Environmental Science and Engineering

Fushuan Wen
Jizhong Zhu *Editors*

Frontiers of Energy and Environmental Engineering

Selected Papers from the 2nd International Conference on Frontiers of Energy and Environment Engineering (CFEEE 2023)

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Editors
Fushuan Wen
Zhejiang University
Hangzhou, China

Jizhong Zhu
South China University of Technology
Guangzhou, China

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Contents

Chapter 1
Analysis of Expenditure Benefits with Multi-party Market Participants in the Carbon-Electricity Synergy

Wen Zhao, Qiang Liu, Jie He, Hengzi Huang, and Ruiyang Lu

Abstract This paper introduces the carbon emission trading (CET) mechanism into the electricity spot market, and conducts a unified analysis of expenditure benefits, examining the operation and trading mechanisms of the tripartite market of power generation, grid, and users under the coordination of carbon and electricity. An expenditure benefit analysis model is proposed for each participant, and the impact of CET market operation, changes in user demand share on their expenditure benefit is examined. The results show that the main sources of revenue for power generation and grid come from the price difference of electricity purchase and sale and avoidable capacity expenditure. The operation of the CET market leads to higher electricity market clearing prices, reduces the revenue of power generation and users, and increases the revenue of the grid. With the continuous advancement of electricity market reform, the integration degree of CET and the spot electricity market is constantly deepening, and further research on trading mechanisms and strategies among various stakeholders is necessary.

Keywords Carbon-electricity coordination · Carbon emission trading market · Expenditure benefit rate · Electricity spot market · Dual carbon targets

1.1 Introduction

In the context of the dual carbon goals, China is vigorously promoting the construction of a market system based on carbon-electricity coordination development and establishing a carbon-electricity coordinated management system under a diverse market environment (Bi and Li 2023), making significant contributions to global climate change mitigation.

The carbon emission trading (CET) system in the carbon market is widely considered one of the most effective tools for controlling carbon emissions (Li et al. 2022).

W. Zhao (✉) · Q. Liu · J. He · H. Huang · R. Lu
Zhejiang Power Exchange Center Co., Ltd., Hangzhou 310037, Zhejiang, China
e-mail: zhao_wen@zj.sgcc.com.cn

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In the CET mechanism, each participant (usually a controlled emission enterprise) obtains a certain amount of carbon emission quotas through auctions on the primary CET market and can trade with other participants on the secondary CET market to obtain more quotas to support production or gain benefits using surplus quotas (Li et al. 2022; Demailly and Quirion 2008; Deja et al. 2010; Anger 2010). In recent years, electricity consumption has grown rapidly, and the construction of the electricity market has continued to advance. Although the carbon market and the electricity market operate independently at the institutional level, the two are closely linked and coordinated, and there are price transmission effects between the two mechanisms (Szabo et al. 2006).

It is more in line with the market's actual situation to introduce the carbon emission trading mechanism into the electricity spot market and conduct a unified analysis of expenditure benefits and costs (Day-ahead dispatching scheduling for power grid integrated with wind farm considering influence of carbon emission quota, 2014). Therefore, to analyze the impact of the carbon emission trading market on the expenditure benefits and costs of various market participants, this paper first introduces the coordination model between the carbon emission trading market and the electricity spot market (Hongliang et al. 2017). Based on the trading settlement mechanism of each market participant under the coordination of carbon and electricity, the paper proposes expenditure benefit and cost analysis models for three market participants, including power generation, user-side and grid-side. The paper uses actual grid operation data to quantitatively calculate various indicators and obtain a more complete picture of expenditure benefit and cost situations for each market participant involved in market transactions (Feng 2016; Zhang et al. 2021).

1.2 CET and Electricity Spot Market Synergy Model

To analyze the impact of carbon emissions trading (CET) market operations on the clearing situation of the electricity spot market (Hongliang et al. 2017), this section considers the synergistic interaction between the CET market and the electricity spot market, incorporates carbon trading costs into the unit price bidding of the clearing model, and combines the interaction mechanism of the two markets to reflect the synergistic impact of the CET market.

1.2.1 The Overall Framework of the Electricity Spot Market

Spot market transactions mainly refer to transactions conducted in the day-ahead market and real-time market. The current framework of the Chinese electricity spot market is shown in Fig. 1.1. The expenditure benefit analysis model for the coordinated market of electricity spot and carbon trading in this paper is based on the day-ahead settlement mechanism and real-time settlement mechanism (Feng 2016).

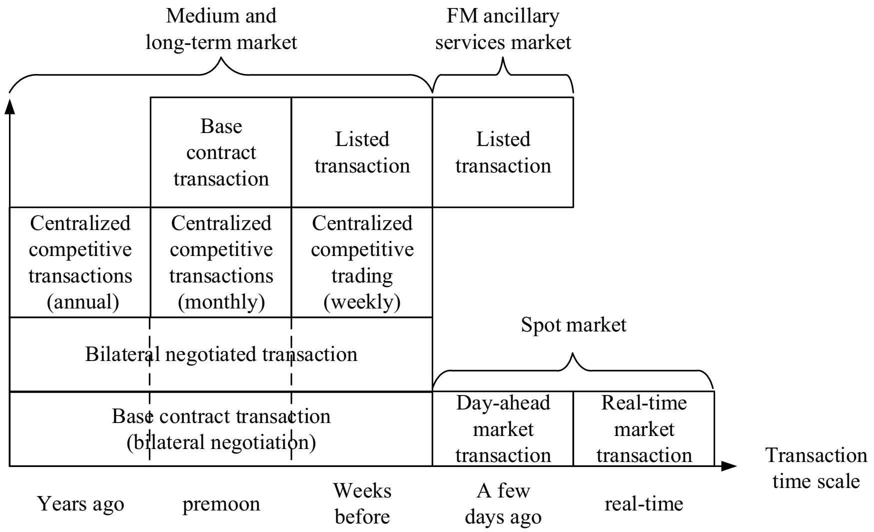


Fig. 1.1 Framework of Guangdong electricity market

1.2.2 *Carbon and Electricity Collaborative Market Clearance Framework*

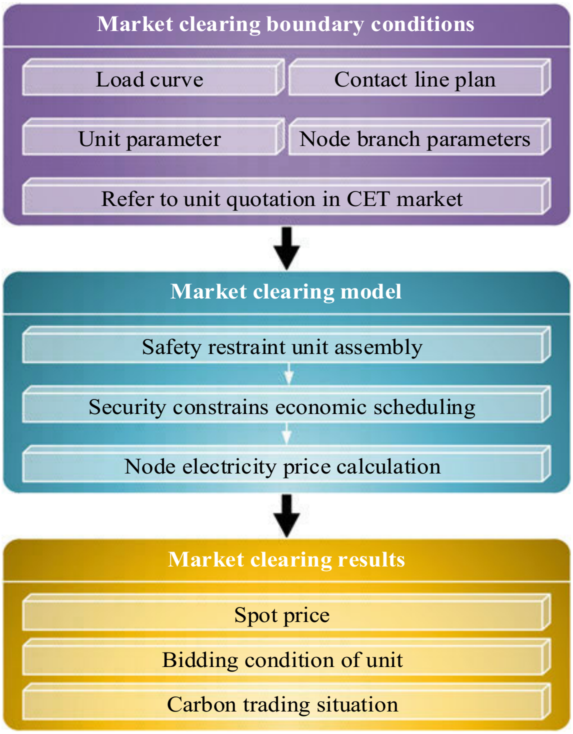
The interaction mechanism between the CET market and the spot market can be summarized as follows: In the CET market, power plants with surplus carbon emission quotas can profit by trading their excess carbon emission quotas. Similarly, when a power plant's carbon emissions exceed the free quotas it received, it needs to pay additional carbon emission costs (Zhang et al. 2021). Therefore, in the spot market, power generation units will evaluate the carbon emission costs they need to pay based on the free carbon emission quotas allocated by the government before bidding in the market (Zhilin et al. 2022).

Incorporating carbon trading costs into the clearing model, the clearing framework of the coordinated market of carbon and electricity is constructed as shown in Fig. 1.2, which calculates the electricity price, unit bidding situation, and carbon trading situation for each node.

1.2.3 *How Free Carbon Allowances Are Allocated*

Currently, China allocates carbon emission quotas on an annual time scale. In this paper, to study the impact of the CET market on the spot market, carbon emission quotas are allocated on a daily time scale. The free carbon emission quotas in the national carbon market are determined by the baseline method. According to this

Fig. 1.2 Framework of electricity market clearing



method, a unit's carbon emission quota is composed of two parts, the electricity supply and heat supply quotas. The carbon emission quota Eq,i that a unit i obtains through the baseline method is given by:

$$E_{q,i} = E_{e,i} + E_{h,i} \tag{1.1}$$

where Ee,i is the carbon emission quota for electricity supply of unit i, and Eh,i is the carbon emission quota for heat supply of unit i. The calculation formula for the carbon emission quota for electricity supply of a unit is:

$$E_{e,i} = P_{e,i} B_{e,i} F_{1,i} F_{t,i} F_{f,i} \tag{1.2}$$

where Pe,i is the electricity output of unit i; Be,i is the electricity generation baseline value for the unit's category, which is determined based on the regulations for carbon emission baseline values for various types of units in China, as shown in Table 1.1; Fl,i is the cooling mode correction coefficient for unit i; Fr,i is the heat supply correction coefficient for unit i; Ff,i is the output correction coefficient for unit i.

Table 1.1 Carbon emission baseline of various unit

Unit category	Power supply reference value (t/MW•h)	Heating benchmark value (t/GJ)
Conventional coal-fired units under 300 MW	1.0026	0.1352
Conventional coal-fired units above 300 MW	1.0889	0.1354
Unconventional coal-fired units	1.2564	0.1348
Gas units	0.4039	0.0589

In addition, the calculation formula for the carbon emission quota for heat supply of a unit is:

$$E_{\mathrm{h},i} = Q_{\mathrm{h},i} B_{\mathrm{h},i} \tag{1.3}$$

where Qh,i is the heat output of unit i, which is proportional to the total heat supply quota of the unit; Bh,i is the heat supply baseline value for the unit's category.

Quotation of conventional units considering the cost of carbon emissions.

After obtaining the free carbon emission quotas, the unit carbon emission cost for the power plant $C_{i,t}^{carbon}$ can be calculated as follows:

$$C_{i,t}^{carbon} = \frac{\left(\sum_{24}^{t=1} \beta_i P_{i,\max} - \eta E_{q,i}\right)\rho_{re}}{\sum_{24}^{t=1} P_{i,\max}} \tag{1.4}$$

where ρ_{re} is the carbon emission price (Zhao 2015), β_i is the carbon emission intensity coefficient for the conventional unit i, η is the proportion of free allocation of quotas, and $P_{i,\max}$ is the maximum output of the conventional unit i in the time period t.

Without considering the CET market, the conventional units submit their offers with an increasing block pricing. With the inclusion of the CET market, the total power generation cost of the conventional unit i will be affected by carbon emission trading. Therefore, each conventional unit will adjust its quotation in the market (Peng and Zhong 2021). The quotation of the conventional unit i in the m-th block in time period t $C_{i,t,m}$ is given by:

$$C_{i,t,m} = C_{i,m} + C_{i,t}^{\mathrm{carbon}} \tag{1.5}$$

where Ci,m is the energy price of the m-th output interval declared by unit i. The operational cost Ci,t of unit i in time period t can be expressed as:

$$C_{i,t} = \sum_{M}^{m=1} C_{i,t,m} P_{i,t,m} \tag{1.6}$$

where M is the total number of bidding blocks submitted by the unit, and Pi,t,m is the awarded electricity quantity of unit i in the m-th output interval in time period t. The market clearing model aims to minimize the system operating cost, subject to safety constraints on unit combinations and economic dispatch. The optimization calculation is performed to obtain the clearing results of the spot market.

1.3 Analysis Model

In the collaborative environment of CET market and spot market, the expenditure and benefit analysis frameworks for each participant on the generation side, user side, and grid side have been developed. The formulas for calculating various indicators have been proposed to evaluate the expenditure and benefits of demand response under the collaboration of CET market and spot market. The specific framework is shown in Fig. 1.3.

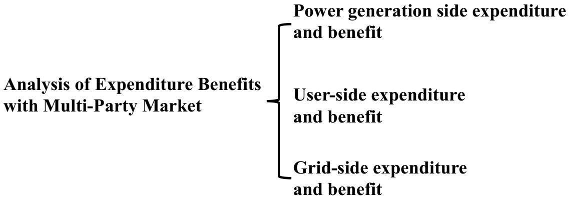
1.3.1 Power Generation Side Model

The overall benefit model is:

$$G = B_{\mathrm{c}} + B_{\mathrm{r}} + B_{\mathrm{LCfD}} + B_{\mathrm{DR}} - C_{\mathrm{g}} - C_{\mathrm{ch}} \tag{1.7}$$

In the formula, G represents the total income of the generation side, Bc represents the settlement income of the day-ahead market, Br represents the settlement income of the real-time market, BLCfD represents the settlement income of the mid-to-long term market for the generation side, BDR represents the income of the generation side under demand response, Cg represents the generation cost and carbon emissions trading costs, and Cch represents the market deviation assessment cost for the generation side.

Fig. 1.3 Overall analysis framework



Benefits Analysis Model

(1) Day Ahead Market Settlement Gains:

$$B_c = \sum \left[\left(Q_{Gc,t} - Q_{\mathrm{GL},t} \right) \rho_{Gc,t} \right] \tag{1.8}$$

where QGc,t is the demand for electricity in the day-ahead market of the power generation side in time period t; QGL,t is the contracted electricity volume of the power generation side in the medium and long-term market in time period t; and ρ Gc,t is the day-ahead node electricity price in time period t.

(2) Real-time market settlement revenue:

$$B_{\mathrm{r}} = \sum \left[\left(Q_{\mathrm{u},t} - Q_{\mathrm{Gc},t} \right) \rho_{\mathrm{Gr},t} \right] \tag{1.9}$$

In the equation, Qu,t represents the real-time online electricity volume on the power generation side of the market, and $\rho_{\mathrm{Gr},t}$ represents the real-time node electricity price for time period t.

(3) Medium-to-long-term market settlement revenue:

$$B_{LCfD} = \sum Q_{GL,t} \rho_{GL,t} \tag{1.10}$$

In the equation, QGL,t represents the net contracted electricity volume for the medium-to-long-term during time period t, and $\rho_{\mathrm{Gr},t}$ represents the net contracted price for unit t during that period.

(4) Demand Response (DR) benefits:

$$\begin{cases} B_{\mathrm{DR}} = B_{\mathrm{i}} - C_{\mathrm{drg}} \\ B_{\mathrm{i}} = \sum c_{\mathrm{o}} P_{\mathrm{DR},t} \\ C_{\mathrm{drg}} = \sum \left[(\rho_{\mathrm{Gr},t} - \rho_t) \Delta Q_{\mathrm{DR},t} \right] \end{cases} \tag{1.11}$$

In the equation, Bi represents the reduced expenditure cost of the power generation side due to demand response; Cdrg represents the reduced power generation revenue of the power generation side due to demand response; co represents the daily expenditure cost per unit of electricity generation capacity; PDR,t represents the power generation capacity for demand response during time period t; ρt represents the bid price of the power generation side during time period t; ΔQDR,t represents the change in electricity consumption before and after demand response during time period t.

Expenditure Analysis Model

(1) Generation and carbon emission trading costs:

$$C_g = \sum \rho_t P_t \tag{1.12}$$

In the equation, Pt represents the output power of the unit during time period t.

(2) Market deviation penalty costs:

$$\begin{gathered} C_{\mathrm{ch}} = \sum \max\left\{\rho_{\mathrm{Gc},t} M_{\mathrm{g}},\, \rho_{\min}\right\} \\ \max\left\{P_{\mathrm{dec,gDR},t} R_{\mathrm{g}} - P_{\mathrm{real,gDR},t},\, 0\right\} \end{gathered} \tag{1.13}$$

In the equation, Mg is the penalty factor; ρmin is the lower limit of the assessed price; Pdec,gDR,t is the declared response capacity of the power generation side; Preal,gDR,t is the actual response capacity of the power generation side; Rg is the response ratio threshold.

1.3.2 User-Side Model

The overall benefit model is:

$$U = B_{df} + B_{loss} + B_{rei} - C_{df} - C_{loss} - C_{uch} - C_{mu} \tag{1.14}$$

In the equation: U represents the total benefit for demand response users; Bdf represents the reduced electricity cost for users participating in demand response; Bloss represents the reduced network loss cost for users participating in demand response; Brei represents the compensation received by users participating in demand response; Cdf represents the electricity cost paid by users; Closs represents the network loss cost borne by users; Cuch represents the demand response participation cost for users; Cmu represents the operation and management cost paid by users to the load aggregator.

Benefits Analysis Model

(1) Cost savings in electricity bills from participating in demand response:

$$B_{\mathrm{df}} = \sum \left(Q_{\mathrm{DR},t} \rho_{\mathrm{df},t}\right) \tag{1.15}$$

In the equation, QDR,t represents the amount of electricity reduced by the user during time period t due to participation in demand response, and ρdf,t represents the electricity bill the user has to pay during that period:

$$\rho_{\mathrm{df},t} = \rho_{\mathrm{Gr},t} + \rho_{\mathrm{tran},t} + \rho_{\mathrm{fund},t} \tag{1.16}$$

In the equation, ρtran,t represents the transmission and distribution price during time period t, and ρfund,t represents the unit price of the fund and its surcharge.

(2) Cost savings in network loss from participating in demand response:

$$B_{loss} = \sum \left(\Delta Q'_{\mathrm{loss},t} - \Delta Q_{\mathrm{loss},t} \right) \rho_{\mathrm{dr},t} \tag{1.17}$$

In the equation, ΔQ’loss,t represents the total network loss during time period t before participating in demand response, and ΔQloss,t represents the total network loss during time period t after participating in demand response.

(3) Compensation received from participating in interruptible load programs:

$$B_{\mathrm{rei}} = \sum_{N}^{n=1} b_{rei,n} Q_{\mathrm{DR}} \tag{1.18}$$

In the equation, brei,n represents the unit compensation price provided by the load aggregator for the n-th time the user participates in demand response, QDR represents the amount of electricity reduced due to demand response, and N represents the number of times demand response occurs.

Expenditure Analysis Model. User electricity expenditure:

$$C_{\mathrm{df}} = \sum \left(Q_{\mathrm{day},t} \rho_{\mathrm{df},t} \right) \tag{1.19}$$

In the equation, Qday,t represents the actual electricity consumption of the user during time period t.

Costs incurred for bearing network losses:

$$C_{\mathrm{loss}} = \sum \left(\Delta Q_{loss,t} \rho_{\mathrm{df},t} \right) \tag{1.20}$$

Costs incurred for demand response performance assessment of users:

$$\begin{gathered} C_{\mathrm{uch}} = \sum \max\left\{ \rho_{\mathrm{df},t} M_{\mathrm{u}}, \rho_{\min} \right\} \\ \max\left\{ P_{\mathrm{dec,uDR},t} R_{\mathrm{u}} - P_{\mathrm{real,uDR},t}, 0 \right\} \end{gathered} \tag{1.21}$$

In the equation, Mu represents the penalty factor, Pdec,uDR,t represents the declared response capacity of the user, Preal,uDR,t represents the actual response capacity of the user, and Ru represents the response ratio threshold.

1.3.3 Grid-Side Model

The total benefit model is:

$$\begin{aligned} P = {} & B_{\text{pc}} + B_{\text{pr}} + B_{\text{pLCCD}} + B_{\text{pDR}} + B_{\text{ploss}} \\ & - C_{\text{ploss}} - C_{\text{reg}} - C_{\text{mp}} \end{aligned} \tag{1.22}$$

In the equation: P represents the total benefit of the grid side, Bpc is the settlement benefit of the difference in purchase and sale of electricity in the day-ahead market, Bpr is the settlement benefit of the difference in purchase and sale of electricity in the real-time market, BpLCfD is the settlement benefit of the difference in purchase and sale of electricity in the medium- and long-term market, BpDR is the total benefit of implementing demand response on the grid side, Bploss is the benefit of load increase caused by network losses, Cploss is the cost of avoiding network losses by implementing demand response, Creg is the compensation paid by the grid to the load aggregator, and Cmp is the project management cost of the grid.

Benefits Analysis Model. Price differential revenue from buying and selling electricity in the day-ahead market:

$$B_{\text{pc}} = \sum \left[\left(Q_{\text{Uc},t} - Q_{\text{UL},t} \right) \left(\rho_{\text{selll},t} - \rho_{\text{Gc},t} \right) \right] \tag{1.23}$$

In the equation, QUc,t represents the user's demand for electricity in the day-ahead market during time period t, QUL,t represents the user's demand for electricity in the medium-to-long-term market during time period t, and ρsell,t represents the selling electricity price in the grid during time period t.

Price differential revenue from buying and selling electricity in the real-time market:

$$B_{\text{pr}} = \sum \left[\left(Q_{\text{u},t} - Q_{\text{Uc},t} \right) \left(\rho_{\text{sell},t} - \rho_{\text{Gr},t} \right) \right] \tag{1.24}$$

In the equation, Qu,t represents the online electricity volume of the unit in the real-time market.

Price differential revenue from buying and selling electricity in medium-to-long-term contracts:

$$B_{\text{pLCCD}} = \sum \left[Q_{\text{UL},t} \left(\rho_{\text{sell},t} - \rho_{\text{GL},t} \right) \right] \tag{1.25}$$

Benefits of implementing Demand Response (DR)

$$\begin{cases} B_{\text{pDR}} = B_t - C_{\text{g}} \\ B_t = \sum c_t P_{\text{DR},t} \\ C_{\text{g}} = \sum \left(\rho_{\text{sell},t} - \rho_{\text{Gr},t} \right) \Delta Q_{\text{DR},t} \end{cases} \tag{1.26}$$

In the equation, Bt represents the expenditure cost of avoided capacity for the grid company, Cg represents the reduction in electricity sales revenue on the grid side due to the implementation of demand response, and ct represents the daily expenditure cost of avoided capacity per unit for the grid company.

Revenue from load increase caused by network loss:

$$B_{\text{ploss}} = \sum \left(\Delta Q_{\text{loss},\rho_{\text{sell},t}}\right) \tag{1.27}$$

Expenditure Analysis Model. Revenue/cost savings from avoided network loss due to the implementation of demand response:

$$C_{\text{ploss}} = \sum \left(\Delta Q_{\text{loss},t} - \Delta Q_{\text{loss},t}\right)\rho_{\text{sell},t} \tag{1.28}$$

Compensation fees paid to load aggregators:

$$C_{\text{reg}} = \sum_{N}^{n=1} c_{\text{reg},n} Q_{\text{DR}} \tag{1.29}$$

In the equation, creg,n represents the unit compensation price provided by the grid for the n-th time the load aggregator participates in demand response.

1.4 Simulation Analysis

1.4.1 Simulation Scenario

To quantify the cost–benefit model of the tripartite synergy in the carbon-electricity trading market, this paper used a typical operating day (with peak load) as the simulation background and simulated the demand response scenario. The real load data for that day in the province was used to clear the market. In this example, the error between the day-ahead load forecast data and the actual load data was set to 5%, and the medium-to-long-term contract electricity volume was decomposed into daily electricity volumes, with a daily electricity volume ratio set at 0.85.In the example, demand response reduced peak load by a total of 3%, of which 2% was reduced by user participation in demand response, and 1% was shifted through discharging of energy storage during peak load periods and supplemented during low load periods (00:00–08:00), as shown in Fig. 1.4.

The simulation parameter settings for the expenditure and revenue analysis model are shown in Table 1.2. The relevant parameters and cleared electricity prices obtained were used for the simulation calculation of the expenditure-benefit for each market participant in the following sections.

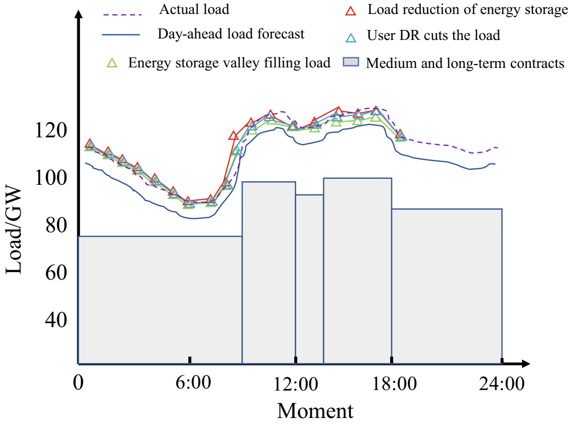


Fig. 1.4 Schematic diagram of load and demand response scenarios

Table 1.2 Simulation parameters

Parameter	Numeric value	Parameter	Numeric value
η/%	95	ρ_{re}/(yuan/t)	55
M_g	0.6	c_t/(yuan/KW)	1
M_U	0.8	c_o/(yuan/KW)	6
R_g/%	80	ρ_{min}/(yuan/KWh)	0.5
R_u/%	80	$\rho_{tran,t}$/(yuan/KWh)	0.0278
c_{op}/%	0.5	c_{BRC}/(yuan/KWh)	2000
σ_{DOD}/%	90	C_{mu}/(yuan/a)	200,000
N	2	C_{mi}/(yuan/a)	10,000
N_{CL}	3500	C_{mp}/(yuan/a)	1,000,000

1.4.2 Simulation Results

Using the model and simulation parameters described in this paper, the cost–benefit for each market participant was quantitatively calculated, and the results for various indicators are shown in Figs. 1.5, 1.6, and 1.7. The solid lines represent benefit indicators, while the dashed lines represent cost indicators. The overall benefits for each market participant on the operating day are shown in Table 1.3.

It can be seen that the benefits for the power generation side mainly come from the reduction in unit expenditure due to demand response and the generation revenue in the spot market, with overall significant benefits. The user's participation in demand response programs brings certain benefits, but since the cost mainly comes from consuming electricity, the overall benefits are negative. The benefits for the grid side mainly come from the price differential revenue from buying and selling electricity

Fig. 1.5 Generation-side results for each time period

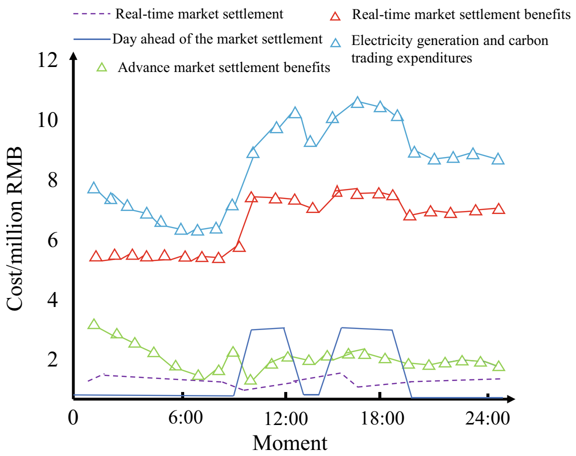


Fig. 1.6 User-side results for each time period

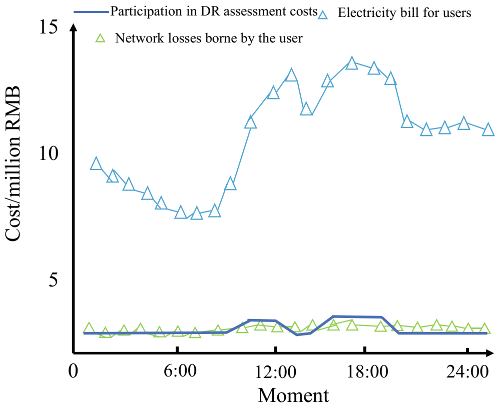


Fig. 1.7 Grid-side results for each time period

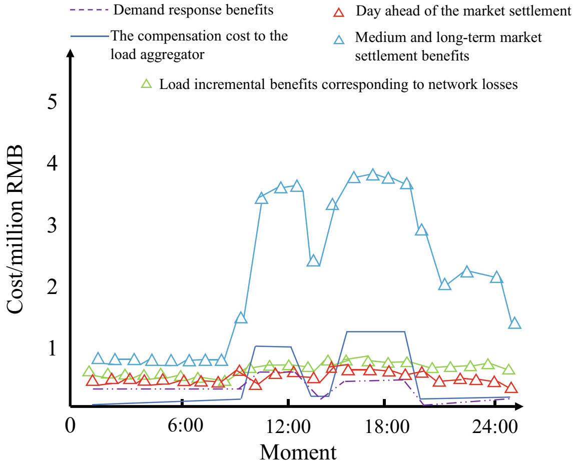


Table 1.3 Total benefit of each market entity on operation day

Market subject	Total daily operating benefit/ten thousand yuan
Generating side	9501.146
User side	−262,038.592
Grid side	68,972.327

in various markets, and the implementation of demand response also brings a significant amount of avoided capacity expenditure, making its overall benefits the highest among all market participants.

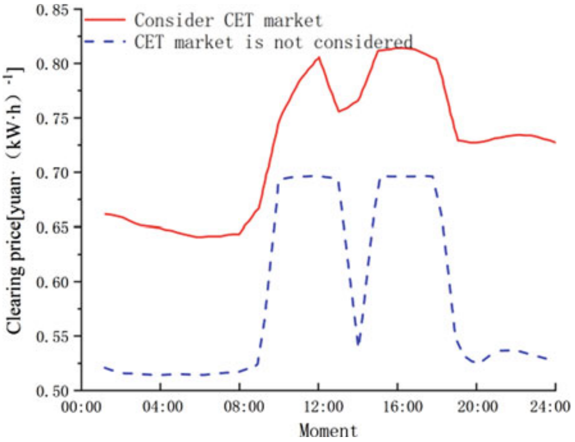
1.4.3 Consider the Impact of the CET Market

Based on the interaction mechanism between the CET market and the spot market and the proposed clearance framework in this paper, it can be seen that carbon emission trading will change the market clearing price, thus affecting the benefits of each market participant. Figure 1.8 provides a comparison of the cleared electricity price in the day-ahead market with and without considering the impact of the CET market.

It can be seen that the market clearing price changes significantly when considering the operation of the carbon market. The cleared electricity price in all time periods during the day is significantly higher than when the operation of the carbon trading market is not considered, with the highest increase of 29.98%. However, the overall trend of price changes is basically the same.

In addition, when not considering the operation of the CET market, the unit carbon emission cost is not included in the unit pricing function, which will greatly reduce the control of the CET mechanism on the total carbon emissions. To highlight the

Fig. 1.8 Comparison of clear electricity prices



emission reduction effect after considering the operation of the CET market, this paper compared the cleared results under two modes: with and without considering the CET market, as shown in Table 1.4.

It can be seen that, although considering the operation of the CET market cannot reduce the total operating costs of units, it can reduce the output of conventional units in the CET market to some extent and effectively reduce the total carbon emissions. Figure 1.9 compares the total benefits of each market participant on the operating day under the two modes.

From Fig. 1.9, it can be seen that the operation of the CET market mainly affects the benefits of the power generation side, the user side, and the grid side. This is mainly because considering carbon emission trading will raise the market clearing price, and the electricity cost of users will also increase, resulting in a decrease in the benefits of the power generation side and the user side, while the benefits of the grid side increase. Among them, the impact of the CET market on the benefits of the power generation side is the largest, and the benefits of the power generation side are reduced by 61.78% when considering the CET market.

Table 1.4 Comparison of the clearing results of the two modes

Operating mode	Unit operating cost	Output of coal-fired unit/MW	Total carbon emissions/t
Consider CET market	2,024,336.08	2,406,373.28	1,639,959.54
CET market is not considered	1,630,385.84	2,728,763.45	1,828,271.51

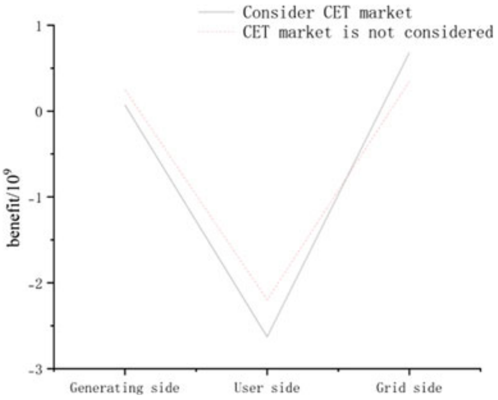


Fig. 1.9 The change of the total benefit of each entity in the two operating days

1.5 Conclusion

This article studies the operational and transactional mechanisms of market participants in the power generation side, user side, and power grid side in the CET market and spot market synergy. A expenditure-benefit analysis model is established for the three-party market participants, and various indicators are quantitatively calculated using actual grid operation data, explores the impact of CET market operations, changes in user demand response ratio on expenditure-benefit for all parties.

In conclusion, the income on the power generation and grid side is mainly based on the price difference between purchases and sales, and implementing capacity investments that can be avoided by demand response. While demand response can bring certain benefits to users, they may have to pay high electricity costs, resulting in an overall negative benefit. The operation of the CET market affects the efficiency of the power generation, user, and grid sides. Overall, optimizing demand response and carbon emissions trading policies can potentially create a more efficient and sustainable energy system.

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Chapter 2
Management and Practice on Classified Hazardous Waste in Laboratories of Universities in China

Chaoyi Jiang, Kezhong Chen, Haifeng Lin, Ming Lin, Qin Cui, Dongya Sun, and Lei Jin

Abstract Hazardous waste produced in university laboratory has a tremendous harm. If hazardous waste in laboratory is disposed improperly, it will cause immeasurable pollution and harm to laboratory safety, environment and human body. This paper takes the current management situation as starting point, analyses and summarizes the classification and treatment methods and experience of hazardous waste in laboratories of Xiamen University of Technology. Starting from top-level design of hazardous waste management, the mode is put forward that establish and improve the management mechanism, strengthen education and training, build an information

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C. Jiang (✉) · K. Chen · H. Lin · M. Lin
Office of Assets and Laboratory Equipment Management, Xiamen University of Technology, Xiamen, China
e-mail: jiangchaoyi@xmut.edu.cn

K. Chen
e-mail: chenkezhong@xmut.edu.cn

H. Lin
e-mail: hflin@xmut.edu.cn

M. Lin
e-mail: linming@xmut.edu.cn

Q. Cui
School of Opto-Electronic and Communication Engineering, Xiamen University of Technology, Xiamen, China
e-mail: 2020000005@xmut.edu.cn

D. Sun
School of Materials Science and Engineering, Xiamen University of Technology, Xiamen, China
e-mail: 2013123205@xmut.edu.cn

L. Jin
School of Environmental Science and Engineering, Xiamen University of Technology, Xiamen, China
e-mail: jinl@xmut.edu.cn

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