# Energy Consumption, Pollutant Emissions and Cost of Electric Vehicles and Fuel Vehicles

Han Yue<sup>1,†</sup>, Shuming Zhang<sup>2,†</sup>, Xinqi Tang<sup>3,†</sup> and Wenmin Wang<sup>4,\*</sup>

<sup>1</sup>Resource Exploration Engineering (Oil and Natural Gas), Changan University, Xian 710061, China

<sup>2</sup>Environmental Engineering, Shenyang Agricultural University, Shenyang 110161, China

<sup>3</sup>Environmental Engineering, Hebei University of Science and Technology, Shijiazhuang 050018, China

<sup>4</sup>Shenzhen International Graduate School, Tsinghua University, Shenzhen 518055, PR China.

<sup>†</sup>These authors contributed equally.

**Abstract.** With the depletion of the earth's energy and the deterioration of the environment, since the United Nations issued the Sustainable Development Goals, all countries have begun research and policies aimed at energy conservation and emission reduction. In the fields of transportation and automobiles, electric vehicles have great potential as an envisioned alternative to conventional fuel vehicles. This article first describes the relevant knowledge about the GREET model and the WTW evaluation system and then discusses and evaluates the differences in energy consumption, pollution emissions and personal use costs between electric vehicles is 11 % lower than that of conventional fuel vehicles. Pollutant emissions of electric vehicles are significantly lower than that of fuel vehicles and their emissions are mainly concentrated in the power generation stage and the overall price of electric vehicles is lower, and the proportion of fuel consumption is smaller than that of conventional fuel vehicles. This article provides a data basis for judging of electric vehicles advantages and development prospects and contribute to reducing social energy consumption and improving environmental degradation.

# **1** Introduction

With global energy depletion and ecological deterioration, the issues of energy consumption and air pollution have been paid attention to by the world. The 2016 International Energy Outlook report released by the U.S. Energy Information Administration (EIA) shows that compared with 2012, global energy consumption will increase by 48 % in 2040. It can be seen that fossil energy still accounts for more than 3/4 of the total global energy consumption [1]. At the same time, according to the OECD, in 2018, greenhouse gas emissions in the transportation sector reached 3,703,709 tons, sulfur oxide emissions were about 421 tons, nitrogen oxide emissions were about 11,145 tons, PM10 emissions were about 779 tons and PM2.5. The emissions amounted to about 479 tons [2]. With the rapid increase in car ownership, car exhaust emissions account for more than 45 % of urban air pollutant emissions [3], becoming the main source of urban air pollution, and CO2 emissions have become an international political issue of global concern. Therefore, pure electric vehicles with the advantages of energy saving and environmental protection have undoubtedly become a breakthrough to alleviate the pressure on urban energy and the environment [4]. Consumers and organizations around the world are seeking low-carbon alternatives to traditional gasoline and

diesel vehicles to reduce greenhouse gas emissions and their impact on the environment [5]. Electricity, as a secondary energy source, has diversified production paths. There is great potential in reducing energy consumption or reducing pollution. Therefore, in response to the sustainable development goals proposed by the United Nations, energy conservation and emission reduction are imminent. As a substitute for conventional fuel vehicles, new energy electric vehicles have become the current research and development trend and direction.

For new energy vehicles (electric vehicles), many scholars have used different methods to study economics, energy utilization and emission benefits of pure electric vehicles. Patrick Mriarty, Damon Hennery [6], Mathew Webber [7], J.VanMierlo [8] and others believe that hybrid and pure electric vehicles are the most promising types of vehicles in various fuels. Yang Feng and others analyzed and compared the life cycle cost of traditional fuel vehicles (RAVA4) and pure electric vehicles (RAVA4 EV) and concluded that the operating cost of pure electric vehicles is lower than that of fuel vehicles, but the total cost is higher than that of vehicles [9]. Wang Enci and others [10] suggested that countries that focus on new energy are more suitable for the development of pure electric vehicles, and their emissions are significantly less than those of countries that focus on fossil energy.

In order to cope with the carbon emissions and

<sup>\*</sup>Corresponding author's e-mail: wangwm17@mails.jlu.edu.cn

environmental problems caused atmospheric by automobile driving, China launched the 'Ten Cities and Thousand Vehicles' demonstration project in 2009. As one of the first pilot cities, Shanghai actively promotes the demonstration of electric vehicles in the fields of sanitation, public transportation, and rental. Application, the promotion plan of pure electric taxis was launched in 2011. According to statistics, as of 2019, there are 1,877 electric taxis on the road in Shanghai [11]. So, this paper uses Shanghai China as the target area by using GREET model and WTW system, and through a comprehensive analysis of the use of fuel vehicles and electric vehicles in energy consumption, emissions and cost of the individual to judge the current advantages, limitations, and future of electric vehicles and provide data reference for energy saving, emission reduction and the feasibility of electric vehicles.

# 2 Methodology

#### 2.1 Vehicle models and basic parameters

#### 2.1.1 Target vehicles

In this paper based on China's Shanghai in 2019 as the target range, based on the analysis of the number of new energy vehicles of Shanghai's mainstream commercial vehicle leasing companies [12, 13], Shanghai Volkswagen, and Shanghai Qiangsheng, the final choice of electric vehicle (EV) models is the Rongwei Ei5 which occupies the largest proportion, and we choose the classic fuel vehicle (internal combustion engine vehicle, ICEV) Tuan L (4), which has the similar weight and scale, as the comparison target.

#### 2.1.2 Vehicle basic parameters

Table 1 shows the basic parameters of target fuel vehicles and electric vehicles.

Table 1. Form	natting sections,	subsections,	and subs	ubsections.
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Parameters	Tuan L4 (ICEV)	Rongwei Ei5 (EV)	
Overall weight (kg)	1515	1560	
Length * width * height (mm)	4527*1829*1659	4600*1818*1543	
The type of power system	internal combustion engine	Permanent magnet synchronous motor	
The type of engine/battery	SIDI (Spark Ignition Direct Injection)	Lithium-ion battery	
<b>Body material</b>	Conventional materials	Conventional materials	
fuel consumption	6 (L/100km)	13.3 (kWh/100km)	

#### 2.2 Model

#### 2.2.1 GREET model

The analytical model used in this paper is GREET model (The Greenhouse Gases regulated Emissions and Energy Use in Transportation Model), GREET model is a one-ofa-kind analytical tool that simulates the energy use and emissions output of various vehicle and fuel combinations. Han used the GREET model to conclude that light-duty vehicles and low-carbon fuels have considerable benefits in reducing greenhouse gas emissions [14]. For different types of fuel and vehicle technology, the GREET model simulates the vehicle fuel from the "well" to "wheel" to evaluate the whole life cycle by defining boundary conditions and parameters, the energy consumption and emissions of different fuel types and different automobile technologies can be obtained [15]. GREET was developed by the U.S. National Argonne Laboratory and sponsored by the U.S. Department of Energy's (DOE) Office of

Energy Efficiency and Renewable Energy. GREET offers two free platforms to use: the GREET.net model and the GREET Excel model. This article uses the GREET.net model.

To get a complete picture of the energy and environmental impacts of ICEV and EV, the greet model consists of two parts- The GREET1 series model (from well to wheels for fuels) adopts the life cycle WTW (Well to Wheel) analysis method, and divides the fuel life cycle into two phases: the fuel generation process WTP (Well to Pump) and the vehicle operation process PTW (Pump to Wheel), and comprehensively considers the fuel life cycle Internal energy consumption and environmental impact. The model uses life cycle evaluation methods to analyze and evaluate the emissions and energy consumption during the life cycle of different vehicle fuels. The GEEET2 series models (from raw material mining to vehicle disposal for automobiles) mainly evaluate the energy consumption and pollution emissions of automobiles in the production and recycling process [16]. As shown in Figure.1



Fig 1. The cycles of GREET model.

#### 2.2.2 WTW evaluation system

The WTW system (Well to wheels) that matches the model is a full life cycle assessment system for the fuel cycle, the entire life cycle starts from the source of the raw materials of the automobile industry until the end of the function after the automobile is used. It is a process from the "cradle" to the "grave" [17]. As shown in figure 2, it is divided into two stages, an upstream stage (Well to pump, WTP stage) and downstream stages (Pump to wheels, PTW stage). The WTP stage is summarized as the fuel acquisition and processing stage, and the PTW stage is summarized as the vehicle driving (fuel combustion) stage, the external environment of the system is material, energy, standard emissions, and greenhouse gas emissions. Among them, material and energy are the external inputs of the entire system, while standard emissions, greenhouse gas emissions, and energy are the external outputs of the entire system [10]. Through analysis and matching different types of fuel and vehicles in different stages to obtain the energy consumption and emissions, and judge this comprehensive sustainability.



Fig 2. Life cycle analysis of WTW system.

#### 2.2.3 The interaction

As shown in Figure 3, the whole interaction process of the model is divided into input process and output process, in the input part, the WTP stage requires the user to set basic data such as the simulation year, fuel type, fuel production method, etc. And in the PTW stage, the user continues to

set the vehicle type, power system type, battery or engine type, and body material type, etc. The GREET.net model will be calculated based on the above settings. And as output items, energy consumption (total energy consumption and fossil fuel consumption), indicators, and emissions (standard emissions and greenhouse gas emissions) indicators will be presented.



Fig 3. The GREET model interaction process.

# **3 Results and discussion**

### 3.1 Energy consumption

#### 3.1.1 Fuel vehicles

Due to the absence of relevant data of Chinese gasoline in GREET model database and the lack of public information about relevant data in China, CA Reformulated gasoline

from the United States was used as the target fuel for the section of gasoline types for fuel vehicles, the reasons are as follows: I. As a high-tech developed country, the United States is relatively strict in terms of gasoline standards and power generation pollution emission management compared with China, so its simulation data will be better than that of China as a whole; II. Among the original data of the GREET model, the data of the United States is relatively accurate, so it is more reliable [10]. The production path of CA Reformulated gasoline selected in this paper is shown in Figure 4.



Fig 4. The production path of CA Reformulated gasoline.

In WTP stage, the research object in this stage is gasoline. By limiting the type of gasoline (CA reformulated gasoline), the production path (default production pathway in GREET model), the simulation year (2019), and functional unit (1KJ) to obtain the energy consumption data. The simulation results data as shown in

Table 2, in the case of the selected settings, every 1 KJ of gasoline produced will cost 1254.01 joules of energy, and the conversion rate will reach about 80 %. The main fossil fuel resource consumption is crude oil, which accounts for 84 % of the total fossil fuel consumption.

 Table 2. The energy consumption of gasoline

Items	Value (J)	
<b>Total Resources Consumption</b>	1254.01	
Fossil Fuel Consumption	1169.23	
Crude Oil	983.4	
Natural Gas	161.27	
Coal Average	13	

In PTW stage, the research object in this stage is fuel vehicle (Tuan L4). By limiting the type of fuel (CA reformulated gasoline), the simulation year (2019), the type of engine (spark ignition direct injection), and function unit (100 kilometer) to obtain the energy consumption data. The simulation results data as shown in **Table 3** The energy consumption data as the energy consumption data.

Table 3, the energy consumption of a fuel vehicle during the driving phase (PTW stage) will be much higher than the energy consumed by its fuel production, approximately four times, and the proportion of renewable energy is only about 6 %.

ble 3	The	energy	consumption	of fuel	vehicles
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Items	WTP	PTW	total
Total Energy (J/100 km)	62,291,872	245,238,620	307,530,492
Non-Fossil Fuel (J/100 km)	20,789,140	0	20,789,140
Total Fossil Fuel (J/100 km)	286,741,352	0	286,741,352
Coal Fuel (J/100 km)	3,188,118	0	3,188,118
Natural Gas Fuel (J/100 km)	39,549,297	0	39,549,297
Petroleum Fuel (J/100 km)	244,003,937	0	244,003,937

Renewable (J/100 km)	20,025,727	0	20,025,727
Biomass (J/100 km)	19,370,780	0	19,370,780
Nuclear (J/100 km)	763,412.68	0	763,412.68

#### 3.1.2 Electric vehicles

Due to the differences in energy consumption and fossil fuel consumption between different ways of producing electric energy, the analysis of electric vehicles should first take the proportion of electricity production ways into account. The power structure shown in Figure 5 is the GREET model default power structure simulated in 2019 in China, the majority is thermal power, which accounts for nearly 70 %, and hydroelectric power, which is about 20 %. According to public information, thermal power generation 5.16 trillion degrees, accounted for 72 %, hydroelectric power generation 1.15 trillion degrees, accounted for 16 %, wind power generation 0.35 trillion degrees, accounted for 5 %, nuclear power generation 0.348 trillion degrees, accounted for 5 %, solar power 0.11 trillion degrees, accounted for 2 % [18], the real structure is basically the same as the simulated result, and it is better than the simulated structure on the whole, so the real result will be more obvious in terms of advantages. Due to the lack of detailed data of electricity production path, we still use the default simulation structure as the underlying setting to analysis. The production path of electricity selected in this paper is shown in Figure 6.



Fig 5. Simulated electricity structure of China.

The production path of electricity selected in this paper is shown in Figure 6, this is a simplified version of the path, its first module on the source of electricity production pathways, as shown in Figure 5 above, is diversified and integrated, the specific production processes for each method use the GREET model default process (China Mix pattern), which will no longer detailed here.



Fig 6. The production path of electricity.

In the WTP stage, the research object in this stage is electricity. By limiting the producing country / region (China), the production path (China Mix pattern), the simulation year (2019) and function unit (1 KJ) to obtain the energy consumption data. The simulation results data as shown in table 4, in the case of the selected settings, the production of 1KJ of electricity needs to consume 2477.04 joules of energy, the conversion rate is about 40 %, and the consumption of coal in the fossil fuel consumption accounts for more than 95 %, is 2053.19 joules. This is because of China's electric energy structure (mainly thermal power generation) and low power generation efficiency of thermal power (The efficiency of thermal power generation is 34.9 %. Since the power generation efficiency of my country's sub-critical thermal power units is 33.1 %, the power generation efficiency of supercritical thermal power units is 41.5 %, and the power generation efficiency of ultra-supercritical thermal power units is 42.1 %. [19]).

Table 4. The energy consumption of electricity

Items	Value(J)	
<b>Total Resources Consumption</b>	2477.04	
Fossil Fuel Consumption	2146.45	
Crude Oil	29.37	
Natural Gas	63.89	
Coal Average	2053.19	

In PTW stage, the research object in this stage is electric vehicle (Rongwei Ei5). By limiting the type of electricity production type (China Mix model), the simulation year (2019), the type of battery (Lithium-ion battery), and function unit (100 kilometer) to obtain the energy consumption data. Due to the structural characteristics of the electric vehicle itself, additional consumption from the components, ADR, fluids and batteries is generated during operation. The simulation results data as shown in Table 5, the energy consumption of electric vehicles in the WTP phase is 124,757,588 J/100 km, and the energy consumption in the PTW phase is 84,464,336 J/100 km, which is 67 % of the former, and due to its own structure, it generates a total of 64,546,932 J/100 km additional energy. Among them, 87 % of the energy consumption comes from fossil fuels, which is

239,819,431 J/100 km. It can be seen that the electric energy structure has a huge impact on electric vehicles. It is worth mentioning that the proportion of renewable energy has reached about 10 %, which means that with the continuous optimization of the energy structure, the advantages of electric vehicles in energy will become more and more prominent.

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Items	WTP	PTW	components	ADR	fluids	battery	total
Total Energy (J/100 km)	124,757,588	84,464,336	38,732,928	7,500,565	2,180,203	16,133,236	273,768,856
Non-Fossil Fuel (J/100 km)	27,187,416	0	3,955,120	940,930.41	39,139.21	1,826,820	33,949,426
Fossil Fuel (J/100 km)	182,034,508	0	34,777,808	6,559,635	2,141,064	14,306,415	239,819,431
Coal Fuel (J/100 km)	173,421,023	0	11,698,903	1,636,701	72,277	3,456,807	190,285,711
Natural Gas Fuel (J/100 km)	5,396,796	0	17,666,775	4,848,344	1,532,552	8,771,855	38,216,322
Petroleum Fuel (J/100 km)	3,216,690	0	5,412,129	74,590	536,235	2,077,753	11,317,397
Renewable (J/100 km)	24,515,879	0	2,797,226	452,673	18,824	1,300,240	29,084,842
Biomass (J/100 km)	3,623,782	0	117,730	34,370	1,430	77,717	3,855,029
Nuclear (J/100 km)	2,671,537	0	1,157,894	488,258	20,315	526,580	4,864,584

#### 3.1.3 Summary

In the WTP stage, Figure 7. (a) illustrates the total energy consumption of electric energy and gasoline during the fuel life cycle, and Figure 7. (b) illustrates the fossil fuel consumption of electricity and gasoline in the fuel life cycle. From the view of fuel energy consumption, because

of China's electricity structure and China's thermal power generation efficiency, the energy consumption for producing electricity is about twice that of producing gasoline, electricity consumes extra 1,223.03 J/hkm energy than gasoline. This trend is also obvious in fossil fuel consumption, you can see a lot of fossil fuels being wasted in the production of electricity, the conversion rate is less than 50 %.





Fig 7. (a) The total energy consumption of electricity and gasoline. (b) Comparison of the fossil fuel consumption of gasoline and electricity.

In the PTW stage, Figure 8. (a) shows the energy consumption data of electric vehicles and fuel vehicles in the whole life cycle, in terms of vehicle operation, although electric vehicles consume about 50 % more energy in the upstream phase than fuel vehicles, the EV is only 34 % of the latter during the driving phase, and even if the electric vehicle has an additional energy consumption, it is about 33,761 KJ/hkm less than fuel vehicles, in terms of total. Figure 8. (b) and Figure 8. (c)

respectively show the fossil fuel consumption of electric vehicles and fuel vehicles during the whole life cycle. From the point of fossil fuels, in the WTP phase, fuel vehicle consume nearly 10 million J/100 km more fossil fuels than electric vehicle (the former is mainly oil, the latter is mainly coal), although electric vehicle generate additional fossil fuel consumption due to its own characteristics, fuel vehicles are still 46,921 KJ/100 km higher than electric vehicles.





Fig 8. (a) Comparison of the total energy consumption of ICEV and EV. (b) Fossil fuel consumption of ICEV. (c) Fossil fuel consumption of EV.

#### 3.2 Pollutant emission

#### 3.2.1 Fuel vehicles

In WTP stage, the research object in this stage is gasoline,

the main 10 pollutants from gasoline combustion, by limiting the type of gasoline (CA reformulated gasoline), the simulated year (2019), and functional units (1KJ) to obtain primary emission data for basic pollutants, the simulation results data as shown in Table 6, in the case of the selected settings. Every 1 KJ of gasoline consumed, Greenhouse gas emissions reached 21090 µg.

Table 6. Main emissions of gasoline

Items	Value (µg)
GHG-100	21090
CO <sub>2</sub>	17340
VOC	28.99
СО	16.89
NOx	44.3
PM10	4.32
PM2.5	3.29
SOx	23.72
CH <sub>4</sub>	100
N <sub>2</sub> O	2.39

In PTW stage, the research object in this stage is fuel vehicles (Tuan L4). By limiting the type of fuel (CA reformulated gasoline), the simulation year (2019), the type of engine (spark ignition direct injection) and function unit (100 kilometers) to obtain the major emission data. The simulation results data as shown in Table 7,  $CO_2$  and greenhouse gas emissions are significantly higher at this stage than at the previous WTP stage, approximately four and three times, while other pollutant emission changes are not very large.

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Items	WTP	РТW	Total
GHG-100 (kg/100 km)	5.17	16.83	22
VOC (kg/100 km)	0.01	0.01	0.02
CO (kg/100 km)	0	0.17	0.17
NO <sub>x</sub> (kg/100 km)	0.01	0.01	0.02
PM10 (kg/100 km)	0	0	0
PM2.5 (kg/100 km)	8.07E-04	0	8.07E-04
SO <sub>x</sub> (kg/100 km)	0.01	0	0.01



Fig 9. Proportion chart of ICEV of basic pollutants.

For the conventional internal combustion engine, the proportion of ten types of pollutants in the two stages of WTP and PTW is shown in Fig 9. From the perspective of solid particulate matter, PM10 emission is zero, while PM2.5 emission is concentrated in the WTP stage. CO emissions are concentrated in the PTW stage, and the emissions of greenhouse gases and  $CO_2$  account for 80 % and 20 % of the total emissions, respectively, in the two stages. VOC emissions did not change between the two stages.

#### Electric vehicles

In the WTP stage, the research object in this stage is electricity. By limiting the producing country / region (China), the production path (China Mix pattern), the simulation year (2019), and function unit (1KJ) to obtain the energy major emissions data. The simulation results data as shown in Table 8, in the case of the selected settings, every 1 KJ of electricity consumed, GHG and  $CO_2$  will reach 200000 µg.

Table 8. Main emissions of electricity

Items	Value (ug)
GHG-100	200000
CO <sub>2</sub>	200000
VOC	17.28
СО	32.11
NOx	110
PM10	35.25
PM2.5	13.37
SOx	500
CH <sub>4</sub>	300
N <sub>2</sub> O	3.36

In PTW stage, the research object in this stage is electric vehicle (Rongwei Ei5). By limiting the type of electricity production type (China Mix model), the simulation year (2019), the type of battery (Lithium-ion battery), and function unit (100 kilometers) to obtain the major emissions data. Due to the structural characteristics of the electric vehicle itself, additional consumption from Table 9. Major emissi the components, ADR, fluids, and batteries is generated during operation. The simulation results data as shown in Table 9, GHG emissions in the PTW phase is 4.25 kg/100 km, while in the WTP phase is 17.82 kg/100 km. It can be see that electric vehicles in this stage has its own advantages.

able 9	<b>)</b> . M	ajor	emissions	from	electric	vehicles

Items	WTP	PTW	Components	ADR	Fluids	Battery	Total
(кд/пкт)			-				
GHG-100	17.82	4.25	2.59	0.47	0.17	1.02	22.07
VOC	0	0.03	0.00	8.39e-4	0.03	2.23e-4	0.03
СО	0	0.01	0.01	2.56e-4	9.67e-5	6.99e-4	0.01
NOx	0.01	0	0.00	4.03e-4	1.31e-4	0.00	0.01
PM10	0	0	0.00	7.09e-5	2.47e-5	7.25e-4	0



Fig 10. Proportion chart of EV of basic pollutants.

Overall, for electric vehicles, the proportions of 10 types of pollutants in the two stages are shown in Fig 10. At this time, CO and VOC emissions are concentrated in the PTW stage, while  $CH_4$  and  $NO_x$  emissions are concentrated in the WTP stage. For solid particles, both PM10 and PM2.5 emissions are zero. For greenhouse gases, the emissions in the WTP phase are 42 % higher

than that in the PTW phase, also  $CO_2$  emissions of electric vehicles have been significantly reduced, which is conducive to environmental friendly.

#### 3.2.2 Summary





Fig 11. Comparison of basic pollutant emission in two aspects.

To sum up, from the perspective of pollutant emissions, the greenhouse gas emissions of electric vehicles will increase dramatically compared with those of fuel vehicles. Except for lower VOC emissions, the emissions of other pollutants will also increase. Therefore, if the use of coal in the grid structure is reduced, that is when the proportion of thermal power generation is low, or the efficiency of thermal power generation is high, the emission of greenhouse gases such as carbon dioxide can be reduced. The policy requirements of energy conservation and emission reduction can be met at the same time.

#### 3.3 Cost

From the perspective of individual users, this article

analyzes the economic costs, namely the purchase cost and the operating cost, according to the production stage and use stage of the car. WTW system does not involve the part of automobile recycling, so the calculation of this article does not consider the disposal cost. Taking fuel vehicles (Tuan L) and electric vehicles (RongWei EI5) as examples of the most commonly used vehicles to calculate cost of personal uses. In the economic calculation, only the cost difference due to the type of car is included in the calculation, so as to compare the difference in the total cost of fuel vehicles and electric vehicles.

#### 3.3.1 Fuel vehicles

According to the reference [20], the purchase cost includes

the suggested retail price and the license fee. The suggested retail price of the car comes from the official website of Tuan L Motor Company, and the price is \$22,011. Calculated according to the cost of one-stop service provided by the manufacturer, the licensing fee is \$72. Adding the suggested retail price and the license fee, you can get the purchase cost of a fuel car of \$22,083.

Operating costs include energy costs and maintenance costs. In the calculation, the mileage is set as the mileage when the car is scrapped. According to the reference [21], in the automobile market, the average life span of a car is 200,000 miles. The oil price data is \$0.95 per liter and comes from the average price of No. 93 gasoline in Shanghai in 2019. The fuel consumption data per 100 kilometers which comes from the official website of this type of fuel vehicle is 6.3 L/100km. With these two data, you can get the energy cost, which is \$19,146. Regarding the maintenance cost of fuel vehicles, according to reference [21], the fifth year of the use of fuel vehicles, expensive items such as tires will be exhausted. The repair and maintenance costs of fuel vehicles are about \$1200, and costs of repair and maintenance of comparable electric vehicles is about \$900. Maintenance items include antifreeze in gasoline engine radiators, engine oil, etc.

The cost of personal use of fuel vehicles is obtained by adding up the purchase cost and the operating cost.

#### 3.3.2 Electric vehicles

According to the reference [20], the purchase cost includes the suggested retail price and the license fee. The suggested retail price of the car comes from the official website of Rongwei EI5 Motor Company, and the price is \$20,416. From the reference [20], it can be seen that electric vehicles and fuel vehicles have the same cost of the license. Calculated according to the one-stop service fee provided by the manufacturer, the license fee is \$72. Adding the suggested retail price and the cost of listing, you can get the purchase cost of a petroleum car at \$20,488.

The calculation process of the operating cost of electric vehicles is the same as that of fuel vehicles, including energy costs and maintenance costs. The mileage is set to the mileage when the vehicle is scrapped, which is 200,000 miles. The electricity price data is \$0.23 per liter and comes from the "Shanghai Interim Provisions on the Construction and Management of Electric Vehicle Charging Facilities". The electricity consumption data per 100 kilometers which comes from the official website of this type of electric vehicle is 13.3 kWh/100km. With these two data, you can get the energy cost, which is \$9874. Regarding the repair cost of electric vehicles, according to reference [21], the repair and maintenance costs of electric vehicles and fuel vehicles are 50 %, and the average cost of replacing battery packs is \$5,500, which often lasts at least 8 to 10 years. The maintenance items for electric vehicles also include cabin air filters to prevent dust and particles outside the vehicle from the heating and airconditioning systems of the vehicle.

The cost of personal use of electric vehicles is obtained by adding up the purchase cost and the operating cost.

#### 3.3.3 Summary

Based on the above analysis, considering WTW system and the whole life cycle of vehicles, the result is shown in Figure 12.



Fig 12. Cost comparison between fuel vehicles and electric vehicles.

From the purchase cost of the two types of vehicles, the purchase cost of electric vehicles is lower than that of fuel vehicles, but the difference between the two is not big. When electric vehicles and fuel vehicles have the same functions, their prices are not much different, electric vehicles will be slightly cheaper.

From the operating cost of the two types of vehicles, the operating cost of electric vehicles is lower than that of fuel vehicles. The energy cost of electric vehicles is 51.56 % of that of fuel vehicles, and the maintenance cost of electric vehicles is half of that of fuel vehicles. Reference [22] shows that, according to the research and analysis of CR, compared with fuel vehicles, users of electric vehicles can save \$500 in repair and maintenance costs on average during the service life of the vehicle.

From the total user cost of the two types of vehicles, the total user cost of electric vehicles is lower than that of fuel vehicles. Therefore, electric vehicles have certain economic advantages compared with fuel vehicles. They are worthy to promotion.

# 4 Conclusion

This paper systematically analyzes the advantages and

feasibility of electric vehicles as a new type of driving type vehicle by using the GREET model and WTW system with energy consumption, emissions, and personal use costs as indicators. The total energy consumption of pure electric vehicles is about 11 % less than that of fuel vehicles per 100 kilometers indicates that the use of electric energy as a driving source can significantly reduce the energy consumption of vehicles during operation; From the perspective of the main emissions of these two types of vehicles, the GHG emissions of electric vehicles are higher than those of fuel vehicles because the energy structure is dominated by thermal power. Therefore, using other clean energy sources to generate electricity or improving the efficiency of thermal power generation will reduce greenhouse gas emissions; in the current life cycle of automobiles, the cost of electric vehicles is lower than that of fuel vehicles. However, electric vehicles require additional battery coolants, battery replacement, and construction of charging equipment, which will increase costs. At the same time, the government also needs to build corresponding infrastructure in accordance with the development of electric vehicles in different regions, such as the construction of charging piles, to encourage enterprises to carry out technological innovation.

Through research, this article believes that the advantages of electric vehicles in energy consumption and emissions will be further revealed with the optimization of the electric energy structure and breakthroughs in automobile battery technology. Countries should to optimize the electric energy structure (For example, increasing clean energy that can generate electricity.) and working to break through battery technology to increase battery life and promoting electric vehicles to achieve harmonious economic and environmental development.

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