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Modeling the benefits of electric cooking in Bhutan: A long term perspective

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ABSTRACT

The study quantifies the benefits of expanding electric cooking in the residential sector in terms of kerosene and fuel wood saved from the perspective of long term optimal energy system development of Bhutan. It also investigates the reductions in the emissions of CO_2 and the indoor pollutants, SO_2 and NO_x due to fuel switching in the cooking enduse. This study method is based on the first ever integrated long-term energy system modeling in Bhutan, which was undertaken previously by the lead author as a master thesis work but not published. The energy system model for Bhutan was developed under the MARKAL model framework. In Bhutan electricity generation is pre-dominantly hydropower based on run-of-the-river schemes. The model results indicate that a sectoral level policy to promote electric cooking reduces the use of kerosene by 1832 kiloliters and fuelwood by 55 kilotonnes per annum which consequently leads to reductions in the emissions of CO_2, SO_2 and NO_x by 17%, 12% and 8% respectively. The electric cooking scenario also complements the vision of Bhutan to reduce deforestation and to remain carbon neutral for all times to come.

Contents

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1. Introduction

This study quantifies the environmental benefits of expanding electric cooking in Bhutan, as opposed to the current dominant practice of burning fuel wood, especially in the rural area. In Bhutan, energy demand for cooking accounts for 66% of the final energy consumption in the residential sector [1]. And even at the global level, cooking is said to be one of the largest end-uses in the residential sector, accounting for around 25% of the global residential energy consumption [2]. The World Energy Outlook [3] indicates that 38% of the global population in 2011 relied on traditional biomass for cooking.

Bhutan is committed to maintaining at least 60% forest cover [4] and it is keen to harness its huge available hydro-electric power potential. Bhutan has also pledged to remain carbon neutral for all time to come – this was announced at COP 15 [5]. Hence Bhutan has been encouraging the use of electric cooking appliances with a view to reduce fuelwood consumption. However the implications of such policies have not been quantified previously from the perspective of the national economy in a published scholarly paper or report. To solve the challenges posed by the energy systems of the developing countries, Urban et al. [6] stated that good energy planning calls for a good energy model.

Works on integrated energy modeling for Bhutan are rare and peer reviewed journal articles on such topics are even rarer. One of the few previous works was the Integrated Energy Management Master Plan (IEMMP) Report for Bhutan carried out by The Energy Resources Institute (TERI), India, using the LEAP model [7]. LEAP is an accounting model and the study used it for energy accounting purposes over the period 2007 to 2020. The study highlighted the huge consumption of fuelwood in the residential sector and the need to curb such consumption habit. LEAP stands for Long-range Energy Alternatives Planning system, a widely used tool for energy planning developed at the Stockholm Environment Institute [8]. The modeling capability of LEAP was enhanced to evaluate least cost system planning only from the LEAP2011 version by integrating it with a new Open Source Energy Modeling System (OSeMOSYS).

Another such energy modeling work for Bhutan was the study carried out for framing 'A national strategy and action plan for low carbon development for Bhutan' [9]. This study also cited the IEMMP report and conducted a Microsoft Excel based scenario analysis of the Bhutan energy system from 2005 to 2040. The aim of the study was to analyze long-term strategy to help Bhutan to remain carbon neutral. In the study, fuel prices were omitted and the model does not incorporate an economic module. The Asian Development Bank (ADB) had conducted a study using MARKAL model on options and costs for reducing GHG emissions for selected five South Asian countries including Bhutan [10]. Since the study is for reducing GHG, it did not include replacing fuelwood stoves by electric stoves amongst the fourteen cleaner technology options chosen for Bhutan. Conservation of forest is given due importance in Bhutan and fuelwood is essentially extracted from forest. Therefore, given the research gap in long term energy modeling, the present study, based on part of the lead author's unpublished Master thesis – the first ever MARKAL modeling of Bhutan [11], reports on the integrated long-term optimization modeling of Bhutan and its application to cooking.

The thesis applied the MARKAL model to Bhutan. MARKAL is a 'bottom-up' model, described by the United States Environmental Protection Agency [12] as a data-intensive, technology-rich energy systems economic optimization model that consists of two parts:

- an energy-economic optimization framework, and
- a large database that contains the structure and attributes of the energy system being modeled.

The MARKAL model has been applied previously in some developing countries. Larson et al. [13] used it to study the energy technology choices in the energy system of China with a time horizon of 55 years. The researchers modeled China as a single geographic region arguing that geographic disaggregation would significantly increase the complexity of the model without providing a commensurate increase in fundamental insights into the technology choices. Amongst other questions, the researchers sought insight into the question of plausible scenarios by which China could meet the projected needs of liquid fuels especially in the transportation while not becoming overly dependent on imported energy.

TERI [14] applied the MARKAL model for developing a roadmap and presenting a vision 2030 document for the energy sector of India. Numerous plausible scenarios were formulated and results were compared with subsequent recommendation for a desirable energy future. The study was conducted with a planning period from 2001 to 2031. On the choice of modeling framework, the study states that MARKAL is preferred over other models due to its dynamic optimization capability, having adequate scope for representing technologies in detail and ability to include user defined constraints.

Shrestha et al. [15] investigated the implications of promoting seasonal and year round electric cooking in Nepal. The study had proposed electric cooking as a means of Demand Side Management (DSM) for the electric utility in Nepal. It was seen as an effective policy for reducing both indoor air pollution and demand for kerosene for cooking.

The present paper consists of six sections. Background information on Bhutan and its energy system is presented in Section 2. Section 3 elaborates the methodology (modeling in MARKAL and end-use demand projections) and the base case scenario description. Section 4 explains the alternative electric cooking scenario. Section 5 discusses the model result of promoting electric cooking and its implications for the energy system development with a focus on reduction in fuelwood consumption and reduction in the emission of pollutants. The concluding remarks are presented in Section 6.

2. Background on Bhutan and its energy system

Bhutan is a small country in the inner Himalaya, sandwiched between the two large booming economies of the world, India and China. Bhutan has been following the middle path development strategy via its guiding principle of Gross National Happiness [4]. Bhutan still remains predominantly an agrarian society, with an estimated 70% of the population of 635,000 dependent on subsistence agriculture for employment and livelihood [16]. The annual average growth of GDP rose from 4.6% in 1996 to 7.8% in 2005 [17], the base year of the MARKAL model. Per capita real GDP in 2005 was US$ 1021 [16] which rose to US$ 1341 in 2012 [18], one of the highest in the South Asian region. The economic structure of Bhutan is changing over the decades, slowly shifting towards industrial activities from the age-old agriculture activity. Despite such desirable structural changes in the economy and impressive economic growth, Bhutan still faces challenges in achieving its vision due to constraints of resources, good governances, legal frameworks and human capacity, as pointed out by Uddin et al. [19].

Bhutan is endowed with rich water and forest resources that can be used substantially for energy purposes. Bioenergy, in its traditional form of firewood, dominates the energy supply spectrum of the country and is the mainstream energy source for a large proportion of the people, especially in the rural areas. The estimated annual sustainable yield of fuelwood is around