Research on Value Estimation of Carbon Capture, Utilization and Storage Project

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ABSTRACT

Economic value is an important indicator to judge whether a Carbon Capture, Utilization and Storage (CCUS) project is worth investing in, and it provides a scientific basis for the decision to establish a public finance system. This paper analyses the value chain composition of CCUS projects, establishes a value evaluation model for CCUS using cost analysis, and uses examples to make a case study on the value estimation of CCUS projects. It provides a reference basis for decision making on the government's financial input and policy formulation.

Keywords: *CCUS, Value estimation, Value chain, Public finance.*

1. INTRODUCTION

Economic value is an important indicator to determine whether a CCUS project is worth investing in, and it provides a scientific basis for making decisions on the establishment of a public finance system. It is a prerequisite for the formulation of public finance policies for CCUS, and an important foundation for the development of public finance policies for CCUS, which is to transform the non-accountable value of CCUS into accountable wealth by estimating the cost value of CCUS projects.

Without value estimation of CCUS, the formulation of public finance policies will lack a reference basis and will remain in theoretical emphasis. Without value estimation of CCUS, the government will not be able to determine the specific amount of capital investment and financial subsidies based on the value of CCUS, and will not be able to solve the financial bottlenecks encountered in the development of CCUS.

Estimating the value of CCUS is conducive to promoting the quantification of the value of CCUS, which in turn provides a scientific basis for investment decisions in CCUS projects. It is also conducive to promoting the rational utilization and effective flow of national resources in various aspects of CCUS output, and improving the economic, social, and ecological benefits of CCUS projects. It can also provide quantifiable amounts for public financial investment and policy formulation, promote coordination between public financial investment and corresponding policy formulation and implementation, and regulate various interests during policy implementation. The CCUS value estimates are used as a basis for making projections on the current status of CCUS development, future trends and the extent to which they will guarantee economic and social development and sustainability, and provide an important basis for national policy formulation. It helps to leverage the law of value and price to regulate the relationship between supply and demand and to guide the rational allocation of CCUS resources and the direction of the use of various "carbon products".

2. ANALYSIS OF THE VALUE CHAIN COMPOSITION OF CCUS

The CCUS system is a complex system that integrates technology, enterprise and industry. To complete the value determination of the entire CCUS system, it is necessary to first identify the value generated by each of the four constituent links of the system, and then aggregate the value of these four links, i.e. the total value of CCUS. In order to calculate the value of each of the carbon capture, transport, storage and reuse links, a model of the composition of the carbon dioxide value chain can be constructed based on the carbon dioxide handling process, and then the value of the chain can be analysed and calculated based on its value chain composition.

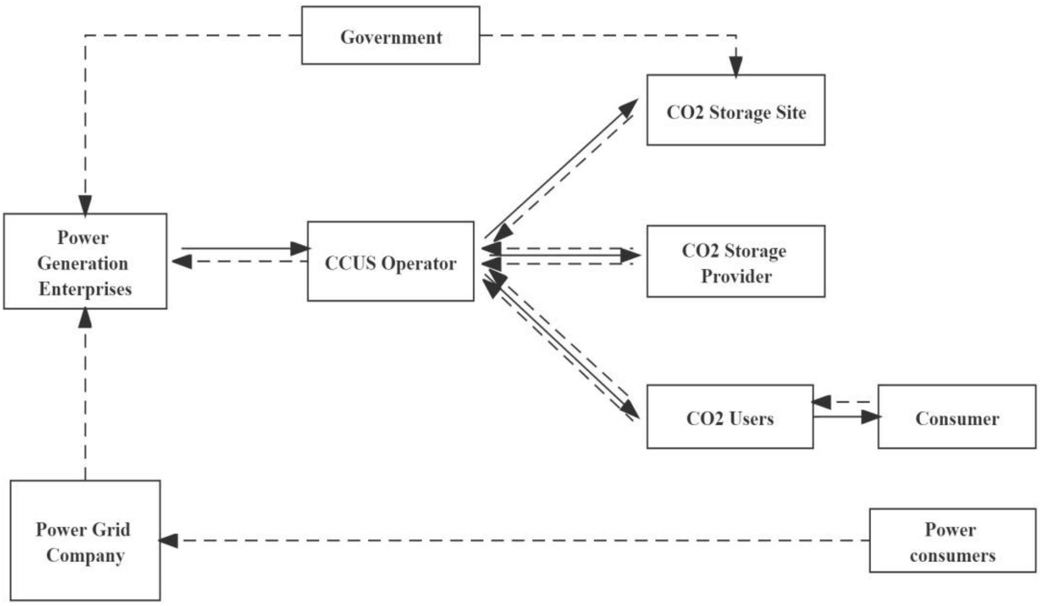

Figure 1 Diagram of the CCUS value chain operation model.

The solid line in the diagram ("Figure 1") indicates the direction of the CCUS value chain operation, and the dashed line indicates the direction of the CCUS capital flow.

2.1 The Value Chain Components of CCUS

The CCUS system consists of four stages: the capture stage, the transport stage, the storage stage and the reuse stage of carbon dioxide. In the different stages of the system, carbon dioxide is handled in different ways, and it takes different specific forms. In the different forms, carbon dioxide transfers value and forms a value chain for carbon dioxide.

In this value chain, carbon dioxide is initially released in its original form during the production process, generally in the chemical industry, steel manufacturing, power generation, oil industry, mineral products production, etc., with the power generation industry being the main one. The treatment of this form of CO_2 is the first stage of the CCUS system, i.e. the capture of CO_2, which is also the first stage of the CO_2 value chain. Given that the power generation industry is the largest source industry, this book assumes that the capture of CO_2 is done in the power generation companies.

In its raw form, CO_2 exists in liquid, gaseous form after it has been treated to a certain standard by means of capture technologies such as post-combustion separation or pre-combustion separation or oxygen-enriched combustion separation. This form of CO_2 is transported by pipeline, ship or other means of transport to the storage or use sector, which is the middle stage of the CO_2 value chain in the CCUS system.

The third stage of the CO_2 value chain is the direct storage of CO_2 underground or under the sea.

The fourth stage of the CO_2 value chain is the reuse of CO_2 by processing, manufacturing and converting it into organic matter or injecting it into oil or gas reservoirs.

2.2 The Financial Flow Operating Model of the CCUS

The four stages of the CCUS value chain contain operators that process CO_2 at different stages: capturers, transporters, storers and users of CO_2. These four types of operators not only transform the value stream of CO_2, but also allocate the financial flows in the CCUS system.

At the beginning of the value chain in the CCUS system, the power producer has to invest in retrofitting existing equipment for the capture of CO_2. At the same time, the power station, which is the start of the CO_2 value chain, sells the collected CO_2 to the operator (transport sector) for a fee on the one hand, and on the other hand, in order to cover the cost of the retrofitting investment, the power station increases the tariff proportionally to the price of electricity. This increased cost is borne by the grid company, which will ultimately receive compensation from consumers. As an important industry for CO_2 abatement, the government will also grant a certain level of subsidy to power stations.

In the middle of the value chain is the transport part of the CCUS, where the operator is responsible for selling the CO_2 purchased from the power station to CO_2 users and storers at a profit, as well as incurring the cost of investing in the infrastructure for CO_2 transport and its operation and maintenance.

The third stage of the CO_2 value chain is storage, i.e. the direct sequestration of CO_2, where CO_2 is injected underground or into the ocean for long-term storage to reduce the amount of CO_2 in the air. In this process, the government, as the representative of the public interest, is responsible for its costs.

The industry at the final end of the value chain consists of two parts: the storage operators, who adopt CO_2 drive technology to increase oilfield (CBM) recovery and extend the production life of the oilfield (coal seam) for a portion of the profits; and the producers, who continue to use the use value of CO_2, converting it into products or using it to increase production, who buy CO_2 from the operators and put it into production processes, eventually converting it into products, such as fertilisers, CO_2-degradable plastics, etc., which are sold to consumers, thus making a profit.

The value components of the CCUS system value chain are shown in "Figure 2".

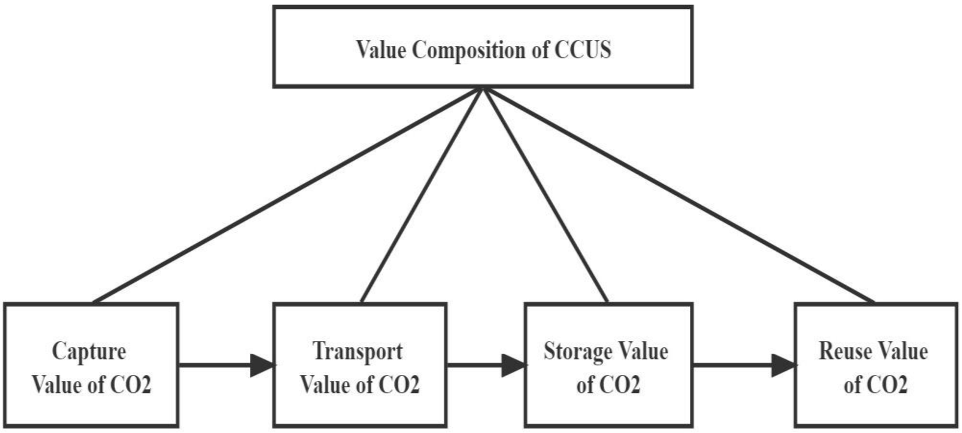

Figure 2 Value composition of the CCUS system.

3. VALUE ESTIMATION MODEL OF CCUS

The value of a CCUS project consists of the value of CO_2 capture, the value of CO_2 transport, the value of CO_2 storage and the value of CO_2 reuse. The value of CO_2 transport is the amount of money that the CCUS operator has to invest in the transport system and is measured by the amount of input from the operator. The value of CO_2 reuse should be measured by aggregating the cost of the two uses of CO_2 at that stage: firstly, the cost of the input required to inject CO_2 into the oil or gas reservoir to enhance recovery using CO_2 drive technology. The second is the capital required to reprocess the CO_2 as a raw material for production to produce new industrial manufactured products or foodstuffs.

Taking the above analysis together, the model for estimating the value of a CCUS project can be expressed as:

$$V_T = V_c + V_t + V_s + V_r \qquad (1)$$

$$V_{\mathrm{r}} = V_e + V_u \qquad (2)$$

where

V_r ——the value of the CCUS project.

V_c ——the cost invested in the project's power station for CO_2 capture.

V_t ——the cost of transport used that has been invested in the project.

V_s ——the cost of direct CO_2 sequestration for the project.

V_r ——the total value invested in the reuse of CO_2 from the project.

V_e ——the cost of the inputs required for CO_2 removal from the project.

V_u ——the cost of inputs for resource-based reuse of CO_2 from the project.

3.1 Value Determination for CO_2 Capture

The power station is the starting point of the CCUS value chain and its effectiveness in capturing CO_2 directly affects the operation of the CCUS project. According to the previous analysis of the CCUS system capital flow operation model, in order to carry out a CCUS project, the power station must invest a large amount of money to modify the existing equipment and, depending on the actual situation, adopt post-combustion separation technology or pre-combustion separation technology or oxygen-enriched combustion technology and install the corresponding CO_2 capture system to ensure the normal operation of the carbon capture system. After completing the CO_2 capture, the power station sells the collected CO_2 to the operator of the CCUS project for the next stage of transportation. In addition, the plant will receive revenue in the form of a tariff increase to cover the cost of investment in equipment and operating costs arising from the retrofit.

Under such an operating model, the value of CO_2 capture is measured as:

$$V_c = C_c + T_c - P_{CO_2} \times r \times Q_e - P_e \times Q_e \quad (3)$$

where

C_c ——the investment in equipment modifications and total operating costs of the power station to capture CO_2.

T_c ——Taxes for the power producer.

P_{CO_2} ——the price of CO_2 sold to the operator in (yuan/tonne CO_2).

r ——the amount of CO_2 captured per kWh.

Q_e ——the amount of electricity sold by the grid company.

P_e ——electricity price.

Due to the increase in the price of electricity, the amount of electricity purchased by the grid company is inversely related to the increase in the price of electricity, thus:

$$Q_e = aP_e^{-b} \quad (4)$$

In equation (4), the price of elasticity for power producers, here > 1, is because the exclusivity of China's grid resources dictates that it has a choice of power producers and can achieve its elasticity of demand through product substitution.

3.2 Determining the Value of CO_2 Transport

The transport of CO_2 is in the middle of the value chain and is an important part of the CCUS project, where the operator is responsible for the planning, investment and operation of the entire CO_2 transport system. The operator purifies and compresses the CO_2 and then selects the appropriate transport method depending on the end use of the CO_2. In the case of geological storage or CO_2 reuse, the operator can use road tankers, rail tankers or pipeline transport, with pipeline transport being the main option, or in the case of marine storage, ship transport. The infrastructure investment and operation and maintenance costs of the different transport modes differ. For calculation purposes, it is assumed that the operator's transport network has been optimised and that their transport costs are only related to the quantity transported.

Operators make a profit from transporting and selling the CO_2 purchased from power stations to CO_2 storage sites and reuse sites. Their sales revenue comes from three sources.

First, direct transport to the storage site to complete storage, which reduces atmospheric CO_2 emissions, reduces the greenhouse effect, mitigates the climate crisis and has significant externalities, so the government, as the representative of the public interest, is responsible for the direct storage process and all costs incurred in this segment are paid for by the government.

Secondly, it is sold to the oil and coal industry, which uses CO_2-EOR, CO_2-EGR, CO_2-ECBM, etc., to improve the recovery of oil and gas fields, and receives sales revenues from this industry.

Thirdly, it is sold to, and sales revenue is received from, companies that use CO_2 as a raw material for production for resource and large-scale reuse, such as pharmaceuticals, beverages, chemicals, etc.

Thus, the formula for determining the value of CO_2 transport can be expressed as:

$$V_t = C_t + P_{CO_2} \times r \times Q_e + T_t - P_g \times Q_g - P_{m_1} \times Q_{m_1} - P_{m_2} \times Q_{m_2} \quad (5)$$

where

C_t ——Total cost of investment and maintenance of the CO_2 transport system.

P_{CO_2} ——The purchased CO_2 tariff in (yuan/ton CO_2).

r ——the amount of CO_2 collected per kWh.

Q_e ——the amount of electricity sold by the grid company.

T_t ——Taxes paid by the operator.

P_g ——the price of CO_2 sold to government sequestration sites.

Q_g ——the amount of CO_2 sold to government sequestration sites.

P_{m_1} ——the price of CO_2 sold to the oil industry or the coal industry.

Q_{m_1} ——the amount of CO_2 sold to the oil sector or the coal sector at one time.

P_{m_2} ——the price of CO_2 sold to the CO_2 reuse sector at one time.

Q_{m_2} ——the amount of CO_2 sold to the CO_2 reuse sector on a one-to-one basis.

3.3 Determining the Value of CO_2 Sequestration

CO_2 sequestration plays a vital role in the proper operation of CCUS systems. This link reflects the important value of CCUS, which is conducive to achieving effective carbon emission reduction, achieving greenhouse gas reduction targets, improving the human climate environment and generating significant externalities. Therefore, the government bears the costs arising from CO_2 sequestration, which is measured by the value expression:

$$V_s = C_s + P_g \times Q_g \quad (6)$$

where

C_s ——the total cost of equipment, manpower, etc. invested by the government in the sequestration process.

P_g ——the price of CO_2 purchased by the government from the operator.

Q_g ——the amount of CO_2 purchased by the government from the operator.

3.4 Determining the Value of CO_2 Reuse

CO_2 reuse can create economic benefits to compensate for the huge costs of CCUS projects. This stage is at the very end of the CCUS value chain and consists of two parts: firstly, it is used by the oil and coal industries to improve recovery rates; secondly, it is used by the beverage and chemical industries for product production.

The oil and coal industries use CO_2 to drive oil, using CO_2-EOR and CO_2-ECBM technologies to inject CO_2 into oil or gas seams, achieving storage while increasing the recovery rate of the oil field (coal bed methane), and its value is calculated in terms of the revenue gained from the increased oil and gas field or gas seam production:

$$V_e = C_e + P_{m_1} \times Q_{m_1} + T_e - P_p \times Q_p \quad (7)$$

where

C_e ——the total cost of equipment, manpower, etc. invested by the oil and coal industries.

P_{m_1} ——Price of CO_2 purchased by the oil and coal industry.

Q_{m_1} ——The amount of CO_2 consumed by the oil and coal industries.

T_e ——Taxes on the business.

P_p ——the price per unit of crude oil and gas (coal) sold.

Q_p ——the increase in production of oil and gas fields or gas seams due to CO_2 injection.

Some industries, such as the beverage and chemical industries, purchase carbon dioxide from operators for profit and use it as a factor of production to continue into finished products. Its value is expressed in terms of the return on the production product realised as a result of the use of carbon dioxide, which is measured as:

$$V_u = C_u + P_{m_2} \times Q_{m_2} + T_u - P_q \times Q_q \quad (8)$$

where

C_u ——Total cost of equipment, manpower, etc. invested by the producer.

P_{m_2} ——Price of CO_2 purchased by the producer.

Q_{m_2} ——the amount of CO_2 purchased for use by the producer.

T_u ——Taxes paid by the producer.

P_q ——the price at which the manufacturer sells to the consumer.

Q_q ——the volume of CO_2 that is converted into the produced product after it has been put into the production process.

Aggregating the above total values, the value of the CO_2 reuse phase is:

$$V_r = V_e + V_u \quad (9)$$

3.5 Measuring the Value of a CCUS Project

Taking the above analysis together and aggregating the values of the four links of the CCUS value chain, the value of the CCUS project can be calculated as follows.

$$V_T = C_c + T_c - P_e \times Q_e + C_t + T_t + C_s + C_e + T_e - P_p \times Q_p + C_u + T_u - P_q \times Q_q \quad (10)$$

Similar items can be merged as:

$$C = C_c + C_t + C_s + C_e + C_u \quad (11)$$

$$T = T_c + T_t + T_e + T_u \quad (12)$$

Total value of CCUS project obtained:

$$V_T = C + T - P_e \times Q_e - P_p \times Q_p - P_q \times Q_q \quad (13)$$

It can be seen that the value of a CCUS project depends primarily on the full cost of the CCUS project and the taxes it incurs, with some of the costs being compensated for by the benefits of higher electricity prices from grid companies, higher production from oil or coal companies in oil and gas fields or gas seams, and the benefits of the resource use of CO_2 in the processing industry. In order to determine the value of a CCUS project, it is necessary to first determine the cost of the project inputs, the taxes that need to be paid at each stage of the value chain and the corresponding project revenues that can compensate for some of the costs.

If the project development costs are too high, the taxes are too high or the value of the project is too small to compensate for the investment in the CCUS project. Therefore, in order to develop CCUS projects and stimulate investment, the government's public finance policy can start by increasing government investment and subsidies, attracting investment to reduce cost pressures and lowering taxes, while appropriately increasing electricity prices, accelerating research and development, reducing project development costs and increasing the level and efficiency of CO_2 reuse.

4. APPLICATION INSTANCE

An example of a value estimation method for CCUS is given here. Assuming that a CCUS project is being planned, the equipment is expected to be put into operation for 20 years before being retrofitted. The project will retrofit a coal-fired power plant to capture CO_2 using post-combustion separation technology, and then transport the captured CO_2 by pipeline, partly for EOR storage, and the remaining part to the storage site for deep brine layer storage.

In the CO_2 capture segment, the total investment for the power station to carry out equipment modifications is 126 million RMB, the total annual operating cost is 10 million RMB, the cost of power generation is RMB 0.12/kWh, the installed capacity of the plant is 500 MW, the annual operating time is 5 000 hours, the CO_2 emission factor is 0.833 t/MWh and the annual capture volume is 3×10^5 tonnes. The total annual amount of electricity expected to be sold by the grid company is 2.5 million MW at a price of RMB 0.42/kWh, and the annual tax paid by the grid company is RMB 1.5 million. The captured CO_2 is transported by the operator by pipeline to the two storage sites at a cost of approximately RMB 20/100 km and RMB 30/150 km per tonne of CO_2, with the operator paying a total annual tax of RMB 0.2 million for this segment. The reservoir is 100 km from the capture site and has a storage potential of 4x106 tonnes at a cost of RMB 120/tonne. As a result of the CO_2-EOR approach, the reservoir produces an average of 0.007×10^6 tonnes of incremental crude oil per annum at a crude oil price of RMB 3,100/tonne, and the field pays an annual tax of RMB 2.5×10^6 for the incremental production component. The total equipment input and maintenance costs for transportation to the 150 km storage site for deep brine reservoir storage was RMB 30×10^6.

An evaluation of the value of the project, i.e. the amount to be invested, is calculated as follows.

Based on the value components of a CCUS project, the value of the four components of CO_2 capture, transport, storage and reuse are aggregated, i.e. the total value of CCUS.

The total amount of CO_2 that can be captured by the power plant over 20 years is 6×10^6 tonnes. The grid company's profit on the total electricity sold over 20 years is $25\times10^6\times(0.42-0.12)\times20=150\times10^6\text{(RMB)}$. The total cost of its inputs is: $C_c=126\times10^6+8\times10^6\times20=286\times10^6\text{(RMB)}$. The captured CO_2 is transported by pipeline to 100 km of reservoir for EOR storage and 150 km of storage site for deep brine storage. As the storage potential of the reservoir is 40×10^6 tonnes, the total cost of transporting CO_2 through EOR storage is $20\times4\times10^6 = 80\times10^6$ (RMB); the cost of transporting CO_2 for deep brine storage is $30\times2\times10^6 = 60\times10^6$ (RMB). Therefore, the total cost invested in the transportation link is $C_t=80\times10^6+60\times10^6=140\times10^6\text{(RMB)}$. The cost to the oilfield for CO2 reuse using EOR storage is $C_e=120\times4\times10^6=480\times10^6\text{(RMB)}$. The total price of the additional crude oil produced is $3100\times0.007\times10^6\times20=434\times10^6\text{(RMB)}$. The known equipment investment and maintenance costs for the government to undertake deep brine storage are: $C_s=30\times10^6\text{(RMB)}$. At this time, $C=(286+140+480+30)\times10^6=936\times10^6\text{(RMB)}$, $T=(1.5+0.2+2.5)\times20\times10^6=84\times10^6\text{(RMB)}$. According to the formula for calculating the total value in equation (13), the total value of this CCUS project can be calculated as: $V_r=(936+84-150-434)\times10^6=436\times10^6\text{(RMB)}$.

5. CONCLUSION

The analysis of the CCUS value chain and the establishment of a value estimation model allows for the scientific measurement of the specific economic value of a CCUS project, which provides a reference basis for the government's financial investment and policy-making decisions. The above calculations show that the full value of the project in this case is CNY 436 million, which is the total amount of capital that needs to be invested in the whole project. To achieve this scale of funding, active support from government-led public finance policies is required, which includes not only substantial investment of public finance support funds, flexible use of financial subsidies, implementation of tax incentives and exemptions, but also the optimisation of diversified financing channels, improvement of the legal system, establishment of public participation mechanisms and other systematic policies and support systems. Guided by the value of the project, the government can assess whether the project is within the financial reach of the state and whether to implement it, based on the annual public revenue and expenditure situation. In addition, the government can develop and deploy the amount of public investment in CCUS, the investment method, the taxation system and other supporting policies and measures based on the funding requirements calculated by the economic value analysis of the project.

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