Research on Carbon Accounting Method and Economy of Electric Vehicle Charging Facilities Participating in Carbon Emission Permits Trading

Weicheng Chen 1, *, Yuqing Wang 1, Shi Tian 1, Ming Zeng 1, Bin Zhu 2 and Xingzhe Hou 2

1 State Key Laboratory for Alternate Electrical Power System With Renewable Energy Sources, North China Electric Power University, Beijing, China
2 Chongqing Electric Power Research Institute, Yubei District Chongqing, China

*Corresponding author e-mail: eversf@126.com

Abstract. The development of electric vehicles (EV) has been widely established as an important way to ensure energy security and transform low-carbon economy in the world. However, the construction and operation cost of EV charging facilities is high and the profit channel is single, which makes operators in a long-term loss state. It is necessary to study the participation of EV charging facilities in carbon trading in order to find new profit growth points. On this background, firstly, the calculation method of carbon emission of whole life cycle of EV charging facilities is studied from the construction stage and the operation stage, which shows that the carbon emission accounting has technical feasibility. Secondly, the economic benefits of EV charging facilities participating in carbon trading market is analyzed, which shows that participating in carbon trading has economic rationality. Finally, a case study of the carbon emission accounting and economic benefits of EV charging facilities participating in carbon trading is carried out. The result shows that the economic benefits of EV charging facilities participating in carbon trading increase, and with the increase of charging amount and carbon trading price, the economic benefits increase continuously.

1. Introduction

With the advantages of energy saving and environmental protection, EV have become an effective way to solve the problem of energy and resource shortage and serious air pollution. The development of EV has been widely established as an important way to guarantee energy security and transform low-carbon economy in the world [1]. However, the construction and operation cost of EV charging infrastructure is relatively high, the profit channel is single, a large number of charging facility operators are in a state of loss for a long time, and various capital investment power is insufficient [2]. Therefore, in order to promote the healthy and orderly development of the EV charging facility industry, it is urgent to broaden the profit channels of charging facilities and explore new profit growth points. As the core link of the low-carbon industry of EV, charging facilities can increase revenue by participating in the carbon trading market, which requires accounting the carbon emissions of EV charging facilities participating in carbon trading.
In terms of carbon emission accounting, literature [3] introduces the spatial effect into the analysis of the influencing factors of China's traffic carbon emissions. Based on the "top-down method", carbon emission factors are used to calculate the traffic carbon emissions of various provinces and cities, and the time-space change trend of the traffic carbon emissions of various provinces is analyzed through the calculation results. Literature [4] sorted out the existing carbon verification policies and analyzed the carbon accounting based on the actual cases of the chemical industry. Literature [5] takes the accounting scope as the entry point, proposes the carbon emission accounting method, and defines the boundary conditions of carbon emission accounting.

In terms of measuring the economic benefits of carbon trading, literature [6] established a carbon trading revenue model for wind power projects based on multi-stage real options and dynamic recursion theory. Literature [7] uses the cost-income economic model of electric bus charging and changing station to calculate the economic benefits with the example of electric bus charging station. Literature [8] puts forward the mathematical model of economic benefits of the international maritime carbon trading mechanism, and conducts numerical simulation calculation on the ship type of river-sea direct container ship to obtain the economic benefits.

It can be seen from the relevant literature that the research on the participation of EV charging facilities in carbon trading is still in the preliminary stage. In this context, this paper first studies the accounting method of carbon emissions in the whole life cycle of EV charging facilities from the two levels of construction stage and operation stage. Secondly, this paper analyzes the economy of EV charging facilities participating in carbon trading market. Finally, this paper analyzes the carbon emission accounting and economic benefits of EV charging facilities participating in carbon trading with an example.

2. Research on accounting method of carbon emission in whole life cycle of EV charging facilities
The whole life cycle of EV charging facilities mainly includes the construction stage and the operation stage, and carbon dioxide emissions are generated in each stage. This section will study the accounting method of carbon emissions in whole life cycle of EV charging facilities based on the above two stages.

2.1. Accounting of carbon emissions at the construction stage
The carbon emissions in the construction stage of EV charging facilities are mainly composed of the carbon emissions in the construction of charging facilities and the carbon emissions in the equipment purchased. The carbon emissions can be calculated according to the advanced carbon dioxide emission intensity of related industries. Therefore, the carbon emission accounting method in the EV charging facility construction stage is shown as follows:

\[
CE_1 = \frac{V_{ei} \times S + V_{ec} \times D}{1000}
\]

Where \( CE_1 \) is Carbon emissions during the construction of EV charging facilities; \( V_{ei} \) is Advanced carbon dioxide emission intensity of the real estate industry, value for 29.13 kg CO\(_2\)/m\(^2\); \( V_{ec} \) is Advanced carbon dioxide emission intensity of electronic components and components manufacturing industry, values for 31.920 kg CO\(_2\)/per thousand; \( S \) is area of the building covered by EV charging facility; \( D \) is Acquisition cost of charging and distribution facilities.

2.2. Accounting of carbon emissions at the operation stage
The carbon emissions at the operation stage of EV charging facilities are mainly determined by the charging amount for the vehicle and the average loss rate of power technology transmission and distribution for charging. The calculation method is shown as follows:

\[
CE_{2,n} = \sum_{i} EF_{elec,i,n} \times EC_{PJ,i,n} \times (1 + TDL_{n})
\]

Where \( CE_{2,n} \) is Carbon emissions from EV charging facilities in year \( n \); \( EF_{elec,i,n} \) is CO\(_2\) emission factor of electricity consumed by vehicle type \( i \) in year \( n \), the unit is t CO\(_2\)/MWh; \( EC_{PJ,i,n} \) is Charging
capacity of EV charging facilities for vehicles of model I in year n; \( TDL_{i,n} \) is Average loss rate of power technology transmission and distribution for charging EV in year n; \( i \) is Vehicle models, such as large vehicles(buses) and small vehicles(private cars, taxis).

2.3. Life cycle carbon emissions accounting

The carbon emissions in the whole life cycle of EV charging facilities are equal to the sum of the carbon emissions in the construction stage and the carbon emissions in the operation stage. The calculation formula is shown as follows:

\[
CE = CE_i + \sum_{n} CE_{2,n} = \frac{V_{ai} \times S + V_{ae} \times C_{D} \times 1000}{1} + \sum_{n} \sum_{i} EF_{elec,i,n} \times EC_{P,i,n} \times (1 + TDL_{i,n})
\]  

3. Economic analysis of EV charging facilities participating in carbon trading

EV charging facility operators can trade the carbon emission reduction of EV users in the carbon market and obtain certain benefits. This section will analyze the costs and benefits of EV charging facilities.

3.1. Cost analysis of EV charging facilities

Assuming that the exit cost of ev charging facilities is not taken into account, the construction cost of EV charging facilities mainly includes land cost, construction cost, acquisition cost of charging and distribution equipment, and monitoring system cost, and the operation cost mainly includes electricity purchase cost, charging station maintenance cost and labor cost within the operating cycle. The construction and operation cost structure of ev charging facilities are shown in Fig 1.

![Figure 1. EV charging facility construction and operation cost structure](image)

(1) Construction cost of EV charging facilities

The construction cost of EV charging facilities \( C_{1} \) is mainly composed of land cost, construction cost, acquisition cost of charging and distribution equipment and monitoring system cost. The calculation is shown as follows:

\[
C_{1} = C_{L} + C_{B} + C_{D} + C_{S}
\]  

Where \( C_{L} \) is land cost; \( C_{B} \) is building cost; \( C_{D} \) is charging and distribution equipment costs; \( C_{S} \) is monitoring system cost.
(1) Land cost \( (C_L) \) is an important part of the initial construction investment of charging stations, which is mainly determined by land price per unit area and land area occupied by charging facilities. The calculation is shown as follows:

\[ C_L = L_P \times L_S \]  

(5)

Where \( L_P \) is land price per unit area; \( L_S \) is land area occupied by charging facilities.

(2) Building cost \( (C_B) \) is the construction cost of electric vehicle charging facilities, mainly including office area, parking area, power distribution room, monitoring room and other buildings. The calculation is shown as follows:

\[ C_B = C_c + C_F \]  

(6)

Where \( C_c \) is construction fee of office area and parking area; \( C_F \) is construction fee of power distribution room and monitoring room.

(3) The acquisition cost of charging and distribution equipment \( (C_D) \) is the most important expense in the initial stage of EV charging facilities construction. Among them, the charging equipment mainly includes ac charging pile and dc quick charging machine. Distribution equipment mainly includes 10kV switch cabinet, transformer, low voltage distribution cabinet, etc. The acquisition cost of charging and distribution equipment \( C_D \) is calculated as shown as follows:

\[ C_D = \sum_{i=1}^{1} P_{i1} \times N_{i1} + \sum_{i=2}^{2} P_{i2} \times N_{i2} \]  

(7)

Where \( P_{i1} \) is Unit price of class i charging equipment; \( N_{i1} \) is Purchase quantity of class i charging equipment purchased; \( P_{i2} \) is Unit price of class i distribution equipment; \( N_{i2} \) is Purchase quantity of class i distribution equipment.

(4) Monitoring system cost \( (CS) \) refers to the purchase cost of equipment and system software for EV charging facilities, power distribution system monitoring, charging security and defense monitoring, etc.

(2) Annual operating cost of EV charging facilities

The annual operating cost of EV charging facilities \( C_{2,n} \) are mainly composed of electricity purchase cost, labor cost and charging equipment maintenance cost. Its calculation is shown as follows:

\[ C_{2,n} = C_{E,n} + C_{H,n} + C_{M,n} \]  

(8)

Where \( C_{E,n} \) is Annual electricity purchase cost; \( C_{H,n} \) is Annual labor cost; \( C_{M,n} \) is Annual charging equipment maintenance cost.

(1) The purchase cost of electric vehicle charging facilities \( (C_{E,n}) \) mainly refers to the electricity charge purchased by the power supply company for charging needs, as well as the electricity charge required by the normal operation of equipment in the station and the work and life of employees, which is mainly determined by the electricity purchase price and the total demand for electricity. The calculation of annual electricity purchase cost is shown as follows:

\[ C_{E,n} = P_E \times N_E \]  

(9)

Where \( P_E \) is Unit price of power purchase; \( N_E \) is quantity of electricity purchase.

(2) The annual labor cost \( (C_{H,n}) \) is mainly determined by the staffing of the station and the local wage level. It mainly includes the basic salary, bonus, social security, welfare and other expenses of employees.

(3) The annual maintenance cost of charging equipment \( (C_{M,n}) \) refers to the cost combination of equipment maintenance and parts replacement in the year \( n \) of project operation. It is usually calculated according to a certain proportion \( (\beta) \) of investment in charging and distribution equipment. The calculation is shown as follows:

\[ C_{M,n} = \beta C_D \]  

(10)

Where \( \beta \) is Scale factor; \( C_D \) is Acquisition cost of charging and distribution equipment.
3.2. Economic benefit analysis of EV charging facilities

(1) The revenue composition of EV charging facilities

The main business of EV charging facilities is to provide charging services to customers, which is their main source of revenue. In addition, EV charging facilities enjoy state and local subsidies. During the operation period of EV charging facilities, the emissions of carbon dioxide is effectively reduced. With the large-scale development of future city EV and the continuously open of carbon emissions trading market, the benefit of CO2 emission reduction will increasingly highlight, so the contribution of carbon trading income to EV charging facilities income will be greater and greater. In addition, some residual income will be generated when the project is returned.

It can be seen from the above analysis that the income of EV charging facilities mainly includes four parts: charging service income, carbon emission reduction trading income, national and local subsidy income and residual value income. The income composition of EV charging facilities is shown in Fig 2.

\[
I = I_{E,n} + I_{C,n} + I_{Sub,n} + I_R
\]

Where \(I_{E,n}\) is Revenue from providing charging services in year n; \(I_{C,n}\) is Carbon Emission Reduction Trading; \(I_{Sub,n}\) is State and local subsidies; \(I_R\) is residual value income.

(2) Quantitative analysis of the income from the construction of EV charging facilities

The income item of EV charging facility construction is calculated as shown follows:

\[
I = \sum_{i=1}^{365} P_{i,n} \cdot N_{i,n}
\]

Where \(P_{i,n}\) is The charging price on day i (includes the charging service fee); \(N_{i,n}\) is charge quantity on day i.

Revenue from carbon emission reduction trading (\(I_{C,n}\)) is to convert CO2 emissions reduced by replacing conventional fuel vehicles with electric vehicles into revenue, and its calculation is shown as follows:

Figure 2. Income composition chart of EV charging facilities
\[ I_{c,a} = W \cdot V \]  
(13)

Where \( W \) is Less CO\(_2\) emissions when EV replace conventional fuel vehicles; \( V \) is Carbon emission reduction trading price.

③The subsidy (\( I_{sub,a} \)) is mainly in accordance with the relevant policies and regulations of the location of charging facilities.

④Residual income (\( I_r \)) is determined by the residual return rate \( r \) and the size of fixed assets, as shown follows:

\[ I_r = r \cdot C_p \]  
(14)

Where \( r \) is The residual return rate; \( C_p \) is Acquisition cost of charging and distribution equipment.

4. Case study

4.1. Basic data

In order to verify the practicality and effectiveness of the model, this paper selects an EV charging facility as the research object to calculate the total life cycle carbon emissions and economic benefits involved in carbon trading. Tab 1 shows the basic data of this EV charging facility.

| The basic parameters | The values | Unit |
|----------------------|------------|------|
| site area            | 1500       | m\(^2\) |
| 60kW DC fast charging equipment | 5          | station |
| 7kW AC slow charging equipment | 15         | station |
| A feed-in tariff     | 0.45       | yuan/kwh |
| Charging price of quick charging equipment | 1.45       | yuan/kwh |
| Charging price of slow charging equipment | 1.25       | yuan/kwh |
| Purchase cost of charging and distribution facilities | 100        | ten thousand |
| operation and maintenance cost of Charging station | 15         | ten thousand/year |
| Typical daily charging quantity of quick charging equipment | 75         | kwh |
| Typical daily charging quantity of slow charging equipment | 40         | kwh |
| CO\(_2\) emission factor of grid | 0.666      | tCO\(_2\)/MWh |
| CO\(_2\) emission factor of fuel vehicle | 0.157      | tCO\(_2\)/1000km |
| Residual value rate of fixed assets | 5          | % |
| Depreciation period of fixed assets | 5          | year |
| Carbon trading price | 60         | yuan/t |

4.2. Carbon emission measurement of EV participating in carbon trading

(1) Carbon emissions during construction

According to Tab 1, this EV public charging station occupies an area of 1,500 square meters and the cost of charging and distribution equipment is 1 million yuan. Therefore, according to equation (1), the carbon emission of this EV public charging station in the construction stage is 75.62 t CO\(_2\).

(2) Carbon emissions during operation

From table 3-1, it can be known that the CO\(_2\) emission factor of this EV public charging station is 0.666 tCO\(_2\)/MWh, the typical daily charging amount of fast charging equipment is 75 KWH, the typical daily charging amount of slow charging equipment is 40 KWH, there are 560kW dc fast charging devices and 157kW ac slow charging devices. According to equation (2), the carbon emission of this EV public charging station in the operation stage is 237.01 t CO\(_2\)/year.

In addition, it can be known from table 3-1 that the CO\(_2\) emission factor of fuel vehicles is 0.157 t CO\(_2\)/MWh, and it can be calculated that the carbon emission of fuel vehicles is 372.48 t CO\(_2\)/year under the same driving distance of EV. Thus, it can be calculated that the carbon emission reduction of EV public charging stations in the operation stage is 135.47 t CO\(_2\)/year.
4.3. **Measurement of the economy of EV participating in carbon trading**

The EV charging infrastructure belongs to public property. According to local policy, the government reduce operating costs of charging infrastructure construction through fiscal subsidies, free of charge transfer in electrical installations construction sites and other ways. At the same time, the construction cost of charging facilities and distribution network facilities shall be borne by the power grid enterprises. Therefore, in the process of calculating the construction cost, the land cost, supporting power grid and road network construction cost can be temporarily ignored, and the related equipment purchase and installation cost can be mainly considered.

The Tab 1 shows that the purchase price of EV public charging station is 0.45 yuan/KWH, fast charge equipment selling electricity price is 1.45 yuan/KWH, slow charge equipment selling electricity price is 1.25 yuan/KWH, the typical daily charge capacity of a single fast charging device is 75 KWH, the typical daily charge capacity of a single slow charging device is 40 KWH, the annual operation and maintenance cost (including labor cost) of the charging station is 150,000 yuan.

1) Calculation of economic benefits of EV charging facility construction without considering carbon trading

Put the data in table 3-1 into the economic measurement tools of 2.1 and 2.2, and do not consider the benefits of carbon trading, the financial indicators can be obtained as shown in Tab 2:

| Total initial investment cost | 100.00 |
|------------------------------|--------|
| Annual operation and maintenance cost | 15.00 |
| Annual charging service revenue | 47.22 |
| Annual after-tax profit | 21.10 |
| Cumulative net present value | -2.14 |
| Internal rate of return | 7.24% |

It can be seen from Tab 3 that, without considering the carbon trading case, the total initial investment cost is 1 million yuan, annual operation maintenance cost is 150,000 yuan, charging service income is 472,200 yuan, charging service income is 472,200 yuan, annual after-tax profits is 211,000 yuan, the cumulative net present value in the sixth year of operation is -21,400 yuan and the internal rate of return is 7.24%. The total cost cannot be recovered in the whole operation cycle.

2) Calculation of economic benefits of EV charging facilities construction considering carbon trading

Put the data in table 3-1 into the economic measurement tools of 2.1 and 2.2, and take the revenue of carbon trading into consideration. The financial indicators are shown in Tab 3:

| Total initial investment cost | 100.00 |
|------------------------------|--------|
| Annual operation and maintenance cost | 15.00 |
| Annual charging service revenue | 47.22 |
| Annual carbon trading gains | 0.81 |
| Annual after-tax profit | 21.71 |
| The net present value | 0.47 |
| Internal rate of return | 8.17% |
| investment recovery period | 6.96 |

It can be seen from table 3-3 that, in the case of the consideration of carbon trading, total initial investment cost is 1 million yuan, annual operation maintenance cost is 150,000 yuan, charging service income is 472,200 yuan, in carbon trading income is 8100 yuan, annual after-tax profits is 216,100 yuan,
the cumulative net present value in the sixth year of operation is 4,700 yuan, internal rate of return is 8.17%. So the investment payback period is 6.96 years.

(2) Economic analysis of EV charging facility construction participating in carbon trading market

Fig 3 is obtained by summarizing the cumulative net present value under the circumstance of not considering carbon trading and considering carbon trading:

![Accumulated net present value in both cases](image)

**Figure 3.** Cumulative net present value in both cases

It can be seen from Fig 3 that in the two cases, additional carbon trading income is obtained when the carbon trading case is considered, and the cumulative net present value during the operation period is always higher than the case without considering the carbon trading. In addition, in the case that carbon trading is not taken into account, all costs cannot be recovered in the whole operating cycle, while in the case that carbon trading is taken into account, all costs can be recovered at the end of the operating period. At the end of the sixth operating period of the charging station, the cumulative net present value (NPV) considering the carbon trading situation was 0.47 million yuan, which was 26,100 yuan higher than that without the carbon trading situation.

(3) Sensitivity analysis of EV charging facility construction participating in carbon trading market

When other factors unchanged, under the condition of considering whether to participate in carbon trading, one of these factors (EV charging infrastructure construction cost, carbon trading and charging quantity) was reduced or increased in proportion, we can get different construction investment, carbon trading price, charge level under the net present value. Then we list the different construction costs, carbon trading, charging amount of the net present value of the result, the result is shown in Fig 4 and Tab 4.

As can be seen from Fig 4 and Tab 4, the sensitivity degree of the change level of different variables to the influence of NPV is ranked from big to little: charging quantity > input > carbon trading price. With all variables unchanged, it is necessary to participate in carbon trading if the cumulative net present value of the carbon trading scenario is positive, while the cumulative net present value of the carbon trading scenario is negative. No matter how the input, charge quantity and carbon trading price change during the construction period, the economic benefit of considering carbon trading is always better than not considering carbon trading. With the increase of charging quantity and carbon trading price, the economic benefit of carbon trading is continuously improved.
5. Conclusion
(1) It is technically feasible for EV charging facilities to participate in the carbon trading market. The whole life cycle carbon emission accounting of EV charging facilities can be obtained by calculating the carbon emission accounting of construction stage and operation stage respectively.

(2) From two aspects of cost and economic benefits, the economic efficiency of EV charging facilities participating in carbon trading can be calculated, and EV charging facilities participating in carbon trading has additional benefits.

(3) The technical feasibility and economic rationality of electric vehicle charging facilities participating in carbon trading are proved by case study. With the increase of charging amount and the rise of carbon trading price, the economic benefits of carbon trading are continuously improved.

Acknowledgments
This work was supported by the State Grid Technology Project (52200018000C).

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