Policy analysis and technical evaluation index of multi-energy complementary projects in China

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Abstract. Multi-energy complementary renewable energy system is an efficient energy supply system based on thermolectric-gas-storage coupling technology to realize full renewable energy supply in local regions, with biomass power generation as the basic energy, wind, light and storage as the supplement. Since 2000, China has promulgated a series of policies related to multi-energy complementarity to promote energy reform and renewable energy development. China supports the construction of multi-energy complementarity, micro-grid and renewable energy projects. By optimizing the process route of "source-network-load-storage" and adopting chain and vertical integrated feedback as auxiliary technical measures, the deficiencies of renewable energy projects in energy production, storage, transportation, conversion, use and recovery can be complete. Intelligent dispatch through "end-pipe-cloud" integrated energy management platform can compensate the characteristics of non-flexible operation, uncertainty and volatility of renewable energy. According to the characteristics of renewable energy in multi-energy complementary projects, technical evaluation index, economic evaluation index and social benefit index are established, and the advantages and disadvantages of renewable energy projects are evaluated by multi-dimensional indicators.

1. Introduction
The utilization of traditional energy, especially coal, which takes the form of "carbon-based" as its main form, is not friendly to the environment, may not meet the requirements of energy quality for social activities, and deviates from sustainable development [1]. Meanwhile, coal, oil and natural gas as the representative of primary energy are limited reserves. So it is of great benefit to develop renewable energy and implement multi-energy complementarity [2]. Almost any kind of energy or several kinds of energy sources are connected in the process of production, storage, transportation, transformation and recovery, especially in the process of transformation or conversion. The "complementarity" of various energy sources are often used to improve energy efficiency [3, 4].

The energy production and consumption mode of multi-energy complementary in characteristic towns may not be realized by a single energy mode. It is necessary to fully consider the energy production, storage, transportation, consumption and other links to establish a multi-energy complementary energy system in characteristic towns. Energy supply system should be analyzed systematically, finely and integratively in the energy production process to improve system robustness and energy conversion efficiency. Energy consumption process should be modeled on the basis of physical system, driven by maximum economy, and forecasting model should be established.
theory model [5], system dynamics model [6], multi-agent simulation model [7], etc. are widely used to analyze the characteristics of energy utilization, improve energy utilization rate and reduce energy supply cost.

The multi-energy complementary renewable energy system is the key channel to integrate the key information of the core energy system of characteristic towns. Relying on regional energy data aggregation and application of large data, artificial intelligence and other technologies, and in-depth mining of energy situation of regional users, attributes, proportion, layout, structure, region and other aspects of multi-dimensional development and future trends, the situation of environmental protection and industrial and commercial activities in service cities are analysed and population distribution, consumption structure, transportation and industrial agglomeration are comprehensively studied to constructs a comprehensive energy management and control service system, reduces the level of resource consumption and improves the operational efficiency of characteristic towns, assisting decision-making for the construction, planning and layout of the town and optimization and adjustment of the town, facilitating networked sharing, intensive integration, collaborative development and efficient utilization of characteristic towns development, and promoting regional sustainable development.

2. Policy analysis and technical route

2.1. Policy analysis
In order to implement the energy strategic idea of "four revolutions and one cooperation" put forward by General Secretary Xi Jinping and promote the technological innovation of energy industry [8], active exploration has been made in clean energy and renewable energy utilization, thermal power substitution and intelligent energy construction and to construct of the "Internet + Smart Energy" demonstration project. New energy vehicles, multi-energy complementary [9-10], micro-grid, energy internet [11-13] and other new energy formats have been tentatively entered into the market. Renewable energy as a way of energy supply in Garden type characteristic towns is a form of micro-grid project landing [14].

In 2006 and 2007, the State the Outline of the National Medium-and Long-Term Science and Technology Development Plan (2006-2020) and the Medium-and Long-Term Renewable Energy Development Plan respectively were promulgated in China. Vigorous development and large-scale application of new and renewable energy are be classified as the priority development theme in the field of energy, and the development and construction of renewable energy in China are guided through all-round policies. In 2016 and 2017, the 13th Five-Year Plan for Energy Technological Innovation and the Energy Technological Revolutionary Innovation Plan (2016-2030) were issued successively to promote the development of clean energy and renewable energy technologies. The "Trial Measures for Promoting the Construction of Grid-connected Micro-grid" promulgated in 2018 broke the policy barriers of renewable energy in grid-connected links, and effectively standardized and promoted the healthy and orderly development of micro-grid [15].

2.2. Technical background
The technology of micro-grid plays an important role in the friendly interaction among the large power grid, specific users and micro-grid. As a new type of power exchange system which integrates power production, transmission, storage and distribution, micro-grid can provide users with safe and reliable energy sources, and can also be a powerful supplement and support for large power grid, which is beneficial to improving the reliability and economy of existing power grid operation.

There are still three core technologies that need to be broken through urgently: fast isolation between micro-grid and large-grid, seamless switching between isolated network and grid-connected state, and stable autonomy of micro-grid. To this end, the "chain" transformation will be initiated, and the evolution trend of the new generation of energy system will present the following three complex characteristics [16-17]:

2
(1) Horizontal multi-energy complementary integrated optimization. A multi-energy complementary supply system of "wind, light, water, fire and storage" is established on the source side, and an integrated energy supply system to meet the balance of supply and demand is established on the load side to realize the cascade utilization of energy and the coordination of multi-energy, break the traditional energy pattern, and form a new generation of energy system fully coupled with the characteristics of traditional fossil energy [18].

(2) Vertical "source-network-load-storage" collaborative interaction. By virtue of the balance between supply and demand and price guidance mechanism within the market scope, the load side dominates the market trend of production, consumption and storage of the whole energy system, and realizes the multi-energy "supply-demand-storage" linkage system [19]. It is gradually transformed into a self-balanced mode of production, transmission, storage and consumption by organic combination of various energy entities, so as to promote the coordination, complementarity and upgrading and optimization of resources and channels in the field of integrated energy.

(3) Coordination between centralized energy and distributed energy. Traditional energy systems and distributed energy self-control units are relatively independent and cooperative. Centralized energy is managed through a top-down network, and distributed energy is established in accordance with the principle of proximity. Both of them coexist amicably in the new generation of energy system. Through the open and peer-to-peer information-energy integration architecture, the two-way on-demand transmission and dynamic balanced use of energy can be realized, providing opportunities for energy sharing and information exchange.

2.3. Technical route
In the multi-energy complementary system, there are physical factors of "source-network-load-storage" and soft information layers such as users, value, business, information and energy. Therefore, energy management platform is required to have functions of measurement, statistics, analysis and processing. The logical relationship among various energy sources is described by taking a town with all renewable energy sources as an example.

![Diagram](image_url)

**Figure 1.** Multi-energy complementary system composition.

Figure 1 is the composition diagram of the multi-energy complementary system. The system describes the construction of a town-level renewable energy micro-grid system with multi-energy complementarity, grade correspondence and active regulation and coordination by using biomass energy to stabilize energy and coordinate wind/solar/geothermal energy. Through the "end-pipe-cloud" integrated energy management platform, the "source-network-load-storage" link is optimized to achieve seamless docking between the on-line and off-line of "send-transport-allocate-use-sell".
3. Evaluation index and optimize process

3.1. Evaluation index

In order to evaluate the merits and demerits of multi-energy complementary integrated optimization, the evaluation index is introduced appropriately, including technical indicators, economic indicators and social indicators. Social indicators include energy efficiency, renewable energy penetration, utilization of key equipment, proportion of power generation load, proportion of energy self-consumption and other factors. Economic indicators include investment payback period, financial internal rate of return, financial net present value and other factors. Social indicators include annual carbon dioxide emissions reduction, annual sulfur dioxide emissions reduction F_{SO2}, annual fossil energy conservation and other factors.

3.1.1. Technical indicators

(1) Energy efficiency
Unit of measurement: percentage (%).
Index Interpretation: The ratio of output energy to input energy.
Calculating method: Energy efficiency is the percentage of the ratio of output available energy (kJ) to input energy (kJ) of energy system.

\[ \eta = \frac{\sum_{i=1}^{n} p_i}{\sum_{j=1}^{m} q_j} \times 100\% = \frac{p_1 + p_2 + \cdots + p_n}{q_1 + q_2 + \cdots + q_n} \times 100\% \]  

(1)

(2) Renewable Energy Permeability
Unit of measurement: percentage (%).
Index Interpretation: The proportion of installed capacity of renewable energy in the whole multi-energy complementary system.
Calculating method: Renewable energy permeability is the percentage of the ratio of the installed capacity (kW) of renewable energy to the installed capacity (kW) of multi-energy complementary system.

\[ \eta = \frac{\sum_{i=1}^{n} p_i}{\sum_{j=1}^{m} q_j} \times 100\% = \frac{p_1 + p_2 + \cdots + p_n}{q_1 + q_2 + \cdots + q_n} \times 100\% \]  

(2)

(3) Utilization rate of key equipment
Unit of measurement: percentage (%).
Indicator Interpretation: Ratio of actual and planned usage of equipment per year.
Calculating method: The utilization efficiency of equipment is the percentage of the ratio of actual use time (h) to planned use time (h) of equipment every year. The weight of equipment power in the total output power of the system should be taken into account in the utilization ratio of multiple equipment.

1) Indicators of Utilization Rate of Single Equipment

\[ \eta_i = \frac{Q}{Q_0} \times 100\% \]  

(3)

2) Utilization Index of Multiple Equipment

\[ \eta_s = \frac{\sum_{i=1}^{n} \eta_i P_{0i}}{\sum_{i=1}^{n} P_{0i}} \times 100\% = \frac{\eta_1 P_{01} + \eta_2 P_{02} + \cdots + \eta_n P_{0n}}{P_{01} + P_{02} + \cdots + P_{0n}} \times 100\% \]  

(4)
(4) Power generation satisfying load ratio
This ratio refers to the proportion of supply-side generation in the multi-energy complementary system used to meet demand-side load during the statistical period to demand-side load.

\[
OEF = \frac{\sum_{i=t_1}^{t_2} \text{Min}[G(i); L(i)] \Delta t}{\sum_{i=t_1}^{t_2} L(i) \Delta t}; \quad 0 \leq OEF \leq 1
\]  

(5) The ratio of self-consumption of energy
This ratio refers to the proportion of supply-side generation used in multi-energy complementary systems to meet demand-side loads during the statistical period to supply-side generation.

\[
OEM = \frac{\sum_{i=t_1}^{t_2} \text{Min}[G(i); L(i)] \Delta t}{\sum_{i=t_1}^{t_2} G(i) \Delta t}; \quad 0 \leq OEM \leq 1
\]

3.1.2. Economic indicators
(1) Payback period
Unit of measurement: year
Index Interpretation: The payback period of multi-energy complementary system.
Calculating method: From the first year of the project calculation period, it can be calculated by accumulating net cash in the financial cash flow statement. Y, the number of years in which cumulative net cash flow begins to appear positive; r, the cumulative net cash flow of the previous year / the current year's net cash flow.

\[
Pt = Y - 1 + r
\]  

(2) Internal financial return rate
Unit of measurement: percentage, (%).
Interpretation of Indicators: the discount rate when the net financial present value is equal to zero.

\[
\sum_{t=0}^{\infty} NC_i (1 + FIRR)^{-t} = 0
\]  

(3) Net present financial value
Unit of measurement: Yuan.
Interpretation of Indicators: Converting Net Present Value (NPV) Flow of each year in the project calculation period to the sum of the present value at the starting point of development activities.

\[
FNPV = \sum_{t=0}^{\infty} NC_i (1 + i_c)^{-t}
\]

3.1.3. Social benefit indicators
(1) Annual reduction in carbon dioxide emissions
Units of measurement: tons (t).
Explanation of Indicators: On the premise of meeting the demand of heat and cooling load, rational use of multi-energy complementary system can improve the energy efficiency of fossil energy and increase the proportion of clean energy use, and promote the reduction of carbon emissions.

\[
F_{CO_2} = \frac{1}{2.49} \left[ \frac{E_{\text{chiller}} + E_{\text{power-load}}}{\eta_f} CE_s + \frac{Q_{\text{power-load}}}{\eta_f} CE_f \right] - \left( \frac{E_{\text{bat}}}{\eta_f} CE_s + \frac{Q_{\text{power-load}}}{\eta_f} CE_f \right) \eta_{bat} PR_{xt}
\]
\[ F_{CO_2} = \frac{1}{2.49} \left[ \frac{E_{\text{electric}}}{\eta_f^E} + \frac{E_{\text{power-load}}}{\eta_f^E} CE_a + \frac{Q_{\text{power-load}}}{\eta_f^Q} CE_f \right. \]
\[ \left. - \left( \frac{E_{\text{cryo}}}{\eta_f^C} CE_a + \frac{Q_{\text{power-load}}}{\eta_f^Q} CE_f \right) \right] \alpha P R_{eg} \]

(2) Annual reduction of sulfur dioxide emissions
Units of measurement: tons (t).
Explanation of Indicators: To meet the demand of heat and cooling load, rational use of multi-energy complementary system can improve the energy efficiency of fossil energy and increase the proportion of clean energy use, and promote the reduction of SO₂ emission level.

\[ F_{SO_2} = F \times C_{SC} \]  

(11)

(3) Annual fossil energy savings
Units of measurement: tons (t).
Explanation of Indicators: Under the condition of meeting the demand of heat and cold load, rational use of multi-energy complementary system can improve the utilization efficiency of fossil energy and the proportion of clean energy, and promote the level of energy conservation.

\[ F = W_y \times P_{SC} \times 10^{-6} \]  

(12)

Note: Based on the above key indicators and their weight setting, it is recommended to use the weighted method to calculate the scaling syndrome.

3.2. Optimize process

In order to minimize the deviation between the technical indexes of design planning and operation and the data of project operation after completion in the design process of multi-energy complementary projects, multiple iterations are usually adopted to reduce the design errors (Figure 2).

![Figure 2. Multiple complementary integration optimization process.](image)

4. Conclusions and suggestions

The multi-energy complementary full renewable energy project is based on the special case of the traditional renewable energy project. Under the normal operation state, the energy used in the project is all provided by renewable energy, which is a new attempt.

Full renewable energy project is a deep attempt based on the high proportion of renewable energy grid-connected projects, which makes use of smart grid technologies such as energy management platform and energy router to make up for the insufficiencies of renewable energy such as fluctuation, uncertainty and lack of flexibility in operation.
It is suggested that the analysis and implementation of the latest energy policies, especially the access to electricity, should be emphasized in the planning and design stage of such projects to avoid the phenomenon of "demonstration for demonstration".

It is suggested that in the process of planning and design of such projects, the weights of the indicators should be assigned according to the needs of investment decision-making, referring to the technical evaluation index, economic evaluation index and social benefit evaluation index.

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