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Energy Performance Plan Analysis in a New Ecological City

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Abstract: Conforming to urban development needs, in accordance with ecological and low-carbon requirements, is the first priority of contemporary urban construction. At the first stages of planning a new town, energy planning and analysis, and establishing sustainable energy development strategies, are methods to reinforce the ideal of an ecological city. Therefore, to meet urban planning requirements, energy planning often requires determination of the energy consumption index, and knowledge of local energy demands and natural and social environments (to build a reasonable energy structure), adjusted through the evaluation, design, and optimization of the construction of ecological cities. This paper explores energy planning through an analysis of the application of energy sources in the planning of the eco-city of Jinan City.

Keywords: Energy Performance, Energy Analysis, New Ecological City, Scenario setting, energy-resource structure

Introduction

An Eco-city is one in which energy consumption, pollution, and emissions rates are low, thereby saving energy and enhancing environmental protection. Currently, China is constructing a large number of new ecological cities to adapt the development of the city, economy, and population for an ecological purpose. At the beginning of planning a new town, it is important that energy planning is conducted and applied to ensure that the goal of building an ecological city is fully realized. In the design of the 'Xiuyuan river ecological zone' in Jinan City, China, the energy consumption analysis and optimization method is adopted to fulfil ecological goals.

City profile

Jinan City is located in central Shandong Province, and the Xiuyuan river eco-city is located in the western area of the old Jinan city, with a total area of 23.75 km^2, and planned floor area of 28,700,000 m^2. The land is mostly undeveloped, and the river flows through the center of the eco-city.

Research method

The demand for a green eco-city is forecast by the scenario analysis method, which is based on eco-city planning, research on energy consumption in existing buildings, and an understanding and analysis of energy consumption.

A scheme for renewable energy planning, based on an assessment of renewable energy resources such as solar energy, shallow geothermal energy, wind energy, and conventional coal and gas energy in the total land area, is proposed.

The viability of various renewable energy sources is investigated, based on an assessment of renewable energy that matched construction types with renewable energy source.

A type of renewable energy suitable for each area is also proposed; by making efficient and rational use of energy programs, renewable energy sources in the ecological demonstration area and the municipal energy supply combined bear the primary energy load in the region, suggesting a reasonable energy system and mode of operation.

Energy demand forecast

The energy consumption of the region is divided into heating load, gas load, and power load. According to the regional energy demand, heating load includes industrial heating, domestic hot water use, and summer air condition. Gas load includes residential cooking, commercial cooking, industrial, direct combustion engine, and gas vehicles. Electricity load includes residential, public facilities, industry, business, and others.

Basic scenario settings

According to the construction status and the requirements of China's policy standards, based on the buildings energy consumption standards in 1980, short- and long-term residential building constructions require energy-savings of 75% and 80%, new public buildings require energy-savings of 65%, and the status quo is to maintain buildings according to current research results. Recently, public-building commercial gas consumption has accounted for 60% of residential gas use, and long-term commercial gas consumption accounted for 100% of residential gas use. In the long-term, gas-vehicle gasification rate is also considered.

Residential building energy consumption basic scenario

Residential land construction is divided into three categories: residential, basic education, and community services. Among them, the basic scenario parameters include the performance parameters of short/long-term new-building thermal envelopes, indoor thermal envelopes (lighting, equipment, personnel), indoor environmental control parameters, heating and air conditioning system operation mode, and other parameters based on the " Shandong Province Residential Building Energy Efficiency Design Standards " (DBJ 14-037-2012) design. The conditions for maintaining the building energy consumption indicators were based on research of current conditions. The building heating time is 120 days, and the air conditioning period cooling time is 61 days.

The summer indoor temperature and humidity were set at 26 °C/60%, and the winter indoor temperature and humidity were set to 18 °C/40%. The room ventilation time was 1 hr. to meet typical user comfort requirements.

Basic educational buildings include primary and junior high schools, and the air conditioning system is open Monday to Friday with a running time of 08:00-12:00 and 14:00 -18:00. In community service facilities, the air conditioning system is constantly running, and the daily running time is set between 8:00-21:00.

Public building terminal energy consumption basic scenario

Public buildings include business offices, commercial buildings, municipal buildings, and other public facilities. The basic scenario parameters are consistent with those of residential buildings.

Energy consumption of industrial and municipal buildings
Industrial facilities cover the food processing, logistics, and transport sectors. The total area of industrial land is 12.9 ha. As it is only office energy consumption and does not include the actual output value of industrial buildings, energy consumption indicators, in accordance with R&D office building energy consumption indicators, are only calculated.

Municipal buildings mainly include postal services and telecommunications, transportation, and environmental sanitation; their energy consumption is similar to that of community service facilities, so energy consumption targets were referenced from those of community service buildings.

Heating load

The building area is calculated using the area to floor area ratio. The heating area covers 90% of the building area, a total of 25.83 million m^2, and has a heating rate of 100%(see table 1). Simultaneity usage coefficient of heating load design is 0.7.

Table 1. All types of buildings and their heating areas and heating rates

Building type	Construction area ($10^3 m^2$)	Heating area ($10^3 m^2$)	Rate（%）
Residence	20,140	18,126	70.2
Office	2,010	1,809	7
Business	4,890	4,401	17
Culture and entertainment	420	378	1.5
Industry	1,110	1,000	3.9
Others	130	117	1
Total	28,700	25,830	100

The urban area of the eco-city accounted for 70% of the construction area, giving a total of 20.09 million m^2. According to the "Urban Heating Pipe Network Design Specifications" (CJJ 34-2010), and the types of constructions in the region, a comprehensive cooling data would require 75 W/m^2. Simultaneity usage coefficient of design heating load for air-conditioning is 0.7.

According to the "Urban Heating Pipe Network Design Specifications" (CJJ 34-2010), daily residential hot water use has a daily average heating load data of 12 W/m^2. Other buildings has a daily hot water data of 10 W/m^2, and hot water has a design load factor of 0.65.

Based on the above analysis, designed heating load of this city in short- and long-term can be calculated(see table 2).

Table 2. Designed heating load（10^3 kWh）

Type	2017	2020
Heating	5,450	10,090
Cooling	5,690	10,540
Hot water	890	1,640

Gas load

The residential heat quota was 2300 MJ/person • year, with a gasification rate of 100%. According to the scenario, the industrial gas consumption data was 1 $m^3/100m^2$•day. The storage gas consumption indicator was 0.2 $m^3/100m^2$•day, and gas consumption of the thermoelectric cooling triple for direct gas turbine was 1 $m^3/100m^2$•day. Based on the above analysis, gas load of this city in short- and long-term can be calculated (see table 3).

Table 3. Gas load

Load	2017	2020
Annual gas consumption （10^3 m^3）	20,030	42,950
Annual average （m^3/d）	54,873	118,154
Calculate monthly average day （m^3/d）	65,566	151,066
Peak hours （m^3/h）	9,316	18,587

Electricity load

The electricity load in the eco-city is divided into five categories: residential, public facilities, industrial, commercial, and others. Load forecasting is carried out according to the density data method, and the effect of energy saving measures is determined. The prediction results in electricity load of 108.14 million kwh, with a load density of 20.1 MW/km^2.

Energy structure and evaluation

In consideration of the energy situation and natural resources in the eco-city, Energy use model is based on conventional energy, distributed energy, industrial waste heat, new energy and renewable energy supplement, all kinds of energy complement each other. This will ensure that the urban energy supply is safe and reliable, reducing the green eco-city carbon emissions.

Distributed energy systems

The core business district area is about 1,770,000m^2. The energy supply station uses natural gas as fuel for the region to provide CCHP, because of energetic and electrical safety requirements, and can reduce energy consumption by 60%.

Industrial waste heat utilization system

Power plants can circulate low temperature water resource waste to improve their comprehensive energy efficiency, and reuse waste heat. Urban power plants have a heating capacity of about 20 million m^2, and accounting for pipeline transport distance, heat, and other factors, an area of about 8.6 million m^2 in the planned construction area can receive energy from Jinan City power plant using waste heat.

New Energy and Renewable Energy Systems

Solar photovoltaic, light and heat resources assessment

The eco-city is located in an area with a warm, temperate, semi-humid monsoon climate. The average annual solar radiation intensity is 330 W/m^2, average daily sunshine duration of

6.9 h, annual sunshine duration of 2,516.9 h, total annual radiation of 5120.50 MJ/m^2, and average solar radiation intensity of 330 W/m^2. Areas where the daily sunshine duration is greater than 6 h, and average monthly temperature is greater than 10 °C for 239 days, are rich in solar energy resources, and have the potential to develop solar thermal and solar power industries.

Solar energy supply potential is calculated as Solar energy supply potential (kWh) = land area × planned building density × annual total solar radiation [MJ / (m^2·a)] × usable roof area rate (%) × solar cell area and usable roof area (%) × solar power supply system conversion efficiency (%) × building photovoltaic curtain wall application additional coefficient(see table 4).

Table 4. Estimation Coefficient of Solar Photovoltaic Supply Capacity

Building type	Roof utilization rate	Battery pack / roof area	Photoelectric system conversion efficiency	Additional coefficient of photovoltaic curtain wall
Business	40%	50%	15%	1.2
Office	40%	50%	15%	1.5
Market	40%	50%	15%	1.0
Community service	20%	50%	15%	1.0
Education	60%	50%	15%	1.0

Public buildings with solar panels can provide 0.19 billion kWh of electricity, only considering the provision of living electricity demand and ignoring the comprehensive energy efficiency of solar photovoltaic systems, system investment recovery period, and other economic factors, reducing coal use by 0.69 million tons.

Solar heat can be used in residential lands, primary and secondary schools, and other plots, which are large-scale uses of solar resources. Other uses of a centralized solar water heating system in residential and commercial land development can demonstrate the suitability of a solar thermal system. If the solar panels in the eco-city area region provide heat of about 22×10^8 MJ, this provides 60% of residential buildings' energy requirements

Evaluation of shallow geothermal energy resources in soil source

The distribution of geothermal soil heat in the ecological city area is within 100-400 meters of the surface, and the temperature of the soil and groundwater equal to the local average temperature, and is not affected by the environment or climate. Throughout the year the heat fluctuates but maintains a balance.

Utilizing shallow soil geothermal energy is suitable for areas of smaller building density. According to the plans for the eco-city, the construction area for the low-density residential area, basic education, community services, and the other buildings with smaller building density is in the northern part of the zone, with an area of 800,000 m^2.

Evaluation of shallow geothermal energy resources for surface water sources

In the planning area, annual runoff from the river is large, and water flow is good; however, due to large temperature differences between the river and the water source, the water source can not be used for the water heat pump. The city can not use a river water heating pump system for water resource protection, and other reasons.

Wind energy resource assessment
Jinan has an effective wind energy density of 150-200 W/m^2, which can be combined with the river landscape and solar-wind complementary street lamps.

Energy planning conclusions

Through the analysis of the attributes of the new city and the potential of local renewable energy resources, this paper analyzes new and renewable energy generation and utilization strategies, and provides support for optimizing the energy structure of the new city. New energy and renewable energy in this zone will generate about 100.14$\times 10^7$ kWh by 2020, with carbon dioxide emissions of 356,900 tons, a renewable energy utilization ratio of 15.19%(see table 5), waste heat utilization of 3.03%, and clean energy utilization rate of 100%.

Table 5. New energy and renewable energy replacement rate

Energy type	Quality（10^3kWh）	Annual Occupancy ratio(%)
Solar heating	782,028	11.98
PV	197,100	3.02
Shallow soil geothermal	6,700	0.15
Wind energy	1,670	0.04
Total	987,498	15.19

Conclusion

To develop a scientific and rational renewable energy utilization plan for an eco-city, energy demand should be forecast, and new and renewable energy resources assessed and combined with new and renewable energy conversion system performance characteristics. It should be conducted that analysis of construction sites for renewable energy supplies and energy demand; and new and renewable energy engineering practices should be established based on new and renewable energy capacity, preference, reliability, stability, technical difficulty, economic and environmental conditions, and other aspects of the evaluation. An applicability priority gradient, and the establishment of engineering feasibility criteria, will be of use for a renewable energy target assigned to each area of land and will help achieve the goal of ecological planning.

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