Forecasting the Impact of Dual-credit Policy (2021-2023) on China's Electric Vehicle Market[*]

Shiqi Ou[1], Zhenhong Lin[2*], Xin He[3], Rujie Yu[4], Jessey Bouchard[3], Steven Przesmitzki[3]

[1]Oak Ridge National Laboratory. National Transportation Research Center, 2360 Cherahala Blvd, Knoxville, TN 37932. ous1@ornl.gov.

[2](corresponding author) Oak Ridge National Laboratory. National Transportation Research Center, 2360 Cherahala Blvd, Knoxville, TN 37932. linz@ornl.gov

[3]Aramco Services Company: Aramco Research Center – Detroit, 46535 Peary Ct, Novi, MI 48377 USA. Email address: xin.he@aramcoamericas.com (X. He), jessey.bouchard@aramcoamericas.com (J. Bouchard), steven.przesmitzki@aramcoamericas.com (S. Przesmitzki).

[4] China Automotive Technology and Research Center, Dongli District, Tianjin, 300300, China. yurujie@catarc.ac.cn

Summary

China is well known for its ambition on large-scale vehicle electrification which currently is mainly driven by fuel economy and electric vehicle policies. This study adopts the New Energy and Oil Consumption Credits (NEOCC) model, a vehicle policy analysis tool developed by the Oak Ridge National Laboratory, to systematically quantify the potential impacts of the "*Passenger Cars Corporate Average Fuel Consumption and New Energy Vehicle Credit Regulation*" which was released in June 2020 for the timeframe 2021-2023, so called dual-credit policy (2021-2023). It is found that, under the dual-credit policy (2021-2023), the sales of low fuel consumption conventional vehicles will increase faster than they were in 2018-2020, and the share of plug-in electric vehicles (PEVs) could reach 11.4% by 2023 if it keeps the expansion as it was in 2017. Besides, the BEVs with long electric range (such as 400 km) and the plugin hybrid SUVs would be the most popular PEV types.

Keywords: auto industry, electric vehicle, policy, market, modelling

---

1 Introduction

The world is experiencing a revolution on transportation electrification, and the sales of plug-in electric vehicles (PEVs) have been explosively growing since 2010 [1]. As far as 2018, the global stock of plug-in electric passenger vehicles has been more than 5 million [2]. The share of PEV annual sales in the global vehicle market has reached 2.5% in 2019, an increase from the 2.2% market share in 2018 [3]. In fact, the development of the PEV market is largely contributed by China - around 45% of PEV passenger vehicles on the road in 2018 were in China [2]. However, it is not always easy in the pathway of PEV development in China. The vehicle market in China had experienced downturns for two successive years (2018 - 2019), and this gloomy atmosphere also explicitly spread to its PEV sales. In 2019, the PEV sales in China were just over 1.2 million [3], which dropped about 4% off from 1.25 million of PEV sales in 2018 [4]. In 2020, the COVID-19 pandemic and its social and economic impacts also brought new challenges to the development of Chinese vehicle market [5]. Therefore, the market dynamics of the electric vehicle market development in China is of great concerns to the stakeholders from industry, policymakers, and academics.

Considering the potential advantages of the PEV in fuel-efficiency and greenhouse gas emissions, the Chinese government deems PEV as a critical technological revolution in the future mobility choices [6], and the policy orientation is regarded as a significant impetus on PEV development in China [1]. The Chinese policies started with a strong demand-pull strategy on the consumer side by directly monetarily subsidizing the PEV sales (including subsidies from both central government and local government), or non-monetary incentives such as license plate privilege for PEVs, urban free parking, free charging pile installation etc. Though criticized that it could distort the market demand and magnify local protectionism [1], these incentives motivated the sales of PEVs and enlarged the PEV user community in the early stage of PEV market development. For example, the most powerful non-monetary incentive for PEV purchase is a special priority given for vehicle registration and license plate - PEV license plate privilege, and the estimated value of this policy was about $13,060 USD quantified by Ou et al. 2019 [6]. This value is equivalent to half of the vehicle's average price in China [6]. According to the report by Ren et al. 2019, nearly half of the PEVs were purchased by the consumers who live in the regions with policy on PEV license plate privilege, as shown in Figure 1 [4].
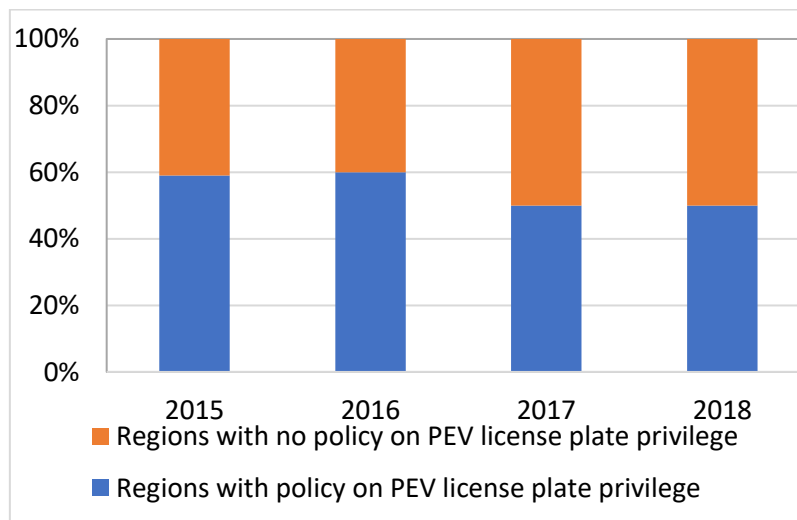
Figure 1: Shares of PEVs from the regions with or without policy on PEV license plate privilege [4]

However, the demand-push brings extra financial burdens to the governments and also causes some problems on subsidy cheating [1]. Therefore, the Chinese government intends to transition the PEV support in a more supply-push approach, indicated by the reduction of purchase subsidies, the enforcement of restrictions on corporate average fuel consumption (CAFC) rate, and the implementation of PEV quota policy. In 2017, the Chinese government issued a policy named as Measures for *Passenger Cars Corporate Average Fuel*

Consumption and New Energy Vehicle Credit Regulation (dual-credit policy) for year 2018-2020 to enforce the auto industry to improve the fuel economy of their vehicle products, and more importantly, to divert the auto industry to an electrification path. This policy does not only lessen the financial pressures of direct subsidies, but also avoids the controversial regional protectionisms blamed by stakeholders. Meanwhile, the government could divert its resources to investing in public charging infrastructure.

Currently adopted only in the passenger vehicles, the dual credit policy consists of two sections: CAFC credit rules, and new energy vehicle (NEV) credit rules. Similar to the U.S. Corporate Average Fuel Economy Standards, the CAFC credit rules require the weighted average fuel consumption of vehicles produced or imported by auto companies should be no larger than the required CAFC calculated by the Chinese vehicle fuel economy standards. Auto companies are allowed to accumulate their positive CAFC credits and to use them for the CAFC deficits in other years. Furthermore, similar to the Zero-emission Vehicle Mandate in California, the NEV credit rules require that the ratio of the PEV numbers to the conventional vehicle numbers from auto companies must be no smaller than a quota. The auto companies can accumulate positive NEV credits and use them for trading or filling the deficits of their CAFC credits.

In June 2020, the Chinese government issued a new official version of *Measures for Passenger Cars Corporate Average Fuel Consumption and New Energy Vehicle Credit Regulation* (a new version of dual-credit policy) for year 2021-2023 to replace the old version [7]. The new version of dual-credit policy is called dual-credit policy (2021-2023) in this study. This vehicle policy formulates the new fuel consumption targets and electric vehicle quotas for the Chinese auto industry in years from 2021 to 2023. This policy is believed to continue to strongly impact the future trends of the vehicle market and the strategies of transportation energy in China [8]. Therefore, it is essential to quantitatively recognize its effects on the market and energy trends in China. This study adopts the New Energy and Oil Consumption Credits (NEOCC) model, a vehicle policy analysis tool developed by the Oak Ridge National Laboratory, to quantify the policy impacts on the electric vehicle market in China and to project the future trends of market dynamics through 2023.

This paper consists of four sections. Section 1 presents research motivations and objectives, and generally introduces the current Chinese PEV market. Section 2 describes the modeling assumptions and modeling approach for the analysis of impacts of the vehicle policies in 2021-2023. Section 3 presents scenario analyses and gives the market share projection through 2023 under the impacts of dual-credit policy (2021-2023). The final section summarizes the conclusions and the future work. In this study, the exchange rate of $1.00 USD is 6.91 CNY (a yearly currency exchange rate in 2019) [9].

2   Data and Model

The vehicle market data for calibrated the NEOCC model is supplied by the China Automotive Research and Technology Center (CATARC), and the data is the aggregated information on the different vehicle technologies with respect to their annual sales, sales-weighted vehicle prices, sales-weighted fuel economy, sales-weighted electricity consumption etc in 2016-2019. Besides, the official version of the dual credit policy (2021-2023) was released in June 2020, and it can be downloaded through the website by China's Ministry of Industry and Information Technology [7]. The NEOCC model was firstly released in 2017 and has been improved and integrated with various functions and features in following versions based on user feedback [10]. This model, developed by the Oak Ridge National Laboratory, is an optimization model used to capture the dynamics changes of the vehicle market with comprehensively quantifying the consumer travel patterns, vehicle production costs, and the government incentives and policy constraints [11]. Figure 2 shows the interface of the 2020 model version.

Vehicle Policy Scenario	Dual-credit Polic	Batch Output	No		BEV FC?	No	PEF	4.094572	11.294118

Year (If calib, Year must be calib year): 2019

Start · Record · Smooth Check · Quick Run · Quick Smooth

CAFC Target (L/100km)	7.11
Veh Total Sales (1,000)	20,544.624
CAFC Target Multiplier	121%
CAFC Achieved (L/100km)	6.31
Industry CAFC credits	16,558,972.06
Non-transferrable Positive CAFC cred	4,356,655
Non-transferrable Negative CAFCs	(5,198,804)
NEV Target %	10%
NEV Target (1000)	1,968.22
NEV Achieved (1000)	3,506.75
NEV Credits	1,538,538
NEV Credits surplus	1,538,538
CAFC/NEV credit conv	1
CAFC credits w/ NEV	18,097,510
Net Internal Subsidy from OEM (¥)	-
NEV Credits price (¥)	-
Profit (¥)	########

Iterations · Wins · Optmization Diff

#	Makes & Models	Vehicle Product	Total Sales (1000)	Sales-weighted Weight (kg)	FC Target (L/100km)	Elec Range (km)	FC Achieved (L/100km)	CAFC Multiplier	NEV credit	US MPG	Battey Size (kWh)	Production Cost ($)	Production Cost (¥)
1		ICE-Hig	2,810.372	1357	5.64	0	8.19	1.0	0.00	29	0	14,990	103,581
2		ICE-Avg	6,551.233	1357	5.64	0	5.82	1.0	0.00	40	0	15,977	110,404
3		ICE-Low	216.995	1357	5.64	0	4.66	1.0	0.00	50	0	17,862	123,426
4		PHEV50	96.919	1625	6.08	60	1.49	3.0	2.00	158	14	22,768	157,330
5	Sedan	PHEV80	10.142	1764	6.30	83	1.04	3.0	2.00	226	19	24,070	166,325
6		BEV150	0.902	966	4.75	153	0.00	3.0	2.64	0	16	12,543	86,671
7		BEV200	11.561	1096	5.20	203	0.00	3.0	3.88	0	22	14,179	97,976
8		BEV250	53.900	1319	5.42	254	0.00	3.0	4.62	0	28	15,815	109,281
9		BEV300	128.516	1400	5.64	307	0.00	3.0	5.00	0	36	17,996	124,354
10		BEV400	290.410	1603	6.08	414	0.00	3.0	5.00	0	57	23,722	163,921
11		ICE-Hig	2,135.187	1621	6.08	0	9.66	1.0	0.00	24	0	16,262	112,372
12	SUV	ICE-Avg	7,890.286	1621	6.08	0	7.22	1.0	0.00	33	0	16,862	116,517
13	Crossover	ICE-Low	78.081	1621	6.08	0	5.65	1.0	0.00	42	0	17,869	123,475
14	MPV	PHEV	85.657	2016	7.08	71	1.65	3.0	2.00	143	16	25,157	173,833
15		BEV250	2.391	1620	6.08	263	0.00	3.0	1.98	0	40	23,451	162,046
16		BEV350	182.073	1854	6.52	365	0.00	3.0	5.00	0	60	28,904	199,729

Calibration

Year 2019

	Total sales market				Personal vehicle market				Fleet vehicle market			
	History	Error	Std. Error	Calculated	History	Error	Std. Error	Calculated	History	Error	Std. Error	Calculated
Total sales of sedans	10,170,949				9,035,891	1.65E-06	0	9,035,891	1,135,058	7.74E-03	0	1,135,058
Total sales of SUVs	10,373,675				9,445,608	1.65E-06	0	9,445,608	928,067	7.74E-03	0	928,067
Total sales of sedan hybrid	216,995				181,737	1.30E-09	0	181,737	35,258	3.34E-05	0	35,258
Total sales of SUV hybrid	78,081				67,850	7.17E-08	0	67,850	10,231	1.71E-06	0	10,231
Total sales of sedan PHEVs	107,061				77,127	4.87E-03	0	77,127	29,934	1.90E-04	0	29,934
Total sales of sedan BEV150s	902				470	1.63E-14	0	470	432	3.71E-04	0	432
Total sales of sedan BEV200s	11,561				5,582	1.17E-13	0	5,582	5,979	8.32E-05	0	5,979
Total sales of sedan BEV250s	53,900				43,798	6.84E-12	0	43,798	10,102	2.20E-04	0	10,102
Total sales of sedan BEV300s	128,516				92,740	3.03E-11	0	92,740	35,776	2.36E-03	0	35,776
Total sales of sedan BEV400s	290,410				110,612	4.37E-11	0	110,612	179,798	5.72E-02	0	179,798
Total sales of SUV PHEVs	85,657				73,423	3.43E-07	0	73,423	12,234	5.54E-07	0	12,234
Total sales of SUV BEV250s	2,391				480	3.41E-07	0	480	1,911	3.42E-08	0	1,911
Total sales of SUV BEV350s	182,073				123,788	3.45E-07	0	123,788	58,285	2.73E-05	0	58,285
Total sales of sedan PHEV50s	96,919				68,635	9.53E-03	0	68,635	28,284	3.17E-04	0	28,284
Total sales of sedan PHEV80s	10,142				8,492	7.76E-04	0	8,492	1,650	9.99E-04	0	1,650
Sed new average FC (L/100km)	6.487	3.00E-17	0.000	6.487								
SUV new average FC (L/100km)	7.722	7.69E-21	0.000	7.722								
Sed ICEV average MSRP ($)	23,595.58	8.81E-06	0.003	23,595.58								
SUV ICEV average MSRP ($)	25,114.59	5.72E-07	0.001	25,114.59								
Other cost calib sedan-ExpUSum (personal)					0.007286498				4.818E-14			

FC Achieved Calibration · Sed Prod Cst Calibration · SUV Prod Cst Calibration · Other Cst Calibration(no PHEV, personal vehicles) · Other Cst Calibration (PHEV, personal vehicles) · Other Cst Calibration(no PHEV, fleet vehicles) · Other Cst Calibration (PHEV, fleet vehicles)
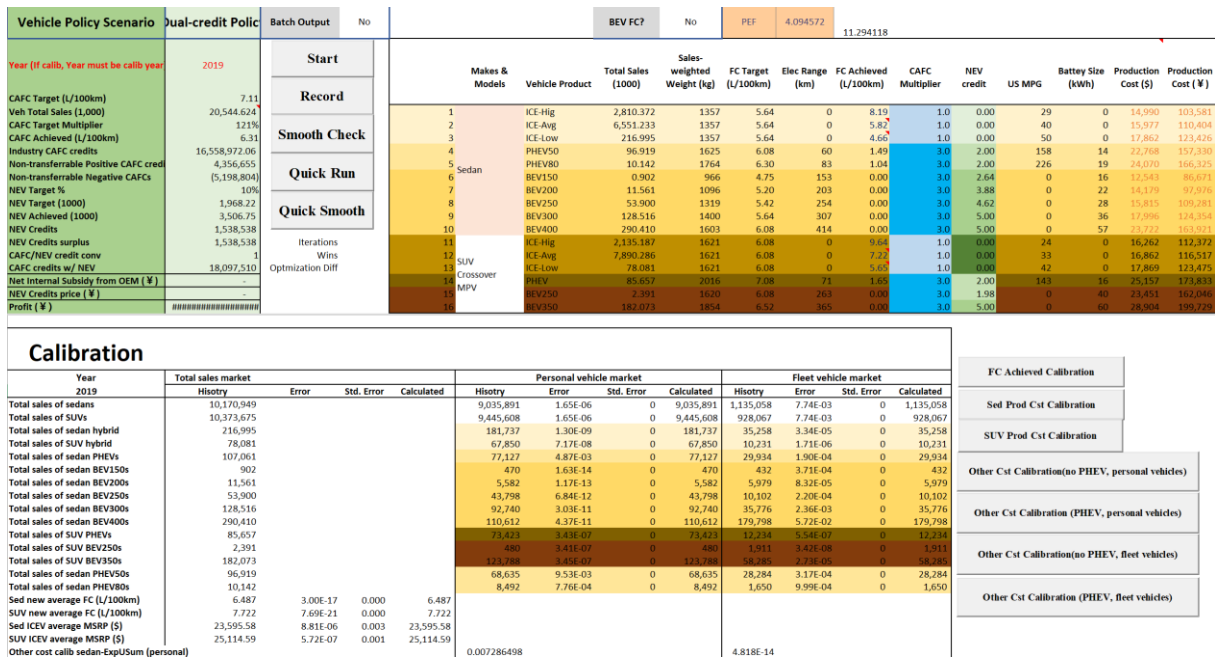
Figure 2: Interface of NEOCC model (2020 version)

The NEOCC model considers the market dynamics among the consumers, government and auto industry. It assumes that the auto industry would maximize its industry profit through selling different types of vehicles to meet the demands of the consumers with respect to the vehicle price, travel patterns, charging infrastructure, fuel cost and so on. The industry constantly adjusts its internal subsidies for different vehicle technologies until it is believed that the total profit reaches the largest one. This model integrates the optimization methodology (genetic algorithm) for seeking the maximum profits with the discrete choice modelling on allocating the market share of vehicles to the consumers based on their utilities [10].

The market shares of 16 different vehicle powertrain technologies (e.g. internal combustion engine (ICE) vehicle, plug-in hybrid electric vehicle (PHEV), battery electric vehicle (BEV)) are calculated through the nested logit function (discrete choice modelling). Besides, the purchase and travel patterns of two consumer types are considered: personal vehicle drivers and public fleet drivers. The probabilities of consumers choosing a particular vehicle type depends on the value of the total ownership cost for each type of vehicle. The total cost of vehicle ownership is calculated and based on the travel patterns, incomes (value of time) and personal preferences of consumers, etc [10], [11]. For example, the NEOCC model quantifies the costs of vehicle ownership impacted by the charging activities and distributions of electric infrastructure. For a BEV owned by a personal consumer, the total cost of vehicle ownership impacted by charging related activities are estimated through estimating three different perceived costs: the electricity charging costs (at home, at public charging stations, and at workplace), the charging inconvenience cost, and the range anxiety cost [10]. Besides, this total cost of vehicle ownership impacted by charging related activities varies depending on whether the consumer owns a dedicated residential parking spot or not [12]. Figure 3 reveals the costs of BEV ownership impacted by charging activities by 2023 under the constraints of dual-credit policy (2021-2023). We can see that, by 2023, the sedan BEVs with electric range at 400 km have the lowest cost of ownership related to the charging activities. In addition, owning a dedicated residential parking could largely decrease the ownership cost on charging activities by 40-50%, although owning a dedicated residential parking is high-cost spending.
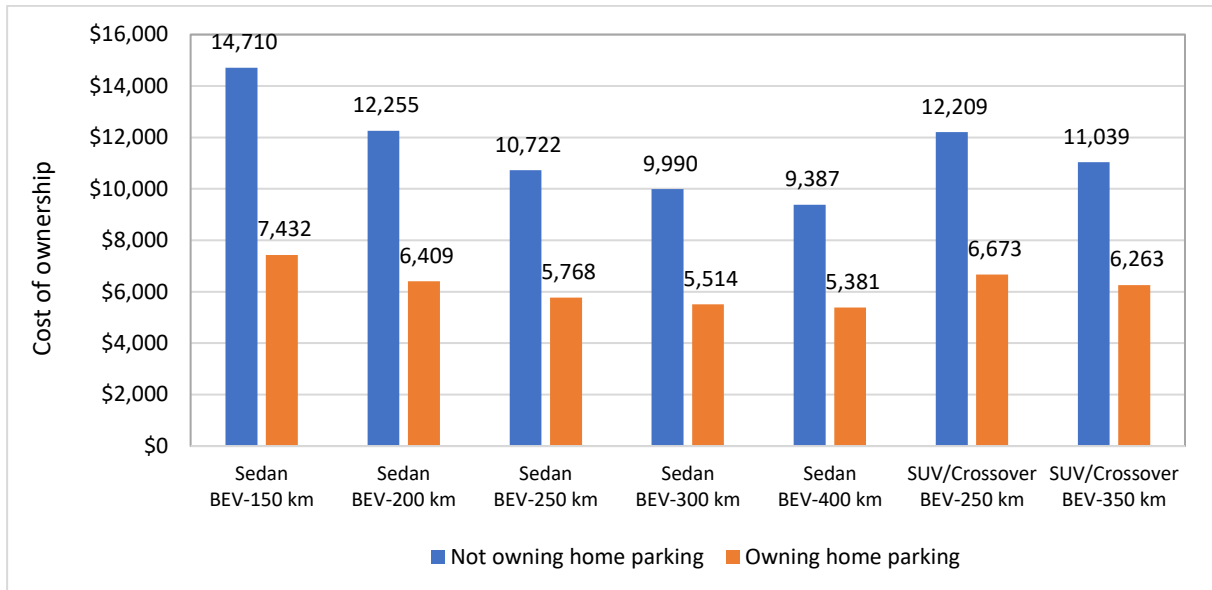
Figure 3: Comparisons on costs of BEV ownership (personal owned) impacted by charging activities by 2023

3 Results and Discussions

3.1 Policy comparisons

This study aims to quantify the possible impacts of dual-credit policy (2021-2023) on the vehicle market in China by comparing the market dynamics under different vehicle policies. Four different policy scenarios are simulated in the NEOCC model, the definitions of these scenarios are described below:

- New dual-credit policy scenario: this scenario assumes that the vehicle market is constrained by the dual-credit policy (2021-2023).

- Dual-credit policy with old NEV-rules scenario: this scenario assumes that the vehicle market in 2021-2023 is still continuously constrained by the NEV credit rules and methods adopted in the dual-credit policy used for 2018-2020. However, the quota targets on PEV share in 2021-2023 are updated to 14%, 16%, and 18% respectively, and all other rules in this scenario are the same as they are in the new dual-credit policy for 2021-2023. So, the rule changes (such as the incentives on the low fuel consumption conventional vehicles) can be better compared and reflected in the simulate results.

- CAFC-only policy scenario: this scenario assumes that the vehicle market is constrained by the Corporate Average Fuel Consumption rules in the dual credit policy phase (2021-2023). In this scenario, the fuel consumption of vehicles instead of the PEV quota is the only factor that impacts the industry market strategy.

- No rules scenario: this scenario assumes that the vehicle market is constrained to no vehicle policies during 2021 and 2023.

Figure 4 presents the market shares of PEVs and high fuel-efficient ICE vehicles under these four policy scenarios. Three types of vehicle are discussed: BEV, PHEV, and ICE vehicle with low fuel consumption (ICE-Low FC). The ICE-Low FC refers to high fuel-efficient ICE vehicles like pure hybrid vehicles in this study.
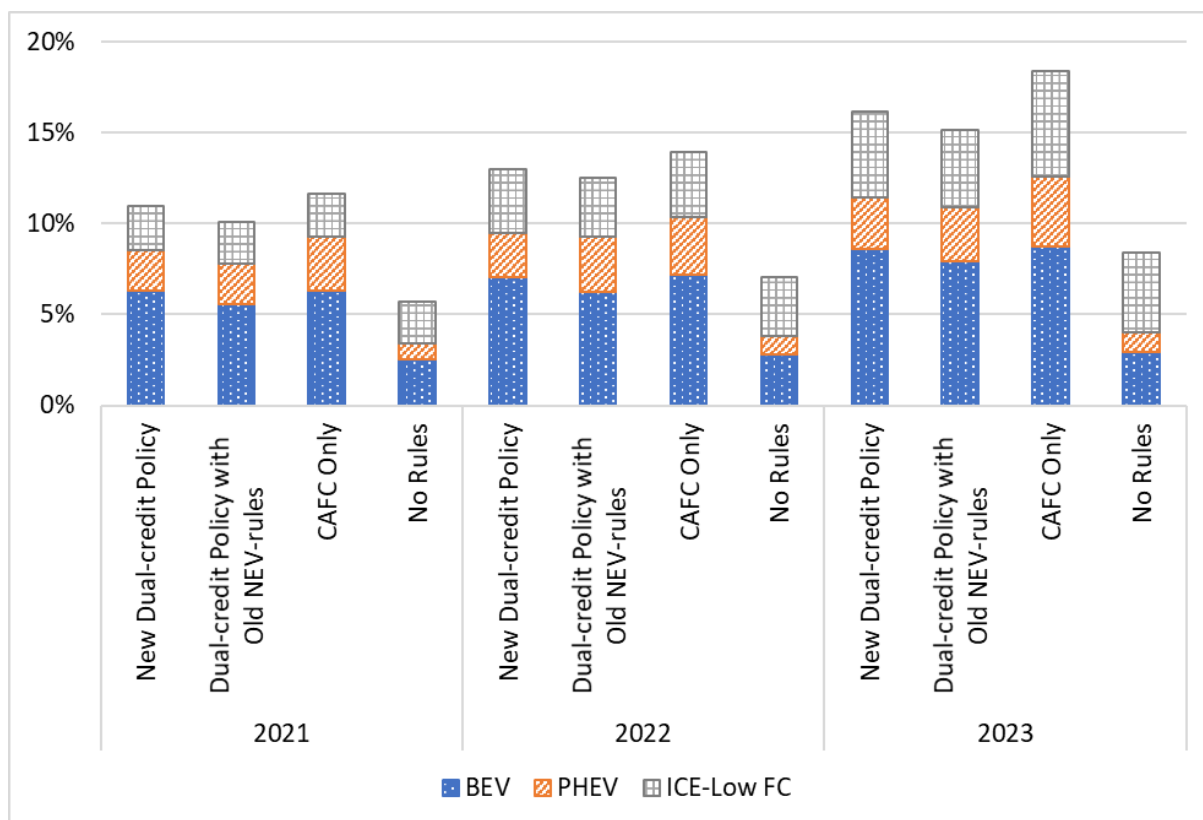
Figure 4: Market shares of vehicle powertrain technologies under different vehicle policies

As shown in Figure 4, the market shares of PEVs with the policy constraints are obviously more than the market share of PEVs under the no rules scenario. Comparing to the dual-credit policy (2018-2020), two major types of adjustments in the dual-credit policy (2021-2023) are changed: (a) the dual-credit policy (2021-2023) more emphasizes the energy efficiency of BEVs, the electricity consumption for a certain driving range (kW/100 km) and the battery's energy capacity (kWh/kg) become more critical performance indicators to determine the value of NEV credit that each BEV can obtain; (b) unlike the dual-credit policy (2018-2020), the dual-credit policy (2021-2023) also encourages the high fuel-efficient ICE vehicles. Therefore, because of more incentives on the ICE-Low FC vehicles by the dual-credit policy phase 2 (2021-2023), the market share of ICE-Low FC vehicles (for example, 4.7% in 2023) in the new dual-credit policy scenario becomes larger than it (for example, 4.2% in 2023) in the dual-credit policy with old NEV-rules scenario. Meanwhile, with the slight changes in policy, the market share of BEVs with long electric range in the new dual-credit policy scenario becomes more than it in the dual-credit policy with old NEV-rules scenario. For example, in 2023, the sedan BEVs at 300 and 400 km take more than 82% of total PEVs in the new dual-credit policy scenario, while it just reaches 80% in the dual-credit policy with old NEV-rules scenario.

It is also clearly shown that, with more strict requirements, the ratio of PEVs in the passenger vehicle market in the new dual-credit policy scenario increases more than it is in the dual-credit policy with old NEV-rules scenario in 2021-2023, as shown in Figure 4. For example, comparing the PEV share under the dual-credit policy with old NEV-rules scenario, the PEV share under the new dual-credit policy scenario increases by 0.5% in 2023. However, the total PEV share (11.4% in 2023) in the new dual-credit policy scenario is smaller than it (12.6% in 2023) is in the CAFC only scenario. This is because the CAFC rules could incentivize the production of more PHEVs, which can be helpful for further reducing the industrial CAFC.

3.2 PEV Market Projection

The NEOCC can also reveal the possible PEV shares by powertrain technologies under the dual-credit policy (2021-2023). Figure 5 shows the market share of PEV sales in 2023. Totally, the PEV sales could reach about 11.4% by year 2023 if the sales continuously grow up as what the market did in 2017. Considering the downturn in the vehicle market in 2018-2019 and negative impacts of COVID-19 pandemic, the projection could be harder to achieve. At the same time, it shows that nearly 69% of PEVs will be sedans. Among these sedans, the BEVs are still much more popular than the PHEVs. The BEVs with longer electric range (more than 300 km) are especially welcomed. This might be because the cost related to charging activities (BEV-300 km and BEV-400 km is better at saving this cost, as shown in Figure 3) takes much in the total cost of ownership on the PEVs, and both the dual-credit policy (2021-2023) and the government subsidies more clearly favour the BEVs with longer electric range [6]. However, on the other hand, it is found that 99% of the daily driving distances of a personal owned vehicle in China is no more than 88.0 to 112.0 km, which means that BEV-150 km could still meet most daily needs of personal vehicle drivers if the electric range anxiety is not considered [13]. Thus, while BEVs with long electric range could be used by the public-fleet drivers (such as taxis, or shared mobility), the BEVs with short electric range can still have their reasonable market space for the personal vehicle drivers. For example, the GM and SAIC's Wuling released a car model – Hong Guang Mini EV with electric range at 120 km or 170 km, which does not target on the government subsidies but aims to meet the driver's basic travel patterns and the potential low-income buyers who are more sensitive to vehicle price [14]. In the SUV/crossover segment, the PHEVs and the BEVs with longer electric range are more popular. This is might because the SUV/crossover keeps more welcomed in the current market, and people who want to buy an SUV/crossover are less sensitive to the vehicle price while having larger range anxiety.
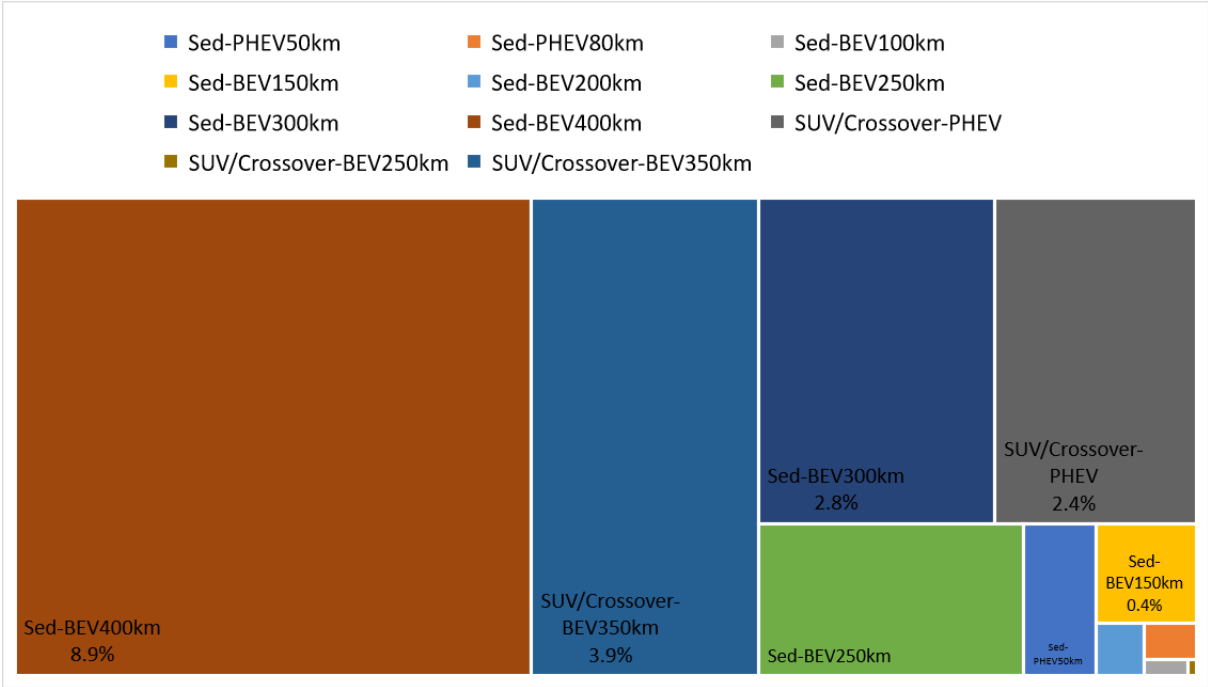

Figure 5: Market shares of PEVs in year 2023 under the dual-credit policy (2021-2023)

4 Conclusions

By adopting the vehicle policy analysis tool – NEOCC model, this study quantified the impacts of the dual-credit policy for 2021-2023 (official version released in June 2020) on the vehicle market in China. Policy scenarios are compared and market dynamics by 2023 are projected. Major findings are concluded based on the simulation results by the NEOCC model:

a) The cost of vehicle ownership impacted by the charging activities is least for BEVs with electric range at 400 km;

b) Owning a dedicated residential parking spot can largely reduce the cost related to charging activities;

c) Compared to the dual-credit policy (2018-2020), the dual-credit policy (2021-2023) can contribute more sales of high fuel-efficient vehicles in the market. For example, comparing with the dual-credit policy with old NEV-rules scenario, the ICE-Low FC will increase by 0.51% in 2023 with dual-credit policy (2021-2023);

d) Under the constraints with the dual-credit policy for 2021-2023, the share of PEVs in the passenger vehicle market can reach about 11.4% by 2023.;

e) The dual-credit policy (2021-2023) can indeed incentivize more PEVs than the dual-credit policy with old NEV-rules. For example, compared to the dual-credit policy with old NEV-rules scenario, the PEV market share will increase by 0.5% in 2023 under the dual-credit policy (2021-2023).

f) The BEVs with longer electric range (such as sedan BEV with electric range at 400 km) would be most popular during 2021-2023.

g) Although the sedan BEVs with electric range at 150 km have also met most travel demands of personal vehicle drivers, the BEVs with short electric range are less favourable by the dual-credit policy for 2021-2023 and the government subsidies.

h) The PHEVs in the SUV segment would be one of the most popular vehicle types in the investigated PEVs in this study.

It is worthy to note that these conclusions mentioned above are based on the premise that PEV sales will continuously grow up as it did in 2016-2019. Considering that the vehicle market experienced a severe downturn during 2018 and 2019 and the uncertainties brought by the COVID-19 pandemic, we believe it is still an open question for researchers whether the electrification transition will continuously expand in this rapidly developing market. However, it is still meaningful to draw a general picture for the public, specifically for policymakers, to understand the possible future trend of the electric vehicle market in China under the dual-credit policy (2021-2023) – one of the most significant vehicle policies in recent years.

The contribution of this study is to create a framework and to discuss the potential impacts of vehicle policy, specifically the dual-credit policy (2021-2023) on the vehicle market through utilizing the quantitative modelling tool. Currently, some assumptions such as the projections of the fuel economy and battery cost are based on review on recent literature; and some calculations are simplified for the data analysis. The market data needs close follow-ups and revisions as more is learnt. The analysis and the NEOCC model will be continuously updated and improved.

Acknowledgments

References

[1] S. Ou *et al.*, "A Study of China's Explosive Growth in the Plug-in Electric Vehicle Market," Knoxville TN, 2017.

[2] IEA, "Global EV Outlook 2019," Paris France, 2019.

[3] H. Maximilian, "Fossil Vehicle Sales In Global Freefall — Down 4.7% In 2019! Electric Vehicle Sales Continue To Grow — CleanTechnica Report," *Clean Technica*, 2020. [Online]. Available: https://cleantechnica.com/2020/01/18/fossil-vehicle-sales-in-global-freefall-down-4-7-in-2019-electric-vehicle-sales-continue-to-grow/. [Accessed: 17-Mar-2020].

[4] Z. Ren, Y. Lian, and S. Guo, "China's New Energy Vehicle Development Report: 2019," Beijing China, 2019.

[5] P. He and Z. Huang, "How China is strengthening its electric vehicle market during the pandemic," *World Economic Forum*, 2020. [Online]. Available: https://www.weforum.org/agenda/2020/05/how-china-is-strengthening-its-electric-vehicle-market-during-the-pandemic/. [Accessed: 30-Jun-2020].

[6] S. Ou *et al.*, "Light-duty plug-in electric vehicles in China: An overview on the market and its comparisons to the United States," *Renew. Sustain. Energy Rev.*, vol. 112, pp. 747–761, 2019.

[7] MIIT, "Measures for Passenger Cars Corporate Average Fuel Consumption and New Energy Vehicle Credit Regulation (in Chinese)," *Division of Industrial Policy and Regulation of MIIT*, 2020. [Online]. Available: http://miit.gov.cn/n1146295/n1652858/n7280902/c7988463/content.html. [Accessed: 29-Jun-2020].

[8] C. Randall, "China to increase NEV quota moderately from 2021," *Electrive.com*, 2019. [Online]. Available: https://www.electrive.com/2019/07/11/china-is-moderately-increasing-the-nev-quota-in-2021/. [Accessed: 19-Mar-2020].

[9] U.S. Internal Revenue Service, "Yearly Average Currency Exchange Rates," 2019. [Online]. Available: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates. [Accessed: 29-Jun-2020].

[10] S. Ou, Z. Lin, X. He, S. Przesmitzki, and J. Bouchard, "Modeling charging infrastructure impact on the electric vehicle market in China," *Transp. Res. Part D Transp. Environ.*, vol. 81, p. 102248, 2020.

[11] S. Ou, Z. Lin, L. Qi, J. Li, X. He, and S. Przesmitzki, "The dual-credit policy: Quantifying the policy impact on plug-in electric vehicle sales and industry profits in China," *Energy Policy*, vol. 121, pp. 597–610, 2018.

[12] S. Ou, Z. Lin, X. He, and S. Przesmitzki, "Estimation of vehicle home parking availability in China and quantification of its potential impacts on plug-in electric vehicle ownership cost," *Transp. Policy*, vol. 68, pp. 107–117, 2018.

[13] S. Ou *et al.*, "Intensity and daily pattern of passenger vehicle use by region and class in China: estimation and implications for energy use and electrification," *Mitig. Adapt. Strateg. Glob. Chang.*, 2019.

[14] J. Yao, "Can Hong Guang Mini EV Be Popular? (in Chinese)," *D1 EV Website*, 2020. .

Authors

Dr. Shiqi Ou is a R&D research staff member from the Transportation Analytics & Decision Science Group of the Energy and Transportation Science Division at Oak Ridge National Laboratory. His research mainly focuses on quantifying the energy market dynamics and risk through stochastic modelling and optimization, technological innovation and diffusion in the energy market and auto industry, and he is also interested in quantitatively addressing the policy implications of energy supply and use from their economic, social and environmental aspects. He is also a CFA charterholder and serves as a member in the TRB transportation energy committee. He has authored nearly 20 journal and conference papers, book chapters, and technical reports by 2020.

Dr. Zhenhong Lin is a senior R&D staff member at National Transportation Research Center of Oak Ridge National Laboratory and joint Associate Professor of University of Tennessee, Industrial & Systems Engineering. As PI and manager of the Transportation Energy Evolution Modeling (TEEM) program, he is interested in analyzing technologies, strategies and policies that can transform the transportation energy system for societal objectives. Lin is a member of the Alternative Fuels Committee of the Transportation Research Board, and is serving on the U.S. National Academies of Sciences, Engineering, and Medicine, Committee on the Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles.

Dr. Xin He is a Fuels Technical Specialist at Aramco Americas. He obtained his Ph.D. in Mechanical Engineering from the University of Michigan, and B.S and M.S degrees from Tsinghua University (China). Previously, he worked for General Motors Corporation, National Renewable Energy Laboratory, and Tsinghua University on fuels and engine combustion research. At Aramco, he works on analyzing transportation technical trends, market prediction, fleet modeling, and life-cycle analysis. He also works on novel engine and combustion techniques to better utilize petroleum fuels achieving higher efficiency and lower pollutant emissions.

Mr. Rujie Yu is the Senior Technical Manager of Automotive Data Center, China Automotive Technology & Research Center, and visiting scholar in Argonne National Laboratory (ANL). His working area and interests are in China automotive energy, vehicle fleet fuel economy trend, new energy vehicle policy and vehicle fuel economy policy. He participates in several research projects commissioned by the United Nations Industrial Development Organization (UNIDO), Energy Foundation, Ministry of Industry and Information Technology (MIIT), etc. He is one of the main authors of the Annual Report on Energy-Saving and New Energy Vehicles in China. His research results have provided support for the policymaking of the automotive industry authorities.

Mr. Jessey Bouchard has over 20 years of automotive experience at automotive original equipment manufacturers and 5 years at Aramco's R&D in engineering, business, advanced manufacturing, and research roles. Leadership positions included Worldwide Head of Powertrain Cost Reduction, Assistant Chief Engineer of an SAE innovation of the year 8-speed transmission and Chief of Staff for the Strategic Transport Analysis Team.
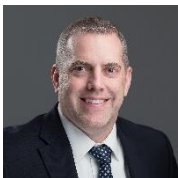
Dr. Steve Przesmitzki is currently the head of Strategic Transport Analysis and Outlooks at the Aramco Research Center – Detroit. Steve has worked at Aramco since April 2014. Steve was previously a Technology Development Manager within the United States Department of Energy's Vehicle Technologies Program from 2009-2014. At DOE, Steve supported the development of energy policy and management of research programs as applied to fuels and lubricants in transportation. Steve holds a PhD from the Massachusetts Institute of Technology, a MS from the University of Michigan, and a BS from Kettering University; all in Mechanical Engineering.