

Assessment of environmental and economic costs of rural household energy consumption in Loess Hilly Region, Gansu Province, China

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ABSTRACT

Due to poverty, serious soil erosion and shortage of rural household energy in Loess Hilly Region, Gansu Province, China, excessive consumption of biofuel has become a critical factor underlying eco-environment degeneration. Data on rural household energy use was obtained by questionnaires, and based on substitutable analysis, environmental and economic costs under different energy consumption structures were estimated using a quantitative model. The results show that annual energy consumption per household is 2112.44 kgce and per capita 428.59 kgce, a low level. The total annual energy consumption cost per household is 1925.25 yuan, of which environmental cost is 621.13 yuan and economic cost 1304.52 yuan. Commercial energy has been used widely. The per household annual cash payment for commercial energy is 536.51 yuan, 8.69% of household net income. Exclusive use of solar energy and biogas obviously decreases energy consumption cost, cash payout and energy source availability being the main criteria for household energy choice. To compare with the actual structure of energy usage, there are clear differences in the total cost, environment cost, economic cost and cash payout for households among the four substitutable structures. All costs are lower when biogas and solar energy are used, so this structure is the primary direction that rural energy should adopt in the future.

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1. Introduction

Energy is the most basic material demand for human existence and development. Energy consumption level is used as the criteria to indicate the economic and social development level of a certain region [1]. Energy demand has also become a critical factor driving resource exploitation and environmental change. In rural areas of developing countries in particular, energy consumption has caused a series of environmental and economic problems. Firstly, there are complex and numerous links between energy and poverty. Not only does energy consumption increase the direct economic payment of rural households, but energy collection results in peasants losing opportunities to increase income [2]. Shortage of energy severely restricts the improvement of people's living standard. Secondly, the rapid growth of total energy consumption causes serious environmental problems [3]. Excessive consumption of biomass energy has resulted in degradation of forest and grass vegetation, accelerated soil erosion, and changed ecosystem substance cycles. Thirdly, burning of biomass and coal has caused massive CO₂ and SO₂ emissions, resulting in atmospheric pollution [4]. Fourthly, indoor

air pollution from household energy use is a leading environmental health risk. Indoor smoke in particular produces obvious impact on the health of women and children [5].

Energy supply and demand is widely and closely connected to eco-social development and environmental protection in developing countries. This issue has received much attention internationally and many studies have probed how to solve the problem in rural areas. Evaluation of the exploitation potential of various fuel sources in different regions, especially renewable energy like solar energy, wind energy, biomass, terrestrial heat, etc. has indicated great potential, but energy utilization is restricted by the payment capability of households and lifestyle. In fact, the shortage of energy sources is still a long-standing problem [6–8]. Exploitation and utilization of renewable energy, improvement of the technology of resource use and transformation of patterns of resource consumption are not only main approaches to resolve the problem of energy shortage, but also play important roles in improving the efficiency of resource use and reducing environmental pollution. These approaches have been put into practice in rural areas of Asia and Africa with good results [9–11]. Moreover, some developing countries have optimized their energy structure and adjusted their energy management policies to advance rural development [12,13].

The demand for rural energy in developing countries is continuously increasing, while the energy consumption structure

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only changes gradually along with population growth and improvement of household living level. These increases impact on the ecological environment, causing shifts in the energy consumption behavior of households and government policies. The above-mentioned studies have discussed issues such as greenhouse gas emission, energy poverty and health risk, but insufficient attention has been paid to the economic and environmental benefits of energy consumption. In Loess Hilly Region, Gansu Province, China, ecological and economic problems of energy use stand out, fuel being in very short supply, rural households poor and soil erosion severe. This article takes this region as the subject and attempts to calculate the environmental and economic costs of rural living energy consumption, comparing the effect variances under different structures of energy use. The aim is to put forward an energy policy for environmental management.

2. Study area

The Loess Hilly Region of Gansu Province, China, is located in the north upper reaches of the Wei River, the biggest branch of the Yellow River. Here the criss-crossing gullies and sparse vegetation on soil of loose structure almost unprotected against heavy rain leads to severe erosion, delivering soil and water into the gullies. The loss of water and soil is the most severe in Loess Plateau. Here the annual average temperature is from 5.9 °C to 10.4 °C. Precipitation is about 400 mm and loose soil is easily cultivated. There is a long agricultural history. Archaeological studies in the Dadiwan Ruins of Qin'an County showed that crop planting occurred in the region over 7000 years ago [14]. Due to the barren soil, however, the cropland yield was very low and unreliable. Therefore, reclaiming land became the main means to increase the food supply. Despite a land reclamation ratio of more than 60%, the food shortage has not been resolved. Living energy use has been very scarce, with rural households obtaining fuel from local sources. A biomass comprising crop straw, wood, weeds and animal dung is used for cooking and space heating, which leads to a contradiction among fuel, feed and organic fertilizer.

The average population density of the region exceeded 300 people/km² in 2005 (about 380 people/km² in Qin'an County), the highest among rural areas in Gansu Province. The demand for food has resulted in reclamation of steep slopes for cultivation, and the demand for fuel has led to destruction of vegetation. The zonal vegetation of shrubbery grassland that had been dominant in the region disappeared completely. Without human interference, the natural vegetation has strong renewing ability under 400–500 mm precipitation. Since there is a large population and agricultural production is low, households are commonly in poverty. In 2005, the annual per capita net income of rural residents was only 1500 yuan in both Qin'an County and Tongwei County, typical low income areas in China. The energy demand of a large population brings great pressure on resources and the environment, and severely restricts sustainable development of this region [11]. Living energy consumption is a key interaction process between the environment and the economy, as shown in Fig. 1.

With the long-term food shortage having been the main focus, energy demand has been paid scant attention to. Through the 1990s, the energy question loomed large following satisfaction of demand for food. Since 1999, China has implemented the western development strategy, attaching most importance to improvement of the eco-environment. A set of measures, like reforestation and growing grass on cultivated land, building terraces, closing forests for rehabilitation, small watershed management, as well as restricting grazing on waste grassland, etc., were actualized in the region. Positive effects have been achieved to a certain extent. At the same time, peasants have increased their incomes by planting economic crops and doing manual work out of the home,

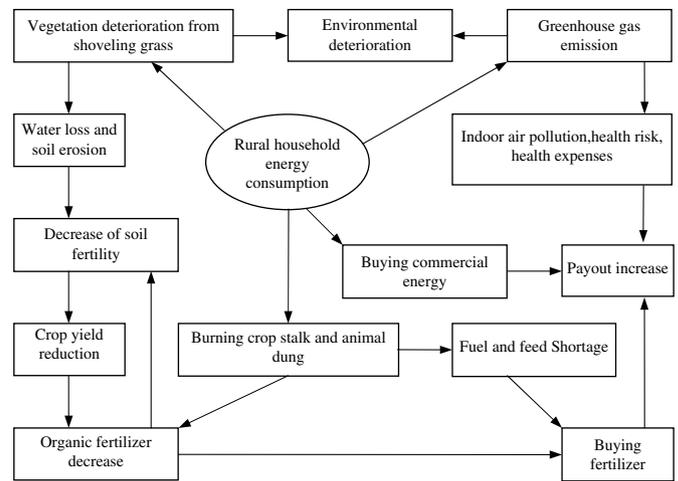


Fig. 1. Rural energy consumption to the impact on Environment and economy.

enhancing consumption of commercial energies like coal, electricity and liquefied petroleum gas (LPG). The rural energy utilization structure is transforming from that of exclusively traditional biomass to multiple energy sources. From the viewpoint of raising the living standard and improving the eco-environment, however, change in rural energy utilization is far from adequate.

In 2003–2005, the State supported a number of households to develop rural energy in the region. Consequently, 6450 households participated in a study to popularize solar stoves and biogas use in both Qin'an County and Tongwei County. This measure effectively shifted the energy use structure, and brought positive effects on the economy and environment. We consider that the synergistic benefit of actively expanding rural energy and protecting existing vegetation of forests and grasslands from destruction is greater than the increase in vegetation by planting trees and grass, in places with poverty and environmental degeneration. Only when the demand for living energy is satisfied fundamentally, is there real significance in protecting and increasing the existing vegetation. Growing trees for many years but without a forest as in the past is one of many factors contributing to the energy shortage. The above are the reasons for addressing the rural energy problem in this article.

3. Study methods

3.1. Calculation of economic and environmental costs on living energy consumption in rural areas

Suppose that there are n kinds of energy resources, m kinds of energy consumption in a certain region, and x_{ij} is the amount of the i th type of resource to use for the j th type of purpose (in coal equivalents), total of energy consumption Te is represented as:

$$Te = \sum_{j=1}^m \sum_{i=1}^n x_{ij} \quad (i = 1, 2, \dots, n, j = 1, 2, \dots, m) \quad (1)$$

The economic and environmental costs of rural energy consumption are not only linked to the quantity of energy use, but also to the energy utilization structure. When different kinds of energy are consumed, there are large differences among their costs and convenience. Suppose that c_i is the unit price of the i th kind of energy source, namely, the coefficient of economic cost, then the total economic cost of energy consumption in a region (or a household) Tc is given as:

$$Tc = \sum_{j=1}^m \sum_{i=1}^n c_i x_{ij} \quad (i = 1, 2, \dots, n, j = 1, 2, \dots, m) \quad (2)$$

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