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Analysis of emission reduction benefits of wind - solar complementary water supply project - taking Siziwang Banner Inner Mongolia as an example

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Abstract: At present, There are few related studies on energy-saving and emission reduction analysis of off-grid wind-solar energy water supply projects which applied in remote areas. This article takes a typical wind-solar complementary water supply project in the pastoral area of Siziwang Banner Inner Mongolia as the research object,discovered the carbon emissions during its life cycle is 83.26kg by using the life cycle assessment method. The emission reduction benefits of the wind solar complementary water supply project plays a positive role in promoting the application of new energy water supply projects in the later stage.

1. Introduction

Promoting low-carbon development in society has become one of the main consensuses of countries around the world with the increasing pressure of carbon emissions in various countries. Diligently promoting renewable energy serves as a crucial means to attain emissions reduction goals. Wind and solar energy, as the main components of renewable energy in China, have received widespread attention and development.Wind and solar energy, besides their application in large-scale power generation, also play a significant and diverse role in water supply projects. Owing to its off-grid and low-power features, it is well-suited for remote and vast pastoral regions. This not only fulfills the water supply requirements for local residents and livestock but also effectively addresses the uneconomical reach of traditional power grids, stemming from the dispersed and distant nature of the residences. At present, there are few analysis on its emission reduction. This article conducts analysis and research on the emission reduction of new energy water supply projects through relevant information and data, clarifying their environmental benefits and laying a foundation for China's subsequent carbon trading and carbon storage construction.

At present, domestic and foreign scholars have conducted extensive research on reducing carbon emissions from wind and solar power generation projects based on the carbon emissions generated g/kw•h, However, there is little research on off grid, small-scale wind and solar power water supply projects. This article takes a typical wind-solar energy water supply project in Inner Mongolia as the research object, conducts emission reduction analysis based on its lifecycle, and clarifies the emission reduction advantages of this type of project.

Research methods. The main method for estimating carbon intensity is Life Cycle Assessment (LCA). Raymond Vernon first defined the concept of lifecycle in 1966 [1]. According to the overview of ISO standards 14040 and 14044, LCA quantifies the environmental impact of products through input-output accounting of the process from cradle to grave or from cradle to gate. Researchers at home and abroad have mainly used life cycle theory to conduct corresponding research on wind and solar power plants in different regions, types, and production processes from different perspectives[2-11] ; In terms of research objects, most of them are large-scale wind energy and solar power plant projects , and a very small number have conducted energy-saving and emission reduction research on small-scale off grid wind power generators[12]; In terms of research indicators, the above-mentioned research objects are all power generation projects, with the goal of meeting electricity demand. Therefore, the evaluation indicators used are the carbon emissions generated per kilowatt of electricity.

For wind power generation projects, domestic and foreign scholars have conducted sensitivity analysis and research on emission reduction benefits and related factors around different types (offshore, onshore), regions, and production processes of wind farms; For photovoltaic power generation projects, foreign scholars have analyzed photovoltaic power generation projects with different production processes, scales, and regions using production cycle evaluation methods.

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2. Research methods

2.1. Resource conditions

(1) Wind resource conditions

Siziwang Banner is located in the central part of Inner Mongolia Autonomous Region, and wind resources are sourced from meteorological data from the local national basic meteorological station Zhurihe Meteorological Station in 2019.

The monthly wind speed and wind power density at a height of 10m at the meteorological station in 2019 are shown in Table 1 .

Table 1. Monthly Wind Speed and Wind Power Density at a Height of 10m

Time (month)	1	2	3	4	5	6	7
wind speed（m/s）	4.47	3.51	4.65	5.07	5.87	4.63	3.90
Wind power density（W/m^2）	104.82	72.75	119.07	164.24	246.52	121.11	77.57
Time (month)	8	9	10	11	12	average	
wind speed（m/s）	3.81	3.68	4.60	4.49	4.73	4.45	
Wind power density（W/m^2）	73.56	59.99	128.47	132.26	105.58	117.16	

The distribution of wind speed and wind energy frequency at a height of 10m in 2019 is shown in Table 2.

Table 2. Wind speed and wind energy frequency distribution at a height of 10m

wind speed range（m/s）	<0.1	1	2	3	4	5	6	7	8
wind speed frequency(%）	0.71	0.00	3.84	11.34	15.58	16.72	16.15	12.69	9.09
wind energy frequency （%）	0.00	0.00	0.01	0.28	1.48	4.24	8.48	11.91	13.99
wind speed range（m/s）	9	10	11	12	13	14	15		>15
wind speed frequency(%）	5.82	3.37	2.35	1.03	0.49	0.30	0.22	0.14	0.17
wind energy frequency （%）	13.51	11.58	11.17	6.51	4.14	3.18	3.01	2.28	4.22

(2) Solar energy resource conditions

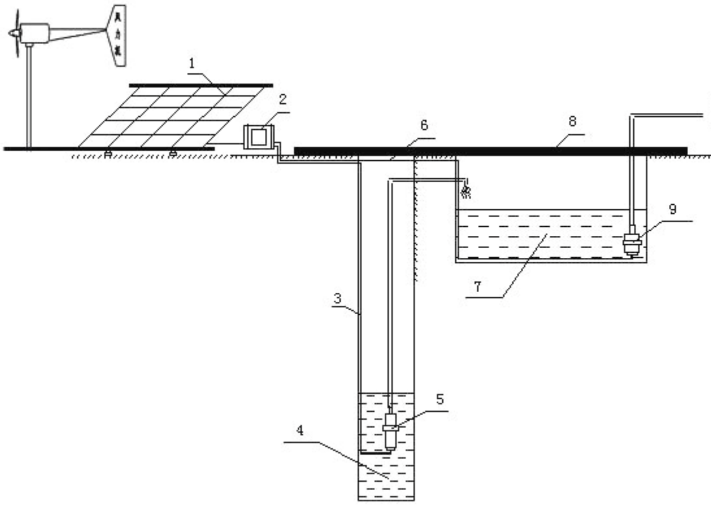
The annual total solar radiation on the horizontal plane is 1703 kW·h/m^2, and the annual scattered radiation is 544 kW·h/m^2. The annual and monthly solar radiation and scattered radiation on the horizontal plane are shown in Table 3.

Table 3. Annual and monthly solar radiation and scattered radiation on the horizontal plane

Time (month)	1	2	3	4	5	6	7	8	9	10	11	12
daily radiation(kwh/m^2)	2.26	3.43	4.61	5.73	6.39	6.73	6.45	5.61	4.90	3.61	2.57	1.90
daily scattered radiation(kwh/m^2)	0.71	0.79	1.32	2.00	2.45	2.60	2.26	2.39	1.70	1.23	0.77	0.71

2.2. Research subjects

The wind-solar complementary water supply project can meet the local water demand based on the production and living water needs、characteristics of local herdsmen, the local water、wind、solar energy resources, pump power and current voltage matching, as shown in Figure 1、2. The main parameters of the water supply project are shown in Table 4.



1.wind and solar power 2.controller 3.first stage water pump cable 4.water source well 5.first stage water pump 6.secondary water pump cable 7.Reservoir 8.anti freezing insulation cover for water source well reservoir 9.secondary water pump

Figure 1. Schematic diagram of water supply engineering structure

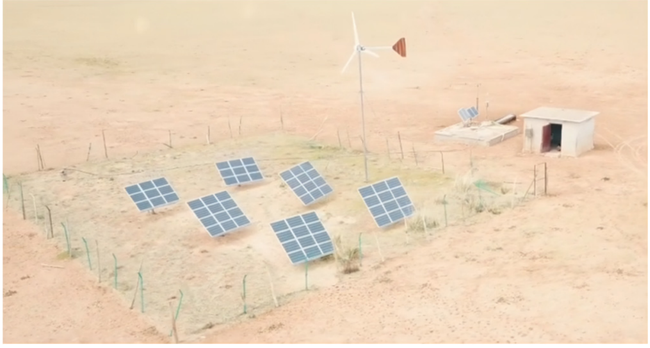


Figure 2. Water supply engineering diagram

Table 4. Table of main parameters of water supply engineering

engineering composition	wind turbine parameters	Photovoltaic array parameters	Reservoir parameters	water pump
main parameter	rated power：2kW Impeller diameter：4.0m Tower height：6m	power：3kW Photovoltaic panel specifications：100W	length：3.0 depth：1.0 width：3.3	model： 100QJ5-108/27

2.3. Research Methods

(1) Formula for calculating wind turbine power generation

$P=0.5\rho AV^3\eta$

P—Wind turbine power generation，W

ρ—Air density，kg/m^3

A—Impeller area，m^2

V—wind speed，m/s

η—conversion efficiency，take 0.35

(2) Calculation formula for photovoltaic array power generation

$$L = W \times H \times \eta$$

L—Photovoltaic array power generation，kw•h

W—Installed capacity，W

H—Peak hours，h

η —conversion efficiency，（Consider a solar energy decay rate of 20% throughout its entire lifecycle）

By combining the above formula with local wind and solar energy resource data, it has been calculated that the wind-solar complementary water supply project will generate 1.46×10^5kw•h of electricity during its lifecycle (20 years). According to the latest notice from the Ministry of Ecology and Environment on the management of greenhouse gas emission reports for enterprises in the power generation industry from 2023 to 2025, the average emission factor of the national power grid in 2022 is 0.5703g/w•h. In summary, the carbon emissions of the wind-solar complementary water supply project during its lifecycle are 83.26kg.

3. Conclusion

It is found that a wind-solar complementary water supply project in Siziwang Banner can generate electricity of 1.46×10^5kw•h and carbon emissions of 83.26kg during its lifecycle by analyzing and calculating its parameters. The research results have clarified the carbon emissions during the regeneration life cycle of wind-solar complementary water supply project which also can supplemente and improve the emission reduction benefits of multi scenario utilization of new energy.

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