Energy Policy 35 (2007) 4391–4401

ENERGY POLICY

www.elsevier.com/locate/enpol

Evaluating the potential of small-scale renewable energy options to meet rural livelihoods needs: A GIS- and lifecycle cost-based assessment of Western China's options

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Received 22 September 2006; accepted 14 February 2007
Available online 23 April 2007

Abstract

The economics and livelihoods impacts of stand-alone, small-scale (less than 2 kW) renewable energy technologies for rural electrification are assessed using a representative sample of 531 rural households in three provinces of Western China. Over 20 small wind, photovoltaic (PV) and wind–PV hybrid configurations were evaluated for their potential to meet local electricity needs. The assessment integrates lifecycle costing and geographic information system (GIS) methods in order to provide a comprehensive resource, economic, technological and livelihoods assessment. The results of the analysis indicate that off-grid renewable energy technologies can provide cost-effective and reliable alternatives to conventional generator sets in addressing rural livelihoods energy requirements. Findings also demonstrate the existence of a sizeable market potential for stand-alone renewable energy systems in Western China. In support of market development for these technologies, policy recommendations are provided.

Keywords: Renewable energy; Rural development; GIS resource assessment

0. Introduction

Electricity service can bring tangible social and economic benefits to rural communities which represent 52% of the human population (UN, 2004). More than 2 billion rural residents in developing countries currently lack reliable electricity service (UNDP, 2004), indicating a significant livelihoods threat if the problem is not addressed. The Millennium Goals described by the 2002 World Summit on Sustainable Development include a recognition of this problem (UN, 2002). Reversing the historical trend of development patterns that have largely neglected such populations will not be easy, but the importance of doing so is increasingly accepted (Zhou and Byrne, 2002).

Small-scale diesel/gasoline generators have been used for decades to serve off-grid, rural electricity needs. But the technology poses a series of special technical, economic and environmental problems for rural communities (see, e.g., Byrne, 1996; Byrne et al., 1998, 2001). Micro-hydropower appears to be a more suitable solution, but is limited to areas where the resource is available (Martinot and Wallace, 2003). Wind and solar energy can offer viable sources of electrification in geographic areas of the developing world and may, therefore, be the most widely available options to meet off-grid electricity demand. The paper focuses on these two options.

1. Methodology

To evaluate solar and wind resource availability and the economic feasibility of such renewable energy options, a spreadsheet-based computer simulation model called *Rural Renewable Energy Analysis and Design* (RREAD)[2] was

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[2]RREAD was developed by the Center for Energy and Environmental Policy (CEEP), University of Delaware during a research project sponsored by the National Renewable Energy Laboratory in the US Detailed dissertation of the model and the project can be found in Shen (1998).

0301-4215/$ - see front matter
doi:10.1016/j.enpol.2007.02.022

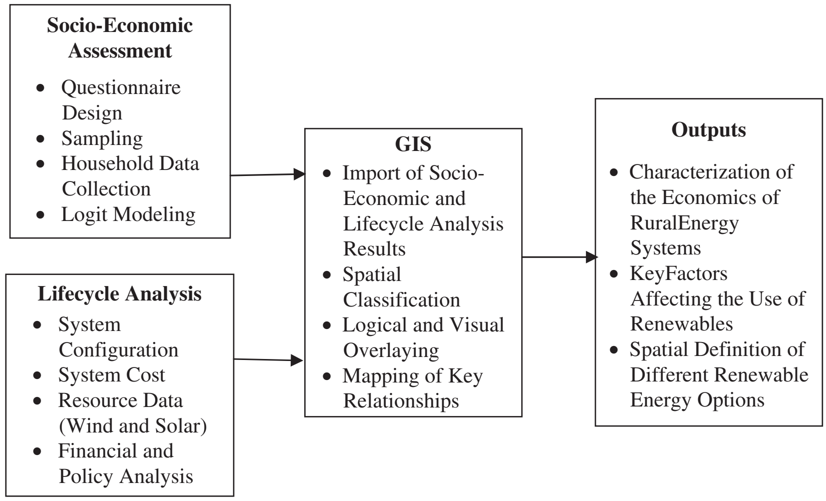

Fig. 1. Conceptual framework of the socio-economic assessment study.

created. This multidimensional simulation tool evaluates the energy and economic performance of off-grid renewable energy technologies including photovoltaic (PV), wind and PV/wind hybrid systems in comparison with conventional gasoline or diesel generators (Byrne et al., 1998; Shen, 1998; Zhou and Byrne, 2002). Hourly data on solar and wind resource availability are processed in RREAD in a technology performance model that includes efficiency and other specifications of renewable energy equipment in order to forecast energy output over the life of different devices. Costs, economics and social and environmental benefits are estimated over the lifetimes of small-scale renewable energy technologies and discounted to the present values in order to evaluate their likely economic impacts.

To assess the socio-economic potential of renewable energy options in rural settings, a comprehensive survey and rural household sample are used to obtain a statistically representative profile of rural energy users.[3] Household survey data, combined with socio-economic statistics, are analyzed with a logit regression model to identify social, economic and technical factors affecting the choice of rural renewable energy options. The model enables the research to isolate statistically robust explanatory variables that offer accurate estimates of household willingness to acquire different energy technologies.

The final step involved the use of geographic information system (GIS) mapping technology to represent in spatial form the socio-economic potential of three renewable energy options for household electricity supply stand-alone small PV system (less than 0.15 kW), stand-alone small wind systems (less than 0.5 kW) and PV–wind hybrids with combined capacities of less than 0.6 kW. GIS methods offer the opportunity to pinpoint the potential size of rural renewable energy demand by combining the parameters of the logit model and lifecycle analyses of system resource and economic performance. The conceptual framework of our socio-economic assessment study is illustrated in Fig. 1.

2. Profile of the three provinces

Over the past three decades, China has dramatically expanded its power supply, including services to rural areas. As a result, over 95% of its rural population has access to electricity (China Statistical Bureau (CSB), 2000, 2003, 2005). Primary strategies for rural electrification have entailed the extension of power grids and the exploitation of small hydropower, or micro-hydro.

However, in spite of these efforts, over 30 million people living in the country's rural areas (more than half of whom reside in Western China) still lack access to electricity (Wang et al., 2004). Additionally, approximately 500–660 million people routinely experience unreliable power supply (Wang et al., 2004; China Statistical Bureau (CSB), 2000, 2003, 2005). Most residents in Inner Mongolia Autonomous Region (IMAR), Qinghai Province and Xinjiang Uygur Autonomous Region experience one or both of these problems.

Grid electric planning is unlikely to meet the needs of the region. Projected electricity demand between 2010 in the three provinces is provided in Table 1.

Table 1 indicates that electricity demand is forecast to increase by 39% from 2005 to 2010, with Xinjiang experiences the highest growth rate (61%). Compared to projected national average growth of 47.1%, electricity demand in the three provinces will be slower. Much of the new demand will be in urban areas and will be met by

[3] As described below, CEEP collaborated with Chinese research partners from the Ministry of Agriculture and the Chinese Academy of Science to interview 531 rural households spread over 22 counties throughout Western China in order to characterize rural energy users in the investigated regions.