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Abstract. This paper proposes economic benefits renewable energy investment decision indices under global energy interconnection. The indices are based on “element-performance-economic benefits” causal relationship and attempt to evaluate investment factors from three aspects. Economic indices consider the influence on investment profits of exchange rate, tariff rate and interest rate fluctuation. An improved net present value algorithm combining with the real options method is used to estimate whether a renewable energy project is worthy of investment and when to invest. Performance indices are given from the point of view of clean energy power and power grid. Element indices are defined from the aspects of user demand, technology and international environment. This paper analyzes the causal relationship between investments decisions, elements, performances and economic benefits. Environmental benefits and economic benefits of electric energy replacement are also discussed. This paper provides a framework for investors evaluating renewable energy investment considering its type, scale and location, as well as power grid structure.

Introduction

The essential feature of Global energy Interconnection [1] is UHV grid + Ubiquitous smart grid+ renewable energy resources (RES). Global energy Interconnection (GEI) is altering the pattern of traditional energy supply and demand, promoting the interconnection, complementarity and interoperability of traditional fossil energy and clean energy. Converting RES into electricity and replacing fossil energy by consuming locally and GEI increases consumption ratio of RES, such as hydro energy, solar energy, wind energy and so on, solves environmental crisis and improves the quality of environment [2-3].Some relevant data suggest that the terminal utilization efficiency of electricity energy can reach more than 90% and its economic efficiency is 3.2 times that of oil and 17.3 times that of coal. If the power consumption in the proportion of end user increased by 1%, the unit GDP energy consumption will fall by 4% [4].

The establishment of the global energy Interconnection involves the site selection and construction of RES base, planning and construction of power transmission line, and other investment activities. During the process, firstly, involving more subjects, not only related to the relationship between power plant and other power plant, power plants and power grid, but also consider the interaction between one country and the other country, between one continent and the other continent; secondly, considering more factors in decision-making, not only to consider the elements of planning, running, security and stability about electricity power and power grid of the state and local government, but also contain elements of resources mechanism, Fiscal and tax system, environment protection level, market mechanism, energy policy, financial policy and international cooperation level.

Under the background of GEI, an advanced investment decision-making faces more uncertain factors, such as fluctuation of electricity price, stochastic output of RES, instability of policy, technology development, various subjects, etc., that brings great risks in planning and construction of electric power system. In order to solve these problems, this paper makes a research on causality of...
investment decision-making “element-performance-economic” three-layer system, the general framework is shown in figure 1.

Economic indices

Economic indices mainly used to calculate the benefits and costs of the project, to examine the profitability of the investment program and the ability to resist the risk of uncertainty. Commonly used evaluation indices include rate of return on investment, the payback period, the net present value rule, the internal rate of return, the profitability index and so on[5]. At present, there are three main methods, the first is net present value rule (NPV) which uses absolute profits as standard to judge project, but unable to give a full consideration of risks and uncertainty in investment[6]. The second method based on real options theory, being able to put a variety of uncertainties into account, to provide investors with more investment options [7]. The third method based on the option game theory is the product of combination of option theory and game theory to solve contradiction that the real option theory to wait to acquire options and real market first occupy a market and get opportunities [8].

Under the background of Global energy Interconnection, investment in electric power system and electricity consumption are usually in different countries and areas, costs and incomes are usually in different currencies, so it is necessary to turn them into base currency and then use economic indices to determine its efficiency. This paper uses NPV including exchange rate and real options as economic indexes, to provide a criterion for investment decision-making in electric power system.

Net Present Value Rule. Net Present Value (NPV) is a formula used to determine the present value of an investment by the discounted sum of all cash flows received from the project. This paper proposes an improved NPV, in which, firstly, investment and all cash flows should turn into the base currency, and then traditional formula is used to calculate. The formula can be rewritten as:

$$NPV = \sum_{t=0}^{n_1} \left( \frac{\sum_{j=1}^{n_2} CI \times lf_k}{(1 + \mu)^t} \right) - \sum_{t=0}^{n_3} \left( \frac{\sum_{j=1}^{n_2} CO \times lf_j}{(1 + \mu)^t} \right)$$

Where, CI is investment returns or cash flows; CO means investment; lf_k is the exchange rate between investment and basic currency; lf_j is exchange rate between income and basic currency; n1 is economic life span years of project; n2 is number of project base; n3 is number of energy consumption countries.

Basic income rate \(\mu\) usually uses average return rate of the industry which project belongs to. The greater risk of investment projects, the higher average return rate.

Each year investment includes the following: power plant construction costs (power plant construction costs, land use costs, original equipment costs), power grid construction period costs (land use costs, power grid construction costs, original equipment costs; power plant running costs, etc.)

![Figure 1. Investment “element-performance-economic benefits” three-layer system.](image-url)
cost, power grid running cost, loan interest, tax (value added tax, income tax, additional tax, equipment import duty, electric export tax).

Suppose \( L_A \) is loans from the Bank of country A, which is used to invest in electric power projects in country B, exchange rate of country A's currency between basic currency is \( \text{If}_i \), country A's annual interest rate of loans is \( i_f \). Assuming that country B's total tax rate for electric power projects is \( i_t \).

According to exchange rate conversion to basic country, the amount of the loan is:

\[
L'_A = L_A \times \text{If}_i
\]  

(2)

Loan rate discounted to basic country is:

According to exchange rate conversion to basic country, loan rate is:

\[
r_f = (1 + i_f) \times (1 + \text{If}_i) - 1
\]  

(3)

The interest calculated on the basic country's currency is:

\[
\text{INT}_i = L_A \times r_f
\]  

(4)

According to the exchange rate conversion to basic country, the cost formula can be written as:

\[
CO = (\text{PPCC} + \text{PPRC}) \times \text{If}_i + \sum_{j=1}^{n1} (\text{PGRC} + \text{PGCC}) \times \text{If}_j + \sum_{j=1}^{n4} (\text{INT} + \text{TAX})
\]  

(5)

Where, PPCC is short for Power Plant Construction Cost; PGCC is short for Power Grid Construction Cost; PPRC is short for Power Plant Running Cost; PGRC is short for Power Grid Running Cost; INT means load interest; SI means Sells income; SS means Subsidy; TAX, means tax on the basic exchange rate; \( n_1 \) is economic life span years of project; \( n_4 \) is number of countries that power grid cross.

According to the exchange rate conversion to basic country, the income and tax formula can be written as:

\[
\text{CI} = \sum_{j=1}^{n1} (\text{SI} + \text{SS}) \times r_f
\]  

(6)

\[
\text{TAX}' = \sum_{j=1}^{n4} (\text{SI} \times \text{rate}_j) \times r_f
\]  

(7)

Formulae (1)~(7) suggests that exchange rate and interest rate can affect the amount of investment income [9].

**Real Options Theory.** Real options can include opportunities to expand and cease projects if certain conditions arise, amongst other options. They are referred to as "real" because they usually pertain to tangible assets such as capital equipment, rather than financial instruments. Taking into account real options can greatly affect the valuation of potential investments.

Real option theory is suitable for the evaluation of high risk projects. Under the background of global energy Interconnection, electric power system investment should take following risk elements into account:
Table 1. Uncertain Elements.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Supply’s side</th>
<th>Power grids’ side</th>
<th>User’s side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate</td>
<td>Hours of utilization</td>
<td>Informationization level</td>
<td>Demand of RES power[20]</td>
</tr>
<tr>
<td>Interest rate</td>
<td>On-grid electricity</td>
<td>Transportation capacity</td>
<td>Price Affordability</td>
</tr>
<tr>
<td>Tariff rate</td>
<td>Price</td>
<td>Reliability</td>
<td>Engineering cost</td>
</tr>
<tr>
<td>International cooperation</td>
<td>Electricity transmission and distribution cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Under the background of global energy Interconnection, electric power system investment should take following real options into account:

① Multi-stage compound options. Multi-stage compound options refers to electric power system investment projects in chronological order, divided into a series of interrelated stages. According to the results of the investment of before stage, how to invest in the next stage is decided. Multi-stage compound options is a so important index that should be put more attention in the initial stage of the project.

② Expansion options. The expansion options refers to the ability to expand the project according to the actual project progress. This index should be considered after the completion of the project.

③ Shrinkage option. It is the possibility of shrinking the scale of investment under unfavorable conditions. The option is the main indicator that should be taken into account after the development of energy global Interconnection reaches its peak.

Evaluation Rule with Consideration on Exchange Rate. From the view of real options, evaluation of the project's feasibility is the real option pricing problem. This article will combine the improved net present value rule and the real option theory to judge the value of the global electric power investment project. The improved net present value method considers the intrinsic value of the project, the real options theory takes the project's external value into account. External value raised by uncertain factors. If NPV > 0, the project is feasible; According to the real option theory, the real value of the project is the sum of the net present value (NPV) of the project and the option value of the project. If NPV ≤ 0, but NPV + real options value > 0, the project is still feasible but needs to be deferred.

Performance Indices

Large scale RES electricity integration creates huge impact on power system. The wind energy, hydro energy and solar energy is complementary in different regions. The output of these RES can be smooth and the fluctuations can be reduced. This will benefit increase the penetration rate of clean energy, the utilization of promote clean energy, the sustainability of electric power, the capacity of power grid, stability of grid voltage, transient performance of electric power system. The transmission line loss rate will directly affect the price of line loss and competitiveness of sells price. The performance indices are discussed in this paper mainly reflect the characteristics of power supply and power grid, details are shown in Table 2:

Table 2. Index of Performance.

<table>
<thead>
<tr>
<th>RE Power supply</th>
<th>Power grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>RES penetration rate</td>
<td>Power grid voltage stability</td>
</tr>
<tr>
<td>RES utilization rate</td>
<td>Transient stability</td>
</tr>
<tr>
<td>RES stability</td>
<td>Line loss rate</td>
</tr>
</tbody>
</table>
RES Penetration Rate (RESPR). RES penetration rate refers to the percentage of installed capacity of RES and the total capacity of RES energy and fossil energy. RESPR formula can be written as:

$$\text{RESPR} = \frac{\sum_{i=1}^{n_1} \text{REIC}_i}{\sum_{i=1}^{n_1} \text{REIC}_i + \sum_{j} \text{FEIC}_j} \times 100\%$$  

Where, \( \text{REIC}_i \) is short for Installed capacity of \( i \) energy resource (\( i \) is wind or solar or hydro); \( n_1 \) is the amount of kinds of clean energy; \( \text{FEIC}_j \) is short for Installed capacity of fossil energy.

Penetration rate reflects the generation potential of clean energy. The consumption state of RES electric power needs to be measured by another index.

RES Utilization Rate (REUR). RES utilization rate refers to percentage of be consumed RES electric energy quantity and the installed RES capacity. REUR formula can be written as:

$$\text{REUR} = \frac{\sum_{i=1}^{n_1} \text{RECQ}_i}{\sum_{i=1}^{n_1} \text{REIC}_i} \times 100\%$$  

Where, \( \text{RECQ}_i \) is consumed as RES electric energy quantity. REUR reflects the efficiency of RES equipment utilization. The higher REUR, the lower the on-line price is. The lower on-line price, the higher the RES electricity attractivity is. Low prices in turn to promoting the utilization rate of RES.

RES Stability (RESS). The stability of power supply studies the percentage of fluctuation of power output with time and the average output of power supply. The smaller the fluctuation, the better the stability is. RESS formula can be written as:

$$\text{RESS} = \frac{P_t - P}{P} \times 100\%$$  

Where, \( P_t \) is real time output of power supply; \( P \) is average output of power supply.

Power Grid Voltage Stability (PGVS). The stability of power grid voltage studies the percentage of fluctuation of end voltage with time and the nominal voltage of power grid. The smaller the fluctuation, the better the stability is. PGVS formula can be written as:

$$\text{PGVS} = \frac{V_t - V_n}{V_n} \times 100\%$$  

Where, \( V_t \) is the voltage of the sampling point; \( V_n \) is the nominal voltage of power grid.

Transient Stability. Transient stability is an important index of power system dynamic stability, which refers to, when electric power system is disturbed in some running states and causes considerable fluctuations, the ability of whether to transit to a new stable state or to return to the original state and continue to maintain synchronize [10].

Transmission Line Loss Rate (TLLR). Under the background of global energy Interconnection, electric power transmission distance is far and transmission line loss rate directly influences the economic performance of the project. LLR formula can be written as:

$$\text{TLLR} = \frac{P_n - P_i}{L} \times 100\%$$  

Where, \( P_n \) is the nominal transmission electric power; \( P_i \) is the terminal electric power.
The transmission line loss rate is, when the initial power is nominal value, the power loss of 1 km. The farther the transmission distance, the bigger the transmission loss is. The bigger the diameter of transmission electric wire, the smaller the loss rate is, but the engineering costs is bigger [11].

**Element Indices**

Under the background of global energy Interconnection, The elements of power investment decision-making are divided into three categories: ① reflecting RES power demand of users [10]; ② reflecting international investment environment; ③ reflecting technology development. Each index is divided into a series of sub items, as shown in table 3.

<table>
<thead>
<tr>
<th>Demand</th>
<th>International investment environment</th>
<th>technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic development level</td>
<td>Taxation level</td>
<td>informationization level</td>
</tr>
<tr>
<td>Energy consumption level</td>
<td>Exchange rate</td>
<td>Power grid technology</td>
</tr>
<tr>
<td>Energy mechanism</td>
<td>Interest rate</td>
<td>Generation technology</td>
</tr>
<tr>
<td>RES Quality</td>
<td>Market mechanism[13,14,16]</td>
<td>Energy storage technology</td>
</tr>
<tr>
<td>Environmental protection level</td>
<td>International cooperation level[11]</td>
<td></td>
</tr>
</tbody>
</table>

**Users Demand.** User’s clean energy demand comes from two aspects, ① to supplement the shortage of fossil energy, ② to improve environmental quality.

(1) Economic development

The evaluation indicators of economic development mainly include GDP, GDP growth rate, Engel coefficient and CPI.

The gross domestic product (GDP) is a basic measure of a country's overall economic output. GDP annual growth rate calculation formula is as follows:

\[
\Delta GDP = \frac{GDP_n - GDP_{n-1}}{GDP_{n-1}} \times 100\%
\]

(13)

GDP growth requires a lot of energy to provide power. The product of energy consumption of ten thousands Yuan GDP and GDP is the total energy that a country one year demands. Usually, the greater the GDP and the greater the GDP growth rate, the higher the demand for energy is. Annual Increased energy demand formula is as follows:

\[
\Delta ED_n = GDP_n \times EC_{n \text{ /tty}}
\]

\[
= GDP_n \times (1 + \Delta GDP) \times EC_{n \text{ /tty}}
\]

(14)

Where, EC/tty means energy consumption of ten thousand yuan GDP.

Engel coefficient is the proportion of total food expenditure in the total consumption expenditure. Calculation formula is as follow:

\[
\text{Engel coefficient} = \frac{\sum EF_i}{TCF} \times 100\%
\]

(15)
Where, \( EF \) means expenditure of food; \( TCF \) means total consumption expenditure. The smaller the Engle coefficient, the richer the country is. The smaller the Engle coefficient, the more the money that uses to improve life quantity can be, so the demand for energy is more.

CPI is a price index that reflects the price of goods and services related to residents' life. It is often used as an important indicator to observe the level of inflation. CPI formula can be written as follows:

\[
\text{CPI} = \frac{P_t}{P_{t-1}} \times 100\%
\]  

(16)

CPI growth rate formula can be written as:

\[
\Delta \text{CPI} = \frac{P_t - P_{t-1}}{P_{t-1}} \times 100\%
\]  

(17)

Where, \( P_t \) means the value of fixed goods calculated according to the current price; \( P_{t-1} \) means the value of fixed goods calculated according to price of the base time.

Too big of the CPI growth rate will cause the economic atmosphere uncertain. Under this background, demand of electric power will be reduced.

(2) Energy Consumption Level

Usually, the evaluation indicators of consumption level mainly include: a) Annual energy consumption (AEC); b) Per capita energy consumption (PCEC); c) Ratio of per capita energy consumption and the world average energy consumption (RPCEC/AEC); d) Energy consumption growth rate (ECGR); e) Energy consumption per ten thousand yuan (EC/tty); f) Utilization rate of high-carbon energy (URHCE); h) Structure of energy consumption.

There are two methods to calculate the total annual energy consumption.

One uses population as variable to calculate AEC, which formula as follows:

\[
\text{AEC} = \text{Population} \times \text{PCEC}
\]  

(18)

Another uses GDP as variable to calculate AEC, which formula as follows:

\[
\text{AEC} = \text{GDP} \times \text{EC/TTY}
\]  

(19)

Energy consumption structure refers to the percentage of coal, oil, natural gas, nuclear power, hydropower, solar energy, wind energy and other energy consumption in the total energy consumption. The greater the proportion of high carbon energy, the more serious environmental pollution is. As a result, the demand for clean energy is higher.

(3) Energy Mechanism

Energy system is a crucial indicator to evaluate the quality and quantity of fossil energy and clean energy and the main sub-evaluation index contains: a) Fossil energy storage (FER); b) The ratio of fossil energy storage and global total energy storage (RFS/GTES); c) Per capita storage of fossil energy (CSFE); d) The ratio of per capita fossil energy storage and world fossil energy average storage (RPFS/WFES); e) Fossil energy production (FER); f) Development potential of RES (DPRES); g) Energy export (EE) (export is positive and import is negative).

Energy export potential formula can be written as:

\[
\text{EE} = \text{FER} + \text{DPRES} - \text{APC}
\]  

(20)

The above indices from the view of energy shortage show a country's demand for RES. In global energy Interconnection, the main role of Good energy mechanism country is energy supplier, the auxiliary role is user. The main role of average energy mechanism country are power users, the auxiliary role is energy supplier.

(4) RES Quality
Sub-evaluation indices include: a) Storage amount; b) Exploitable energy amount in technology; c) Development costs; d) Resource complementarity.

(5) Environmental Protection Level

Environmental protection level is an important index that measures the environmental quality of a country or a region. Its main sub-evaluation indices include: a) Carbon emissions; b) Water quality; c) Forest coverage rate; d) Air quality; e) The amount of sustainable energy sources; f) Bio-diversity.

(6) Energy Policy

Due to the intermittent and stochastic of RES, its development and utilization is not good and its development costs are much higher than the costs of fossil energy. In order to protect the environment and avoid energy crisis, many countries have introduced policy to protect the development of clean power electricity. Specific measures include [12, 17]: a) Price mechanism; b) Tax relief; c) Special funds.

International Investment Environment.

The international investment environment mainly refers to the factors, such as finance, international relationship, social security and electric market mechanism. These indices will affect the transnational generation, transmission and consumption of electric power. Financial indices include tax rate, exchange rate, interest rates, etc.. International relationship and social security indices contain international cooperation level and security mechanisms. The electricity market mechanism mainly refers to the supply and demand mechanism, the price mechanism, the competition mechanism and the matching mechanism.

(1) Tax rate, Exchange rate and Interest rate

Under the background of global energy Interconnection, the tax of electric power system investment mainly includes value-added tax and tariff. Tax rate of each country is different and the difference is not small. These have impact on RES electric energy sales price, price competitive and investment results.

Value added tax is a consumption tax because it is borne ultimately by the final consumer. It is not a charge on businesses. It is actually paid by the buyer to the seller as part of the price. It is thus an indirect tax. On-grid price/kwh formula can be written as:

\[
\text{on-grid price/kwh} = \text{costs/kwh} \times (1 + \text{VATR})
\]  

Where, VATR is short for value-added tax rate.

As can be seen from the formula (21), the value-added tax rate is an important part of on-grid price, which directly affects on-grid price.

A tariff is a tax on exports or imports. This article only considers the import tariff of electric power. In order to encourage exports, for the general merchandise, many countries do not impose export taxes. Imports tariff formula can be written as:

\[
\text{imports tariff} = (\text{on-grid price} + \text{transmission and transmission line loss cost}) \times \text{tariff rate}
\]

As can be seen from the formula (22), the higher the tariff rate, the more the tariff of electric power/kW·h is. Table 4 shows value-added tax and tariff rate of world's main energy countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>VAT rate (%)</th>
<th>Tariff rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>17</td>
<td>0~35</td>
</tr>
<tr>
<td>Mongolia</td>
<td>10</td>
<td>17.5</td>
</tr>
<tr>
<td>Russia</td>
<td>18</td>
<td>7.1</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>20</td>
<td>7.1</td>
</tr>
<tr>
<td>Poland</td>
<td>22</td>
<td>0~15</td>
</tr>
<tr>
<td>Germany</td>
<td>19</td>
<td>5~17</td>
</tr>
<tr>
<td>Denmark</td>
<td>25</td>
<td>5~14</td>
</tr>
<tr>
<td>India</td>
<td>12.5</td>
<td>0~40</td>
</tr>
</tbody>
</table>
The exchange rate directly affects the sells price competitiveness in energy consumptive country.

In figure 2, country A, country B and country C, respectively, is RES electricity producer, conveyor and energy consumer.

Sells price of country B is:

\[
C_B = \frac{(C_A + CT_A) \times lf_A \times (1 + TR_B)}{lf_B} 
\]  

(23)

Sells price of country C is:

\[
C_C = \frac{(C_B + CT_B) \times lf_B \times (1 + TR_C)}{lf_C} 
\]  

(24)

Competitiveness of sales price in country C can be stated as

\[
SCP = CC - BMP 
\]  

(25)

Where, \(C_A\) means RES electric power on-grid price of country A; \(lf_A\) is exchange rate between country A’s currency and basic currency; \(lf_B\) is exchange rate between country B’s currency and basic currency; \(lf_C\) is exchange rate between country C’s currency and basic currency; \(CT_A\) means transmission costs in country A; \(CT_B\) means transmission costs in country B; \(CT_C\) means transmission costs in country C. \(TR_B\) is exchange rate of country B; \(TR_C\) is exchange rate of country C; \(SCP\) means competitiveness of sales price in country C; \(BMP\) means benchmark price of country C.

By calculating, we know that the greater the exchange rate, the lower the competitiveness of the sale price of clean energy is. The higher the loan interest rate, the more the unit time (one year or 3 months, 6 months) the interest rate is and the higher the corresponding electric power cost is.

(2) Market Mechanism

The main evaluation index of market mechanism contains: a) Supply and demand mechanism [14]; b) Price mechanism; c) Competition mechanism; d) Matchmaking mechanism

Under the background of global energy Interconnection, demand function of RES electricity in electric power market can be written as

\[
Q_d = f(SP, GDP, ECL, EN, CPI, ES, AT, PS) 
\]  

(26)

Where, SP means sells price of RES electric power; ECL means energy consumption level; EN means Engle coefficient; AT means attractiveness of RES; PS means policy strength.

Under the background of global energy Interconnection, supply function of RES electricity in electric power market can be written as

\[
Q_s = f(EP, FP, C, EQ, REC, S) 
\]  

(27)

Where, EP means price of RES electric power; FP means price of fossil energy; EQ means RES quality; EC means the costs of RES electric power; REC means the recovery of electric charge; S is Subsidy.

Electricity price system can be divided into three parts: the on-grid price, transmission and distribution electricity price (including transmission costs and line transmission loss costs) and to Sales price. There are two forms of market pricing and government pricing.
In the electric power market, the on-grid Pricing Mechanism includes uniform market clear pricing (MCP) [15], pay as bid pricing (PDP), and the electricity value equivalent pricing (EVEP).

Competition mechanism is one of the most important matters in electric power market, which is directly related to the security and stability of power system operation and the efficiency of market operation.

In electric power market, matching mechanism refers to a logic program of the power exchanges dealing with the commissioned information after the producer's and user's information having delivered to it, including the bidding principles of different trading times, the principle of the priority order of transaction and the way to deal with the transaction price.

Under the background of global energy Interconnection, electricity investment involves too many parties, how to make the subject of different market mechanisms to complete the transaction, in which the matching mechanism is needed to play a role. Matchmaking mechanism should have the following three rules: firstly, the largest trading volume rule; secondly, the minimum residual quantity rule; thirdly, according to the matching rules to calculate the only transaction price [16].

(3)International cooperation Level and Security Mechanism

The evaluation indices of the international cooperation level mainly include: a) The nature of the group and the original intention of cooperation; b) Geographical location and the disputes of resources and territorial; c) Regional security and mutual exclusion; d) Historical tradition; e) Trade contacts; f) Mutual investment penetration.

International cooperation level of energy producers, energy conveyors and the energy consumer will determine whether the investment can be completed or not and investment costs, construction periods, electricity recovery level and so on. Under the background of global energy Interconnection, in the four links of the production, transmission, distribution and consumption, any one country being not willing to cooperate with each other will greatly increase the risk of investment.

Under the background of global energy Interconnection, if we want to achieve energy transnational energy-transmission and consumption, many parties are involved in it and there are a lot of risks affecting the success of cooperation. There are political risk, economic risk, legal risk, bilateral risk, social and cultural risk, etc. In such environment, in order to ensure the success of energy Interconnection, we need to design reasonable security mechanisms to protect the interests of the investors.

Technology Level. Factors that affect the development of the global energy interconnection mainly include power grid technology, power generation technology, information technology and energy storage technology. Power grid technology level determines the power grid's transient performance and steady-state performance, and indirectly changes the cost of transmission, distribution costs and transmission loss. The level of power generation determines power costs and capacity costs, thereby affecting the profit of investment decisions.

(1)Informationization Level

Information technology, mainly referring to the information communication technology, including two aspects of information and communication, is an important basis of the realization of intelligent network, interactive and large power grid running control.

(2)Power Generation Level

The evaluation indices of RES generation technology level mainly include: a) Energy conversion efficiency (ECE); b) Unit capacity (UC); c) Generating availability hours (GAH); d) Equipment life (EL).

(3)Electric Power Grid Technology Level

The evaluation indices of RES power grid technology level mainly include: a) Electric power grid capacity; b) Resources allocation capability; c) Power grid economy.

The key technology of long distance power transmission is the technology of extra high voltage power transmission, which has characteristic of far transmission distance, large transmission capacity and small transmission loss.
The following figure from user's energy demands, international investment environment, RES development point of view, explain causal relationships between key factors, economic benefits, and investment decision-makings.

Figure 3. Key elements causal loop diagram.

**Efficiency of alternative energy**

Efficiency of electric energy replacement can be classified into two types: environmental benefits and economic benefits.

**Environmental benefits.** Traditional fossil energies are mainly coal, oil, and natural gas. The carbon content of coal is approximately 100%. The carbon content of crude oil is about 85%. The carbon content of natural gas is 75%.

The heat content of standard coal is 29.26MJ/kg. According to principle of equal heat, 1 tons of raw coal equivalents to 0.714 tons of standard coal, and 1 tons of crude oil equivalent to 1.43 tons of standard coal and 1000.

The heat content of a kilowatt hour is $3.6 \times 10^6$. How much coal, crude oil, natural gas and electricity do we need to produce $3.6 \times 10^6$ heat? How much carbon dioxide is released into the environment? \[18\] Details are shown in Table 5.

Table 5. Electric energy replacement environment benefit of $3.6 \times 10^6$ energy.

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Petroleum</th>
<th>Gas</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight(kg)</td>
<td>0.172</td>
<td>0.086</td>
<td>0.093</td>
<td>1kw·h</td>
</tr>
<tr>
<td>Carbon dioxide(kg)</td>
<td>0.63</td>
<td>0.268</td>
<td>0.256</td>
<td>0</td>
</tr>
</tbody>
</table>

In conclusion, electric energy substitution can reduce carbon emissions, thereby enhancing environmental benefits.

**Economic benefits.** In order to reduce the pollutant emissions of coal-fired sets, many countries have used the super emission technology.

The environmental costs of coal-fired sets include equipment renovation costs and operating costs. Equipment renovation costs is about 340-440/kW·h and running costs is about 1-2 point/kW·h. The lower the pollutant emissions of 1kW·h, the more the costs is required. If we use clean energy to replace fossil energy, without any cost, we can achieve zero pollutant emissions \[19\].

**Summary**

This paper investigated economic benefits indices, electric power system performance indices and element indices of the electric power investor's decision making process under the background of the...
global energy interconnection. The causal relationships between the indices of each layer have been analyzed. Electric power investors according to element indices to choose electric power system investing activities, such as the kinds of RES, locations of power plant and power grid, the scale of power plants and power grid, and so on. The strength of investment depends on the performance of the power supply and the power grid. Performance indices measure the investor's investment profits. In this paper, the real options theory and the improved net present value method are integrated to better value the investment activities. Investors revise and adjust investment activities according to economic benefits indices.

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References


