# Grid Investment's Impact on Transmission and Distribution Tariffs Considering Carbon Costs

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**Abstract.** In the era of growing emphasis on dual-carbon policies, accounting for the carbon emissions cost in the transmission and distribution tariffs of power grid enterprises should become crucial for power grid enterprises, which is the main source of carbon emissions. This paper incorporates carbon costs into accounting grounded on the 2022 transmission and distribution tariff pricing method and analyzes the impact of power grid investment on transmission and distribution tariffs. The aim is to guide power grid investment decisions towards low-carbon power grids.

**Keywords:** power grid investment; carbon cost; transmission and distribution tariffs; dual carbon

## 1. Introduction

In 2020, China proposed carbon peak and carbon neutral targets. Achieving China's dual carbon targets necessitates that power grid investment and construction maintain both high growth and low carbon emissions. In 2022, a revised version of the transmission and distribution tariff pricing method was issued, introducing evident changes to the effective assets scope, price adjustment mechanism, and more, when it is compared with the 2016 version. Consequently, in the transmission and distribution tariff reform context, power grid investment must consider carbon emission costs. This paper explores how power grid investment influences transmission and distribution tariffs after the inclusion of carbon costs, and aims to construct a relationship model. This will accelerate the unified establishment of a carbon emission accounting system as well as promote low-carbon power grid enterprises.

Xiao et al. [1] established a model to investigate the relationship between power grid investment, socio-economic benefit index, and transmission and distribution of electricity prices. They also conducted a probabilistic analysis to predict future transmission and distribution of electricity prices. In a separate study, Yang et al. [2] constructed a grid entry model for clean energy power generation within the constraints of transmission and distribution pricing. Their research explored the interplay between grid investments, transmission and distribution prices, and

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carbon emissions. Wu et al. [3] constructed a linkage model using data envelopment analysis and system dynamics to illustrate the connections between power grid investment, and transmission and distribution of electricity prices. In another approach, Zeng et al. [4] proposed an optimization strategy to determine the investment scale of distribution networks while considering transmission and distribution electricity prices. Zhu et al. [5] delved into the impact of changes in core pricing parameters on grid investment. Tan et al. [6] harnessed the hybrid cuckoo algorithm to solve the multi-business decision optimization models within power grid enterprises, providing valuable insights for power grid investment. Lastly, Cheng et al. [7] introduced a multi-stage investment optimization decision-making method for power grid projects. Their approach was grounded in the context of the reform of transmission and distribution electricity prices, to maximize returns throughout the entire investment period.

While extensive research has been conducted by Chinese scholars on the relationship between power grid investment and transmission and distribution tariffs, there is a noticeable gap in the literature regarding the influence of power grid investment on transmission and distribution tariffs when factoring in carbon costs [8-9]. Building upon the 2020 version of the transmission and distribution tariff pricing method, this paper analyzes the impact of power grid investments on transmission and distribution tariff pricing by incorporating carbon costs throughout the cost analysis using the full life cycle theory. This study not only informs power grid investment decisions but serves as a catalyst for power grid enterprises in pursuing low-carbon goals.

## 2. Linkage relationship model between power grid investment and transmission and distribution tariffs

### 2.1. The relationship between effective assets and transmission and distribution tariffs

Transmission and distribution tariffs are determined by the Provincial Development and Reform Commission (PDRC) in accordance with the provincial power grid transmission and distribution tariff pricing method. This method involves cost audits of the power grid and determines the allowed costs and returns. Figure 1 illustrates the components of the transmission and distribution tariff.

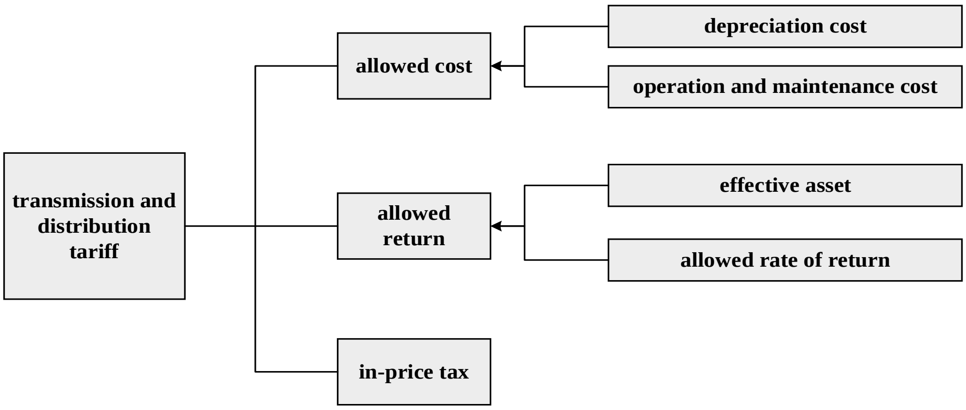

**Figure 1.** Components of transmission and distribution tariffs.

Compared to the 2016 pricing method, the 2020 version introduced three significant changes: (1) It emphasized the importance of effective assets. It stipulated that the ratio of new investments eligible for credit toward fixed assets shall not exceed the upper limit of 75% and shall not surpass the approved value of the preceding regulatory cycle. This measure has further mitigated the A-J effect; (2) It tightened cost constraints. This measure entailed lowering the depreciation rates of equipment and re-stipulating rate caps for materials, repairs, and labor; (3) It adjusted the allowed rate of return, with the return on equity capital no longer being subdivided into policy and general assets. In principle, it should not exceed the return on assets determined by the performance appraisal for the same period.

Clearly, the accounting of transmission and distribution tariffs centers largely on effective assets. The policy clearly outlines that: effective assets of transmission and distribution that can be collectively beneficial, pertain to those assets formed through the investments of power grid enterprises (including government investments or financial allocation investments). These assets are essential for providing transmission and distribution services to utility network subscribers and are granted collective benefits from transmission and distribution assets. Accounting for effective assets offers multiple advantages, such as enhanced asset efficiency management, the maintenance of assets in optimal operational condition, the avoidance of unnecessary subsequent repair and management expenses, and investment costs for new equipment. Furthermore, effective assets contribute to a more precise definition of the “effective degree” of power grid assets, a basis for measurement of transmission and distribution tariffs, an improvement in pricing methodologies, the standardization of investment practices by power grid enterprises, and the advancement of power system reform.

Therefore, it is imperative for power grid enterprises to maximize their investments in projects with higher investment efficiency while ensuring the essential security of the power grid. This strategy aims to secure more favorable transmission and distribution tariff levels in subsequent cycles. As a result, when making investment decisions in the future, power grid companies should prioritize investment scales that feature significant changes in pricing depreciation rates, projects capable of enhancing equipment health, and projects with superior investment efficiencies. Throughout this process, addressing carbon emissions becomes an inevitable consideration.

## 3. Model construction

### 3.1. Allowed costs

Based on the pricing method, it is evident that the allowed cost consists of depreciation costs, operation and maintenance expenses, and other associated costs [10-12]. In this study, we will introduce carbon costs into the allowed cost, utilizing the full life cycle theory as a means to investigate the impact of power grid investments on transmission and distribution tariffs within the framework of current policy guidelines.

(1) Depreciation costs

Depreciation costs are determined through the consistent application of a fixed depreciation rate method to assess power grid assets, aligning with the provincial power grid transmission and distribution tariff pricing procedure using the formula as follows:

$$C_i^z = (A^o + E_i)\times r - (A^0 + \sum_{n-1}^{j} E_j)\times r_{bf} \tag{1}$$

where $C_i^z$ represents the depreciation cost in year $i$; $A^o$ is the initial original value of the asset; $E_n$ refers to the new effective asset in year n; $r$ is the depreciation rate of the original asset; and $r_{bf}$ is the rate of asset obsolescence.

(2) Operation and maintenance costs

Within the pricing method, operation and maintenance expenses encompass materials, repairs, employee compensation, and other costs, with the formula as follows:

$$C_i^m = (A^o + \sum_{j=1}^{i} E_j)(\beta + o) + s \tag{2}$$

where $\beta$ and $o$ are the approved operation and maintenance rates and other rates, respectively; and $s$ represents employee compensation.

(3) Carbon costs

In the "dual-carbon" context, carbon emissions stand as a vital factor that demands consideration to achieve low-carbon economic operations. The cost of carbon emissions consists of two elements: carbon emissions resulting from transmission and distribution losses and those originating from equipment emissions. In this paper, we apply a life cycle analysis to assess the carbon emissions produced by power grid transmission equipment and substation equipment. Applying the life cycle analysis method, we delineate the complete life cycle of grid equipment into five distinct phases: production, transportation, construction, utilization, and decommissioning of equipment. Carbon emissions for each of these phases are aggregated to determine the overall carbon emissions. This total emission value is then multiplied by the carbon price, i.e., the carbon emission cost of the power grid enterprise. The formula is presented below:

$$C_i^t = (I_{sc} + I_{ys} + I_{js} + I_{lsy} + I_{ty})\times P_{co_2} \tag{3}$$

where $P_{co_2}$ refers to the carbon price; $I_{sc}$, $I_{ys}$, $I_{js}$, $I_{lsy}$, and $I_{ty}$ represent the carbon emissions from the five segments of equipment production, transportation, construction, use, and decommissioning, respectively.

Therefore, the formula for calculating the allowed cost is:

$$C_i = C_i^z + C_i^m + C_i^t \tag{4}$$

### 3.2. Allowed return

The allowed return measurement model specified in the pricing method can be expressed as:

$$R_i = E_i \times \varphi \tag{5}$$

where $E_i$ designates the effective assets on which gains can be accrued in year $i$ of the measurement regulatory cycle and $\varphi$ represents the allowed rate of return.

### 3.3. Transmission and distribution tariff measurement models

The transmission and distribution tariff is composed of allowed costs, allowed returns, and the amount of electricity delivered. The formula is as follows:

$$P = \frac{C_i + R_i}{Q} \tag{6}$$

where $Q$ represents the total power delivered by the power grid in year $i$.

## 4. Example analysis

### 4.1. Simulation analysis

Drawing on the pertinent data of various users in a specific southwestern Chinese region, and considering the relatively immature state of the domestic carbon cost market, we have utilized the average carbon trading price as the benchmark for the carbon market price. This approach enables us to assess the cross-subsidy dynamics within transmission and distribution electricity prices while considering carbon cost sharing. Our simulation results presented in Table 1 demonstrate the impact of these factors on new effective assets and transmission and distribution tariffs. Evidently, driven by power grid investments, transmission and distribution tariffs exhibit an upward trend in the early stage. However, in the later stage, investment restrictions and regulatory constraints come into play, causing the investment growth rate to decelerate. Consequently, the transmission and distribution tariffs commence a decline. The shifts in new investments and transmission and distribution tariffs closely align with real-world trends, affirming the model’s credibility.

**Table 1.** New effective assets and transmission and distribution tariffs

| New effective assets | Transmission and distribution tariff |
|---|---|
| 78.7 | 0.2837 |
| 143.55 | 0.3059 |
| 227.92 | 0.3380 |
| 209.67 | 0.3666 |
| 199.22 | 0.3569 |
| 201.23 | 0.3513 |

### 4.2. Scenario simulation analysis

Building upon the baseline scenario data calculated previously, we have developed two distinct scenarios. The first scenario centers on enterprises prioritizing low-carbon policies and augmenting their investments in low-carbon projects. The second one involves enterprises ignoring the cost of carbon emissions and overlooking investments in low-carbon projects for simulation and analysis.

(1) Enterprises prioritizing low-carbon focus and policy-guided investment in green equipment

Enterprises are assumed to prioritize their attention to the financial implications of carbon emissions. They intentionally opt for green equipment when making project investment decisions. However, this strategic choice entails larger initial investments, albeit with less efficient conversion into effective assets. The trade-off lies in a substantial reduction in carbon emissions costs. The detailed results of the calculation are presented in Table 2.

**Table 2.** New effective assets and transmission and distribution tariffs emphasizing carbon costs

| New effective assets | Transmission and distribution tariff |
|---|---|
| 78.7 | 0.3021 |
| 155.23 | 0.4215 |
| 213.97 | 0.4236 |
| 209.45 | 0.5156 |
| 194.45 | 0.4216 |
| 191.23 | 0.3659 |

It can be observed that the transmission and distribution tariffs displayed fluctuations but eventually stabilized within a certain range over a defined period. Concurrently, the trend in new effective assets transitioned from slow growth to a more rapid increase, ultimately maintaining a high level.

(2) Increase in carbon costs as companies neglect the cost of carbon emissions and prioritize investments without considering carbon emissions

It is assumed that enterprises do not give due attention to the financial implications of carbon emissions. Instead, they focus primarily on projects that offer a swift conversion into effective assets when making investment decisions. However, this approach will also increase carbon emissions costs. The specific calculation results are presented in Table 3.

**Table 3.** New effective assets and transmission and distribution tariffs without emphasizing carbon costs

| New effective assets | Transmission and distribution tariff |
|---|---|
| 78.7 | 0.2837 |
| 140.23 | 0.3040 |
| 222.73 | 0.3333 |
| 213.67 | 0.3619 |
| 201.63 | 0.3521 |
| 205.61 | 0.3465 |

The volatility of transmission and distribution tariffs in this scenario is notably pronounced compared to the other two scenarios, characterized by significant fluctuations, which indicates non-compliance with the policy requirements. Additionally, it is worth noting that the growth of new effective assets is faster in the earlier period but experiences a significant decline in the later stages.

(3)Consider cross subsidies, reasonable allocation among different users, and mitigate the carbon costs of the power grid.

Drawing on the current treatment method of cross subsidies, calculate the allocation of carbon costs and cross subsidies among industrial and commercial users, and the results are shown in Figure 2.

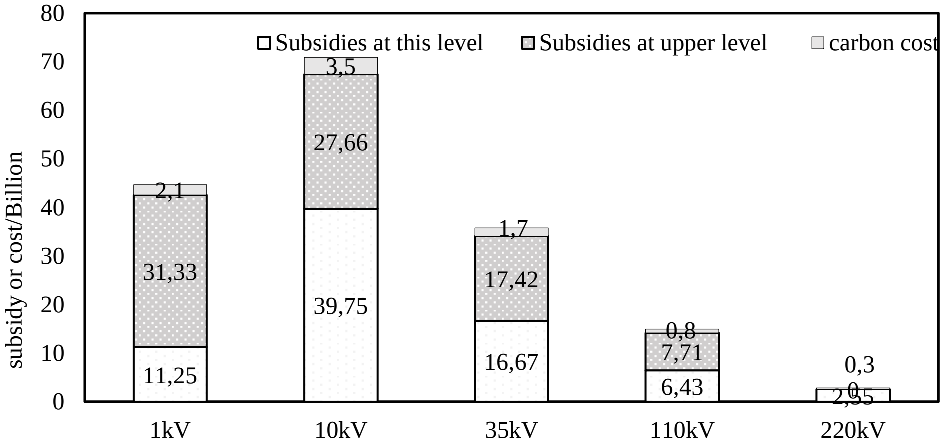

**Figure 2.** Allocation results of subsidies and carbon cost

From Figure 2, it can be seen that among different voltage levels, 10kV industrial and commercial users share the highest subsidy amount, reaching 44.11% of the total subsidy amount. This is mainly due to the high electricity consumption of industrial and commercial users in this voltage level, and they also need to bear the subsidy from the higher level, accounting for 41.03% of the 10kV subsidy amount. Almost half of the cost comes from the higher-level power grid. At the same time, carbon cost allocation is also calculated based on the cross subsidy allocation ratio. Due to the large number of cross subsidies allocated at 10kV, the carbon cost allocated is also high, accounting for 41.67% of the total carbon cost, which is similar to the cross subsidy allocation ratio at this level, and the results are in line with expectations. It should be noted that the carbon cost composition structure is shown in Figure 3.

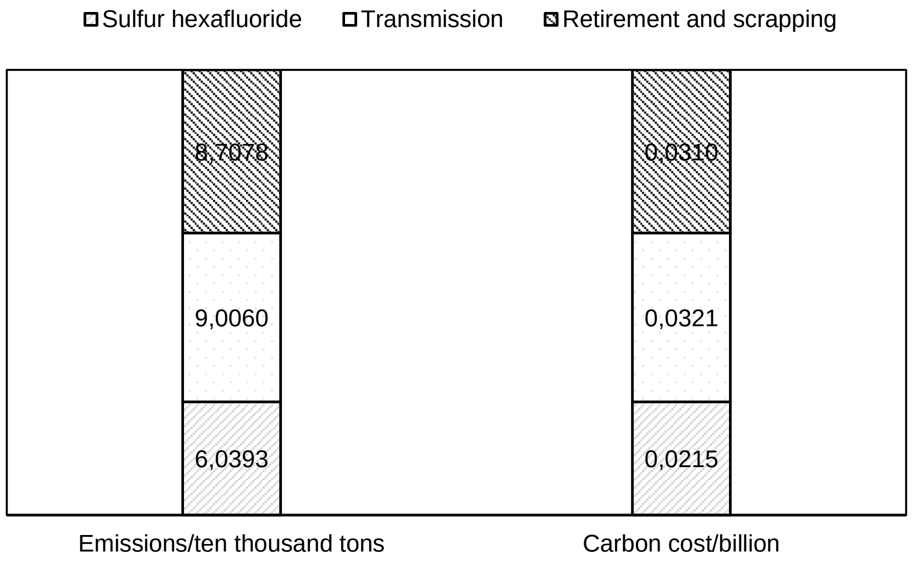

**Figure 3.** Calculation results of carbon cost

## 5. Conclusion

Based on the 2020 version of the pricing method, this paper initially analyzes the differences between the new version and the 2016 version of the pricing method. It establishes a functional relationship between provincial power grid investment and transmission and distribution tariffs within the framework of the 2020 version of the pricing method. Meanwhile, it introduces the cost of carbon emissions, and quantitatively simulates its impacts on transmission and distribution tariffs under different scenarios. The findings underscore the advantages of increased investment in low-carbon projects in shaping the forthcoming transmission and distribution tariff landscape. This strategy not only maintains the stability of transmission and distribution tariffs but also enhances the efficient conversion of new investments into effective assets.

## References

[1] Xiao Y, Liu X, Wan Y et al. (2022) Research on optimization of power grid investment strategy under transmission and distribution tariff regulation--based on the perspective of the relationship between transmission and distribution tariff, power grid investment and social and economic benefits. Price Theory and Practice, 11: 88-92.

[2] Yang Y, Kong J, Yu X et al. (2022) Optimization study of clean energy generation grid-connected portfolio under transmission and distribution tariff constraint. Price Theory and Practice, 07: 169-174.

[3] Wu H, Wang L, Peng D. Research on the Linkage between Power Grid Investment and Provincial Power Grid Transmission and Distribution Tariff [J]. Price Theory and Practice, 2019 (12): 51-54+148

[4] Zeng M, Yu Z, Wang Y, et al. Optimization model for distribution network investment scale based on transmission and distribution electricity price constraints [J]. Smart Power, 2020,48 (11): 1-8

[5] Zhu L, Jin W, Ye B, et al. Simulation and Optimization of Power Grid Investment Strategies under the Background of Transmission and Distribution Electricity Price Reform [J]. Price Theory and Practice, 2021 (05): 101-105.

[6] Tan Z,Tan C,Yu X, et al. (2021) Optimization of smart grid multi-service portfolio investment decision based on hybrid cuckoo algorithm. Smart Power,49(04):51-57+88.

[7] Cheng X, Wu S, Wang J, et al. Research on multi-stage investment optimization decision-making of power grid projects under the background of transmission and distribution electricity price reform [J]. Power System Protection and Control, 2021,49 (15): 116-123.

[8] Yu X, Dong Z, Zheng D. (2023) Research on Critical Peak Price Decision Optimization Considering Industrial Consumer's Risk Appetite under the Carbon Neutrality Goal. SUSTAINABILITY, 15(12): 1-17.

[9] Yu X, Zheng D, Zhou L. (2020) Credit risk analysis of electricity retailers based on cloud model and intuitionistic fuzzy analytic hierarchy process. International Journal of Energy Research, 45(3): 4285-4302.

[10] Andrianesis P, Caramanis M, Li N. Optimal distributed energy resource coordination: a decomposition method based on distribution locational marginal costs. IEEE TRANSACTIONS ON SMART GRID. 2022, 13(2): 1200-1212.

[11] Catrini Pietro; Testasecca Tancredi; Buscemi Alessandro; et al. Exergoeconomics as a cost-accounting method in thermal grids with the presence of renewable energy producers. SUSTAINABILITY. 2022, 14(7).

[12] Dwaikat Luay N.; Ali Kherun N. Green buildings life cycle cost analysis and life cycle budget development: Practical applications. JOURNAL OF BUILDING ENGINEERING. 2018, 18: 303-311.