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Comparative Study on Life Cycle CO_2 Emissions from the Production of Electric and Conventional Vehicles in China

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Abstract

Electric Vehicles (EVs), as expected to help save energy and reduce CO_2 emissions, are facing a rapid growth in China, the country with approximately one quarter of global vehicle production. However, the ability of EVs is estimated mainly on the basis of use phase, which is not complete enough. Aiming to identify the real ability of EVs in China, this study estimates the CO_2 emissions from production phase and compares the results with the level of Internal Combustion Engine Vehicles (ICEVs), the current dominating vehicles in China. The results reveal that the CO_2 emissions from the production of an EV range from 14.6 to 14.7 t, 59% to 60% higher than the level of an ICEV, 9.2 t. The Li-ion batteries and additional components such as the traction motor and electronic controller in an EV are the major reasons, while different curb weights and different composition between these two vehicles contribute as well. As the manufacture techniques of Li-ion batteries are growing and the material recycle industry is developing, huge reduction potential of CO_2 emissions from EVs exists in China.

Keywords: vehicle production; Li-ion battery; life cycle assessment; comparative study

1. Introduction

As expected to save energy and slow down the climate change all over the world, Electric Vehicles (EVs) are growing rapidly now and in the future, especially in China. According to Chinese government, the cumulative output of EVs will reach 5 million in 2020, which is over 10 times larger than the number in 2015[1]. This pattern forecasts a significant change of life cycle CO_2 emissions related to vehicles[2], including material production, components manufacturing, assembly, using, disposal, recycling, etc.

Many scholars have carried out researches focusing on the life cycle emissions from different vehicles. Samaras provided a full Life Cycle Inventory (LCI) of EV production based primarily on energy

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consumption[3]. Lewis assessed the reduction potential of life cycle emissions through vehicle electrification mainly based on the use phase[4]. Oris compared the emissions related to well-to-wheels energy consumption of different vehicles in different regions, including China[5]. And Daimler AG carried out a Life Cycle Assessment (LCA) of its S400 car, providing a comparative result of two different versions (hybrid and conventional)[6].

Many studies pointed out that the emissions from the use phase accounted for the majority. However, as CO_2 emissions from the production of an Internal Combustion Engine Vehicle (ICEV) contributed about 10% to the full life cycle CO_2 emissions, the vehicle production phase is not insignificant[7]. Actually, with the growth of EVs, CO_2 emissions from vehicle production account for a growing proportion, which has seized much attention all over the world in recent years. This subject is an essential complement to the studies focusing on the use phase and is sure to play a more important role in the future.

On the other hand, CO_2 emissions from vehicle production vary among different regions owing to the discrepancies in manufacture techniques. Although existing studies have provided several referential results, it is far from completed due to the rapid growing techniques. In order to delve into this subject, this study focuses on the CO_2 emissions from vehicle production in China, the country with approximately one quarter of global vehicle production[8]. For this purpose, this study employs a life cycle framework of vehicle production, in which the energy consumption of all the processes is taken into consideration.

Nomenclature

E	CO_2 emissions, kg
EF	emission factor, kg-CO_2/MJ
MM	mass of materials, kg
MPF	mass of process fuel, MJ
RP	replacements during life time
Subscripts	
A	assembly
B	batteries
BA	batteries and attachments
BC	basic components
F	fluids
SC	special components
T	total
Ti	tires

2. Method and System

2.1. Assumption and system boundary

This study employs a cradle-to-gate system, including material production and transformation, basic components manufacturing, special components manufacturing, batteries and attachments manufacturing and assembly. As presented in Fig. 1, the replacement of batteries, tires and fluids in the use phase are considered as well. The process fuels used during the vehicle production are normalized with the life cycle CO_2 emissions considered, including extraction, processing and burning. The distribution, use phase and disposal are not included in the system as this study aims to analyze the CO_2 emissions from vehicle production. And the tiny CO_2 emissions caused by materials used in auxiliary, such as limestone, are not considered due to the data availability.

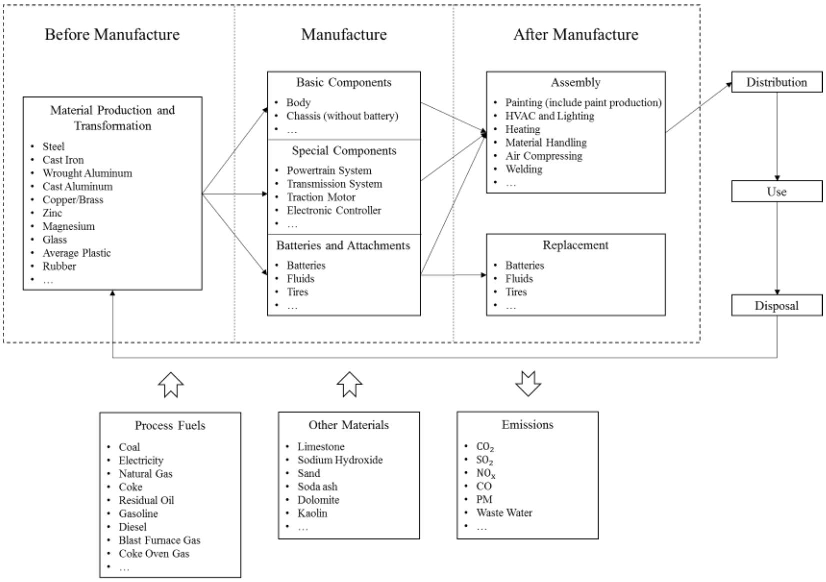

Fig. 1. Vehicle production system and boundary defined

2.2. Vehicle specification

ICEVs and EVs are chosen as the objects in this study as they are the most representative vehicles currently and in the future. In 2015, over 24 million vehicles were produced in China, and only about 380 thousand of them were new energy vehicles. Meanwhile, the growth rate of new energy vehicles, especially EVs, was about 100 times larger than that of ICEVs[9]. In addition, in order to reveal the general situation and ensure comparability, this study takes standard mid-size passenger cars (comparable to B-Class cars in China) with conventional materials as reference vehicles both for EVs and ICEVs.

Since the definition of standard vehicles in China is unclear, this study uses the results from several sources, including the Automotive System Cost Model (ASCM) developed by Oak Ridge National Laboratory[10], which was also adopted in the 2015 Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET-2015)[11], as presented in Appendix A. Table 1.

Furthermore, the specification of batteries, tires and fluids as presented in Appendix A. Table 2. One small lead-acid battery is contained both in an ICEV and an EV, while a large traction battery is contained in an EV additionally. Li-ion batteries are the most widely applied traction battery. For instance, LiFePO4 (LFP) batteries captured about 52% of China's traction battery market in 2015, while $Li(NiCoMn)O_2$ (NCM) batteries accounted for 39%[12]. Therefore this study chooses the LFP and NCM batteries as objects. When it comes to tires, the standard radial tires for mid-size passenger cars are considered both for ICEVs and EVs. Finally, all kinds of fluids used in vehicles are considered, including engine oil, brake fluid transmission fluid, powertrain coolant, windshield fluid and adhesives.

2.3. Methods and data

Equation (1) to (4) describe the life cycle CO_2 emissions from the production phase.

$$E_{BC/SC/B/Ti/F} = RP \cdot \sum MM \cdot \sum MPF \cdot EF \quad (1)$$

$$E_{BA} = E_B + E_{Ti} + E_F \quad (2)$$

$$E_A = \sum MPF \cdot EF \quad (3)$$

$$E_T = E_{BA} + E_A + \sum E_{BC} + \sum E_{SC} \quad (4)$$

Where,

$E_{BC/SC/B/Ti/F}$ is the CO_2 emissions from the production of basic components/special components/batteries/tires/fluids (kg-CO_2 per vehicle);

E_{BA} is the CO_2 emissions from batteries and attachments (kg-CO_2 per vehicle);

E_A is the CO_2 emissions from assembly, for both batteries and vehicle (kg-CO_2 per vehicle);

E_T is the total CO_2 emissions from vehicle production (kg-CO_2 per vehicle).

The emission factors of process fuels and energy consumption of materials and other parts are calculated on the basis of a wide range of sources as presented in Table 1 and Table 2.

Table 1. Life cycle CO_2 emission factors of process fuels

Process fuel	CO_2 emissions factor (*kg-CO_2/MJ, kg-CO_2/kWh*)	Data source
Coal	94.8	[13]
Electricity	834.5	[14], [15]
Natural gas	63.5	[13]
Coke	105.9	[16], [17]
Residual oil	89.3	[13]
Gasoline	82.0	[13]
Diesel	79.9	[13]
Blast furnace gas	260.0	[16]
Coke oven gas	44.4	[16]

Note: Coke, blast furnace gas and coke oven gas are produced during the coke production process included in the steel production.

Table 2. Energy consumption of different materials, batteries, tires and fluids

Material	Data source	Batteries, tires and fluids	Data source
Steel	[18], [19], [20]	LFP battery: active material	[27]
Iron	[18]	LFP battery: other materials	[28]

Cast aluminum	[18], [21]	NCM battery: active material	[27]
Wrought aluminum	[18], [21]	NCM battery: other materials	[28]
Copper/brass	[22], [23]	Tires	[18], [29]
Glass	[24]	Fluids	[11], [23], [25]
Rubber	[25], [26]		
Average plastic	[18], [23], [24]		
Magnesium	[25]		

Note: Most of the energy consumption of the materials and other parts listed above are calculated under the circumstance of China. For instance, as the recycled steel used for steel production only accounts for 11% in China[30], this study mainly considers the virgin steel production in China.

Furthermore, due to the lack of related studies in China, the energy consumption of assembly (including battery and vehicle assembly) is provided by Lu[31], Papasavva[32]-[33] and Sullivan[23].

3. Results

3.1. Overview

Table 3 presents the CO_2 emissions from vehicle production. It is clear that the CO_2 emissions are about 14.6 t per EV with NCM battery, 59% higher than the level of an ICEV, about 9.2 t. And the number is larger for an EV with LFP battery, about 14.7 t, 60% higher than the level of an ICEV.

Table 3. CO_2 emissions from vehicle production

Component		CO_2 emissions per vehicle (kg)		
		ICEV	EV-NCM	EV-LFP
Basic Components	Body: including body-in-white, interior, exterior, and glass	2767.9	4393.5	4393.5
	Chassis (without battery)	1684.7	2665.5	2665.5
Special Components	Powertrain system	2092.5	145.6	145.6
	Transmission system	617.4	455.2	455.2
	Traction motor	/	1179.1	1179.1
	Electronic controller	/	1010.2	1010.2
Batteries and attachments	Lead-acid batteries	24.5	15.1	15.1
	Li-ion batteries	/	2788.8	2892.4
	Fluids	230.2	98.3	98.3
	Tires	677.1	677.1	677.1
Assembly	Lead-acid batteries assembly	14.1	8.7	8.7
	Li-ion Batteries assembly	/	141.5	141.5
	Vehicle assembly	1064.1	1064.1	1064.1
Total		9172.5	14642.5	14746.1

The decomposition of CO_2 emissions from each part is revealed in Fig. 2. It can be found that the CO_2 emissions from Li-ion battery production account for a large proportion in both kinds of EVs, about 19%/20% for an EV with NCM/LFP battery. Meanwhile, more CO_2 emissions are produced from other parts of an EV than the level of an ICEV.

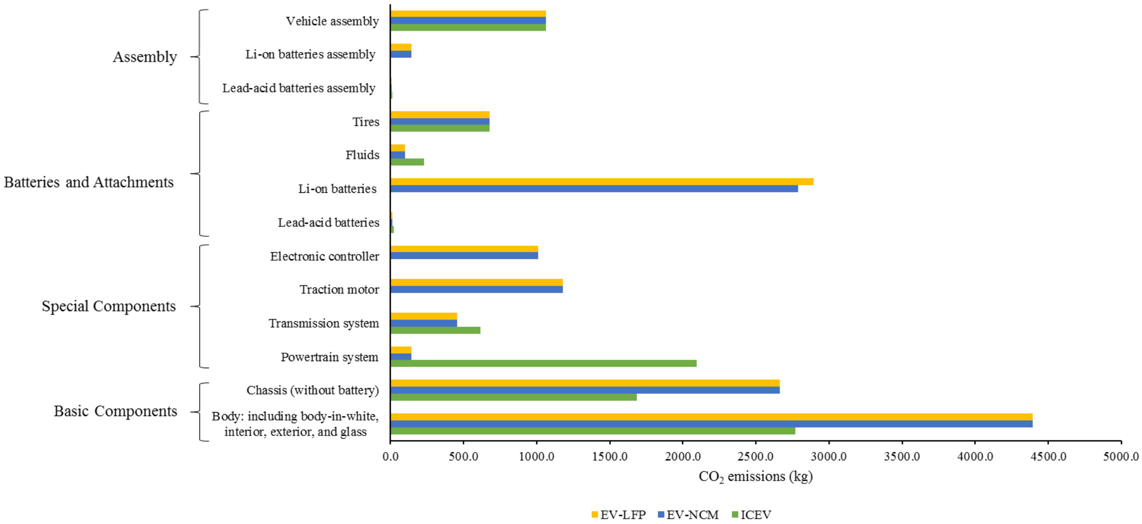

Fig. 2. Decomposition of CO_2 emissions by different parts

3.2. Uncertainty analysis

Li-ion batteries have just been massively applied to EVs in recent years. Therefore few studies focusing on CO_2 emissions from battery production exist and few production standards have been established for battery manufacture in China, which creates uncertainty in this study.

Among the inventory, CO_2 emissions from active material production are the most influential variable for both LFP and NCM batteries. Fig. 3 presents the CO_2 emissions from the production of these two batteries when the variable is multiplied by the uncertainty parameters 0.8, 1.0 and 1.2. The result ranges from 2435.2 to 3142.4 kg-CO_2 per NCM battery and 2596.3 to 3188.5 kg-CO_2 per LFP battery, which is quite wide. Therefore care must be taken when drawing conclusions on the basis of the results.

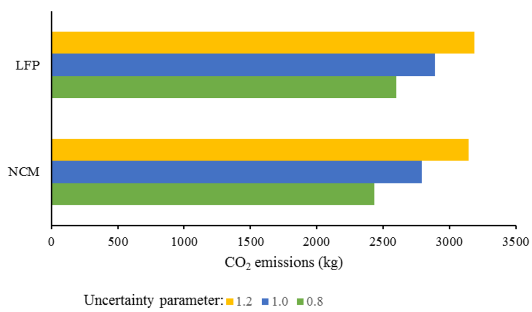

Fig. 3. Uncertainty of CO_2 emissions from battery production

4. Discussions

4.1. Comparative simulation results

Several literature results provided benchmarks of CO_2 emissions from the production of an ICEV and an EV. GREET-2015 used the same vehicle specification as this study, however, it revealed that in the U.S., CO_2 emissions from the production of an ICEV was about 6.4 t and the level of an EV with NCM/LFP battery was about 8.6/8.4 t[11], which is much lower than the level in China. The advanced Li-ion battery production techniques and developed materials recycle industries are the dominated reasons. From another point of view, Hawkins estimated the CO_2 emissions from the production of the Mercedes A-Class ICEV and EV with NCM/LFP battery in Europe based on Ecoinvent v2.2. The results showed that the global warming potential from an EV with NCM/LFP production is about 13/14 t CO_2-eq, which is roughly twice the level of ICEV production, 6.5 t CO_2-eq[7].

In short, results based on different situations vary in a wide range due to the different manufacture techniques, however, they all revealed that EV production caused much more CO_2 emissions.

4.2. Difference analysis

Much more CO_2 emissions are produced from vehicle production for an EV than an ICEV for a series of reasons. Considering the basic components contained in both kinds of vehicles including body and chassis (without battery), CO_2 emissions from the production of them in an EV are 59% more than the level of an ICEV, which is mainly caused by the larger weight. When it comes to the special components, production of the powertrain system and transmission system in an ICEV produces more CO_2 emissions due to the larger weight and different compositions. However, the traction motor and electronic controller only exist in an EV and makes the whole CO_2 emissions from the production of special components in an EV 3% more than the level of an ICEV. Furthermore, it can be found that the production of batteries and attachments, including tires and fluids, produces 3.8/4.0 times CO_2 emissions in an EV with NCM/LFP battery as many as the level of an ICEV due to the mass CO_2 emissions from Li-ion battery production. Finally, more CO_2 emissions are produced from EV assembly due to the Li-ion battery assembly.

4.3. CO_2 emissions reduction potentials

As designed to help save energy and reduce emissions, EVs are not performing well in the production phase currently in China. However, there are reduction potentials to be expected:

- The manufacture techniques of Li-ion batteries in China are still in the primary stage. As a comparison, due to the cleaner production of active materials, one Li-ion battery, such as NCM or LFP battery, produced in the U.S. only leads to around 1.1 t CO_2 emissions[18], one third of the level in China. Therefore the situation is sure to improve with technique growth in China.
- Compared with an ICEV, more steel and aluminum are used in an EV, leading to significant CO_2 emissions. However, the situation can be effectively improved by using recycled materials instead of virgin materials. For instance, as mentioned above, the share of recycled steel used in China is only 11%, compared to 70% in the U.S. and 56% in the EU[30], which implies a huge reduction potential.

5. Conclusions

In this study, life cycle CO_2 emissions from the production of an standard mid-size passenger EV and ICEV with conventional materials in China are estimated from the component point of view, where all the stages and materials are considered in details. The results reveal that the CO_2 emissions from the production of an EV with NCM/LFP battery are about 14.6/14.7 t, 59%/60% higher than the level of an

ICEV, 9.2 t. The Li-ion battery and additional components such as the traction motor and electronic controller in an EV are the major reasons, and different curb weights with different composition between these two vehicles contribute to the difference as well.

Meanwhile, reduction potentials of CO_2 emissions from EV production are analyzed in this study. With the development of battery manufacture techniques, especially active materials, the CO_2 emissions from Li-ion battery production can be reduced to approach the level in the U.S., about one third of it in China. At the same time, as more steel and aluminum are used in an EV than ICEV, huge reduction can be performed with the growth of steel and aluminum recycle industry.

Despite the important results obtained in this study, further steps are needed to carry out more precise estimations. As mentioned in this study, the vehicle specification of standard vehicle is unclear in China, which is sure to lead deviation. And the manufacture standards of batteries have not been established in China, leading to the data's variation in a wide range.

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References

[1] Chinese State Council. Energy Saving and New Energy Vehicles Development Plan (2012-2020). 2012. Acessed: http://www.gov.cn/zwgk/2012-07/09/content_2179032.htm

[2] C. Bauer, J. Hofer, H. J. Althaus, A. D. Duce, A. Simons. The environmental performance of current and future passenger vehicles: Life cycle assessment based on a novel scenario analysis framework. *Applied Energy*, 2015, 157: 871-883.

[3] C. Samaras, K. Meisterling. Life cycle assessment of greenhouse gas emissions from plug-in hybrid vehicles: implications for policy. *Environmental science & technology*, 2008, 42(9): 3170-3176.

[4] A. M. Lewis, J. C. Kelly, G. A. Keoleian. Vehicle Lightweighting vs. Electrification: Life Cycle Energy and GHG Emissions Results for Diverse Powertrain Vehicles. *Applied Energy*, 2014, 126, 13-20.

[5] F. Oris, M. Muratori, M. Rocco, E. Colombo, G. Rizzoni. A multi-dimensional well-to-wheels analysis of passenger vehicles in different regions: Primary energy consumption, CO_2 emissions, and economic cost. *Applied Energy*, 2016, 169: 197-209.

[6] Daimler AG. Life Cycle Environmental certificate for the S400 Hybrid. Mercedes-Benz. Stuttgart, Germany: Daimler AG, 2009.

[7] T. R. Hawkins, B. Singh, G. Majeau-Bettez, A. H. Stromman. Comparative environmental life cycle assessment of conventional and electric vehicles. *Journal of Industrial Ecology*, 2013, 17(1): 53-64.

[8] Organisation Internationale des Constructeurs d'Automobiles (OICA). Global Vehicle Production. 2016. Acessed: http://www.oica.net

[9] Ministry of Industry and Information Technology. 2015.1~12 Economic operation situation of automobile industry. 2016. Acessed: http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057585/n3057589/c4622317/content.html

[10] S. Das. A Comparative Assessment of Alternative Powertrains and Body-in-White Materials for Advanced Technology Vehicles. *SAE Technical Paper*, 2004, 01-0573.

[11] A. Burnham. Updated vehicle specifications in the GREET vehicle-cycle model. *Argonne National Laboratory*, 2012.

[12] China Auto Industry Association. *The development of Chinese automobile industry annual report*. Social sciences academic press, 2016.

[13] Y. S. Chen. A study on life cycle ecological benefits assessment of automotive parts (unpublished publicly). Ph.D. Academic Dissertation, *Hunan University*, 2014, 42-48.

[14] C. Ma, S. Li, Q. Ge. Greenhouse gas emission factors for grid electricity for Chinese provinces. *Resources Science*, 2014, 36(5): 1005-1012.

[15] National Bureau of Statistics of China (NBSC). Annual provincial power generation. 2016. Accessed: http://data.stats.gov.cn/easyquery.htm?cn=C01

[16] Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC guidelines for national greenhouse gas inventories. 2006. Accessed: http://www.ipcc-nggip.iges.or.jp/public/2006gl

[17] National Development and Reform Commission (NDRC). Chinese low carbon development and training materials of listing of provincial greenhouse gas. 2014. Accessed: http://qhs.ndrc.gov.cn/gzdt/201403/t20140328_604827.html

[18] Argonne National Laboratory (ANL). The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model. 2015. Accessed: https://greet.es.anl.gov

[19] X. H. Weng. Research about the problems exist in the statistics of comprehensive energy consumption per unit product of coke in China. *Metallurgical Economics and Management*, 2009 (4), 22-26.

[20] R. Jing, J. C. P. Cheng, V. L. Gan, K. S. Woon, I. M. C. Lo. Comparison of greenhouse gas emission accounting methods for steel production in China. *Journal of Cleaner Production*, 2014, 83: 165-172.

[21] H. Hao, Y. Geng, W. Hang. GHG emissions from primary aluminum production in China: regional disparity and policy implications. *Applied Energy*, 2016, 166: 264-272.

[22] G. Y. Zeng, J. X. Yang, X. L. Song, B. Lv. Energy consumption and carbon emissions scenario analysis of pyrometallurgical copper based on LCA. *China population, resources and environment*, 2012, 22(4): 46-50.

[23] J. L. Sullivan, A. Burnham, M. Wang. Energy-consumption and carbon-emission analysis of vehicle and component manufacturing. *Argonne National Laboratory*, 2010.

[24] G. Keoleian, S. Miller, R. Kleine, A. Fang, J. Mosley. Life cycle material data update for GREET model. *Argonne National Laboratory*, 2012.

[25] A. Burnham, M. Wang, Y. Wu. Development and applications of GREET 2.7--The Transportation Vehicle-Cycle Model. *Argonne National Laboratory*, 2006.

[26] H. L. Brown. *Energy analysis of 108 industrial processes*. The Fairmont Press, Inc., 1996.

[27] Q. Wang. Cathodes materials of lithium ion battery comparative analysis based on life cycle assessment. M.S. Academic Dissertation, *South China University of Technology*, 2012, 35-36.

[28] J.B. Dunn, L. Gaines, M. Barnes, M. Wang, J. Sullivan. Material and energy flows in the materials production, assembly, and end-of-life stages of the automotive lithium-ion battery life cycle. *Argonne National Laboratory*, 2012.

[29] D. Yang, L. Jingru, Y. Jianxin, N. Ding. Carbon Footprint Analysis of Radial Tyres of Passenger Cars. *Chinese Journal of Population Resources and Environment*, 2014:24, 110-114.

[30] J. Wuebbeke, T. Heroth. Challenges and political solutions for steel recycling in China. *Resources, Conservation and Recycling*, 2014, 87: 1-7.

[31] Q. Lu, P. F. Wu, W. X. Shen, X. C. Wang, B. Zhang, C. Wang. Life cycle assessment of electric vehicle power battery, *Materials Science Forum*, 2016: 847, 403-410.

[32] S. Papasavva, S. Kia, J. Claya, R. Gunther. Characterization of automotive paints: an environmental impact analysis. *Progress in Organic Coatings*, 2001, 43(1): 193-206.

[33] S. Papasavva, S. Kia, J. Claya, R. Gunther. Life cycle environmental assessment of paint processes. *Journal of Coatings Technology*, 2002: 74.925: 65-76.

Biography

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Appendix A. Vehicle specification

Table 1. Weight composition by components (excluding batteries, fluids and tires)

Component	ICEV: Conventional Material (*kg*)	EV: Conventional Material (*kg*)
Powertrain system	332.2	28.8
	39.5% steel, 28.6% cast iron, 17.1% cast aluminum, 2.9% copper/brass, 9.3% average plastic, 2.6% rubber	50.0% steel, 20.5% copper/brass, 29.5% average plastic
Transmission system	81.4	55.8
	30.0% steel, 30.0% cast iron, 30.0% wrought aluminum, 5.0% average plastic, 5.0% rubber	60.5% steel, 18.9% copper/brass, 20.0% wrought aluminum, 0.2% average plastic, 0.4% others

Traction motor	/	113.3 36.1% steel, 36.1% cast aluminum, 27.8% copper/brass
Electronic controller	/	99.8 5.0% steel, 46.9% cast aluminum, 8.2% copper/brass, 3.7% rubber, 23.8% average plastic, 12.4% others
Chassis (without battery)	309.0 84.1% steel, 6.9% cast iron, 1.0% cast aluminum, 1.2% copper/brass, 1.8% average plastic, 4.4% rubber, 0.6% others	488.8
Body: including body-in-white, interior, exterior and glass	570.1 68.3% steel, 0.7% wrought aluminum, 1.9% copper/brass, 6.5% glass, 18.1% average plastic, 0.5% rubber, 4.0% others	904.9

Table 2. Weight composition and replacements during life time of batteries, tires and fluids

Batteries, tires and fluids		ICEV: Conventional Material (*kg*)	EV: Conventional Material (*kg*)	Replacement
Lead-acid battery		16.3 6.1% polypropylene, 69.0% lead, 7.9% sulfuric acid, 2.1% fiber glass, 14.1% water, 0.8% others	10.0	2
LFP battery		/	230.0 24.4% active material, 15.2% graphite/carbon, 2.1% binder, 12.4% copper, 20.3% wrought aluminum, 18.2% $LiPF_6$, 7.8% ethylene carbonate, 7.8% dimethyl carbonate, 1.9% polypropylene, 0.3% polyethylene, 1.3% polyethylene terephthalate, 1.5% steel, 0.3% thermal insulation, 1.0% glycol, 1.0% electronic parts	0
NCM battery		/	170.0 28.2% active material, 18.3% graphite/carbon, 2.4% binder, 11.4% copper, 19.7% wrought aluminum, 1.9% $LiPF_6$, 5.4% ethylene carbonate, 5.4% dimethyl carbonate, 1.7% polypropylene, 0.3% polyethylene, 1.2% polyethylene terephthalate, 1.4% steel, 0.4% thermal insulation, 1.0% glycol, 1.3% electronic parts	0
Tires		9.1 (one tire) 66.7% rubber, 33.3% steel	9.1 (one tire) 66.7% rubber, 33.3% steel	3
Fluids	engine oil	3.9	0.0	39
	brake oil	0.9	0.9	3
	transmission fluid	10.9	0.8	1
	powertrain coolant	10.4	7.2	3
	windshield fluid	2.7	2.7	19

adhesives	13.6	13.6	0