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Feasibility Analysis of Building Heating System Based on Thermal-Economical Evaluation

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Abstract

Building heating energy consumption accounts for about 19.12% of total energy consumption in China in 2014. With the development of building energy-saving technology, renewable energy heating systems, such as GSHP (ground source heat pump), solar energy, air source heat pump, show high energy efficiency and low emissions, which are gradually replacing traditional heating systems. However, due to the restriction of existing productivity and environment conditions, the capital investment of such renewable heating systems is often much higher than traditional ones. As a result, the advantage of renewable heating system is hard to be realized, since its application is highly limited by economic factors. In this paper, traditional thermal-economical evaluation method is modified and improved for feasibility analysis of renewable heating system. Moreover, an illustrative example, which combines solar heating and air-source heat pump together, in Sichuan is given to show the preliminary application of the proposed method. The results indicate that the modified thermal-economical evaluation method can assess the feasibility of renewable heating systems more comprehensively, since it takes the indirect economic effects caused by energy saving and environment protection into consideration, which can balance the huge capital investment of such systems. For the studied case, solar collector combined with air-source heat pump is more preferable than traditional systems. This work is important for feasibility analysis and design optimization of building heating system with renewable energy.

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Keywords: Energy-saving；Building heating system；Economic analysis；Renewable energy；The indirect economic benefits

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1. Introduction

Nowadays with the development of economy and living standard, energy conservation and green building become more important to human beings. In 1996, building energy consumption stood at 246 million tce while it rised to 563 million tce in 2006. In 2014, building energy consumption accounted for 19.2% (814 million tce) of total energy consumption in China with 60.55 billion m² building area. It follows the necessity to reduce building energy consumption [1]. In response to the "thirteenth five years" plan, renewable heating systems like GSHP (Ground Source Heat Pump),solar energy, air-source heat pump are gradually replacing traditional heating systems. At the same time, the thermal performance, economic and environmental effects of such advanced systems has caused increasingly growing research concerns. In engineering field, the applicability or feasibility of specific energy systems are almost based on its economic factor assessment and analysis. However, because of the restriction of existing production levels and environment conditions, the capital investment of renewable heating systems is often much higher than that of traditional ones. It is not obvious to find out the difference between two renewable energy systems on the economic to make a better choice so that it is difficult to show the advantages of the renewable system.

2. Available economic analysis methods and its limitations

The following equation is widely used to evaluate the economy of renewable energy heating systems:

$$E = C + R \cdot n \tag{1}$$

Where E is the system's economic efficiency. C is the capital investment of the system. R is the annual operation cost and n is the life span of the system. For more elaborate depth economic analysis, the following formula can be used:

$$YTC = COF + COR \tag{2}$$

Where YTC is the system's equivalent year-economic efficiency. COF is the constant expenses. COR is the annual running cost of the system. And there is also a formula to calculate COF:

$$COF = D + I + T + INS = \frac{C}{n} + (R + R_S \times 0.8) \times \frac{C}{2} + INS \tag{3}$$

Where D is the depreciation of equipment. I is interest. T is tax. INS is insurance. And C is the cost of equipment. n is compensation period of the system. R is the rate of interest.R_S is the rate of tax.

The above method is always used to analyze heating systems' economic efficiency and it has feasible result to designers and researchers. However, with the development of renewable heating systems it is difficult to select better one by using traditional economy calculation formulas. The following are explained through an actual demonstration project.

This illustrative heating system is of 951 m² heating area, located at West Sichuan in plateau area. With desirable building envelope insulation, its heating load is 39 kW in winter.

Considering the local solar energy and geographical conditions, there are three viable systems to choose from:

1. Electrical boiler heating system
2. Air-source heat pump