure in the major cities will likely be alleviated. In the near term, EVs are mostly deployed in China's first-tier cities, where the air pollution problems are the most severe. The vehicle tailpipe emissions are considered to be a major cause of the air pollution problems. The deployment of EVs, which feature zero tailpipe emissions, will contribute greatly to improving the air quality in China's major cities. Besides, replacing the conventional vehicles with EVs reduces the dependence on oil. Thus, China's oil import and the associated energy security concerns will be significantly eased.

On the other hand, the government also faces great challenges. First, due to China's coal-dominating power mix, the CO_2 emissions issue of EVs in China is still quite controversial (NBS, 2015). Currently in China, over 70% of electricity is generated from thermal power and most of the thermal electricity is from coal power plants. About 20% of the electricity is generated from hydropower. Nuclear, solar and wind powers take relatively small proportions in the generation mix. Therefore , the government needs to make more efforts in reducing the carbon intensity of the power grid. Otherwise, the deployment of EVs will bring burden to China's climate change mitigation efforts. Second, different from the conventional vehicles, the manufacturing of traction batteries needs considerable amount of rare metals, such as lithium and cobalt. In 2015, 86% of China's lithium supply depends on import (Hao et al., 2017). To secure the supply of these rare metals will be a great challenge for the Chinese government. Third, the deployment of charging infrastructures is still lagging behind the vehicle market development. The charging infrastructures need to be deployed in a much faster pace to comply with the vehicle side demand.

3.2. Concerns

Under the technology roadmap, the technology targets should be specified based on both the technology-side and market-side considerations, i.e., what the technology improvement can offer versus what the market demands. For traction batteries, from the technology perspective, factors such as the potential application of the next-generation battery chemistries, manufacturing improvement and learning curve, should all be considered to set reasonable targets for battery technology improvement. From the market perspective, the performances of the traction batteries are expected to comply with the market penetration targets of EVs.

According to our analysis, China's targets are generally in line with developed countries like the U.S. and Japan. The concern is that although the technology-side and market-side considerations should be balanced, the market side seems to play a more substantial role in determining the targets under China's new technology roadmap. In other words, the technology roadmap is more market demand-oriented than technology capacity-oriented. The risk is that there is considerable uncertainty in the technology side, especially the development of next-generation battery technologies. Many next-generation battery technologies are still in the laboratory research stage, far from commercialization. For example, the lithium-sulfur battery, which promises high energy density, has a very low durability. Intensive researches are being conducted to enhance its durability. However, to what extent its durability can be extended remains quite uncertain. Another example is zinc air battery, which has a considerably higher theoretical energy density and better safety performance. Nevertheless, the lack of efficient air catalysts and the low durability hampered its large-scale application. Various studies have been conducted to improve the performance of zinc-air battery. However, there exists great uncertainty in terms of the improvement potential. If these next-generation technologies do not evolve as expected, the targets specified in the technology roadmap will hardly be achieved. Unfortunately, these technology uncertainties did not receive adequate emphasis in the technology roadmap, which might result in over-optimism in the future of battery technologies and EV market penetration.

Acknowledgements

This study is sponsored by the National Natural Science Foundation of China (71403142, 71690241, 71572093), State Key Laboratory of Automotive Safety and Energy (ZZ2016-024), Young Elite Scientists Sponsorship Program by CAST (YESS20160140), China Automotive Energy Research Center of Tsinghua University (CAERC), Beijing Natural Science Foundation (9162008).

References

CAAM, 2017. China's Automotive Industry Satus in 2016. China Association of Automobile Manufacturers, Beijing.

DOE, 2013. EV everywhere - grand challenge blueprint. U.S. Department of Energy. ⟨http://energy.gov/eere/vehicles/downloads/ev-everywhere-grand-challenge-blueprint⟩.

Fraunhofer ISI, 2012. Technology Roadmap Energy Storage for Electric Mobility 2030. Fraunhofer ISI, Germany⟨http://www.isi.fraunhofer.de/isi-wAssets/docs/t/en/TRM-ESEM-2030_en_web.pdf⟩.

Hao, H., Liu, Z., Zhao, F., et al., 2017. Material flow analysis of lithium in China. Resour. Policy 51, 100–106.

IEA, 2016. CO_2 Emissions from Fuel Combustion 2016 edition. International Energy Agency, Paris⟨https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustion_Highlights_2016.pdf⟩.

NBS, 2015. China Statistical Yearbook 2015. National Bureau of Statistics, Beijing.

NEDO, 2013. Battery Roadmap 2013. The New Energy and Industrial Technology Development Organization. ⟨http://www.nedo.go.jp/content/100535728.pdf⟩.

NPE, 2012. Progress Report of the German National Platform for Electric Mobility. Nationale Plattform Elektromobilität, Germany⟨http://nationale-plattform-elektromobilitaet.de/fileadmin/user_upload/Redaktion/Third_Progressreport_NPE.pdf⟩.

SAE-China, 2016. Technology Roadmap for Energy-Saving and New Energy Vehicles. Chinese Society of Automotive Engineers, Beijing.

State council, 2015. 'Made in China 2025' initiative, ⟨http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm⟩.