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Techno-economic demand projections and scenarios for the Bolivian energy system

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ABSTRACT

Increasing energy access in emerging economies has played an important role to maintain or achieve desirable social and economic development targets. As a consequence, the growing energy requirements need policy instruments to ensure energy supply for future generations. The literature reports many studies with different approaches to model and test policy measures in the energy sector, however few energy-related studies for Bolivia are available. This paper addresses this knowledge gap, representing the first national level energy demand model and projections for Bolivia. The model use demographic, economic, technology and policy trends with a pragmatic model structure that combines bottom-up and top-down modelling. The scenario analysis has a particular focus on alternatives for energy savings, energy mix diversification and air quality. Three scenarios were analysed: Energy Savings, Fuel Substitution and the aggregate effects in a Combined scenario. The reference scenario results show the overall energy consumption grows 134% in 2035 compared to 2012 with an annual average growth of 3.8%. The final energy demand in the energy savings scenario is 8.5% lower than the Reference scenario, 1.5% lower in the fuel substitution scenario and 9.4% lower in the combined Scenario. The aggregate impact of both energy savings and fuel substitution measures leads to potential avoided emissions of 25.84 million Tons of CO2 equivalent in the model horizon 2012-2035.

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1. Introduction

Although energy itself does not ensure human well-being, having access to energy has been identified as essential to fulfilling many social, economic and environment needs of the Sustainable Development Goals, (SDGs) [1] [2]. In developing economies, as standards of living rise with economic development, the energy consumption patterns tends to increase, encouraging the intensification of energy use for industrial and productive activities [3]. Nevertheless, most of the dominating energy consumption and supply patterns are clearly unsustainable when related to growing resource depletion and environmental degradation.

Recent studies such as the Global Energy Assessment (GEA) pathways demonstrate the feasibility of achieving sustainability for such objectives as improved energy access, affordable energy services, better air quality and higher energy security simultaneously through integrated policy design [4].

Achieving sustainability objectives offer multiple benefits beyond environmental and monetary value. Studies have demonstrated the relation between energy and social development showing that energy access allows better conditions for education, increased quality of life, health benefits and higher income opportunities [5] [6].

Meeting sustainability conditions during the economic development process implies cost-effective investments, the tightening of climate legislation and the introduction of new energy policies [7]. These should aim wide, targeting from the very basic energy requirements for achieving social equity, to cutting edge challenges of greater efficiency in energy production and rational use of natural energy resources by “win-win” solutions [8].

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In this context, energy forecasts have been widely used as a starting point for the articulation of energy policy and planning [9]. The forecast outputs represent key data for investment planning research, climate change and natural resource management [10]. Energy forecasting models for policy formulation use different exogenous variables such as population, income, growth factors and technology to determine energy consumption patterns [11] [12] with a scenario formulation that provides insights into specific policies and measures.

Although energy models do not determine policy or substitute political judgement, they project the long term consequences of policy targets, representing a tool to develop informed choices required to tackle the sustainable development challenges.

1.1. Energy and development process in Bolivia

Bolivia is a land-locked country in South America and is classified as a lower middle income economy [13] with a multi-ethnic population of 10.67 million. It has a diverse geography, including Andean mountains, deserts, valleys and tropical forests [14]. The country has considerable wealth in minerals and energy resources and has the 2nd largest reserves of Natural Gas in South America which are fast becoming a strategic source of its economic prospects [15].

From an access perspective however, about 700 thousand Bolivian households were still without access to electricity in 2012 [16] and about 750 thousand households still cooked with traditional forms of biomass [17]. Like most of developing countries, access to modern energy services is characterized by in-equitable access between the rural poor and the urban areas.

Since 2006, Bolivia has undergone an institutional change with increased participation of the government in decisions relating to the economy and energy sectors [18]. The Energy Development Plan 2008–2027 [16] outlines the objectives of national energy policies such as energy security, efficiency and sovereignty; it also identifies strategic targets with a special focus on increasing the standard of living of the poor population and diversifying the electricity generation mix through identified renewable technologies.

In addition, the new Bolivian State Constitution approved by referendum in 2009 [18] in paragraph I of Article 378, defines Bolivia's natural resources as a strategic industrial strength. For this purpose, in 2015 several energy intensive projects were identified in the investment portfolio, PDES,[1] to be implemented by 2025 [19]. However, Bolivia still lacks of energy efficiency standards nor carbon tax or emissions cap regulations.

Few energy-related forecasts for Bolivia have been developed and most are focused on isolated sectors offering only a partial overview of future energy demand trends. These studies, available in the literature, include such reports as the assessment of future demands for natural gas within committed industrial and electric projects [20], inventory of energy related emissions for Bolivia [21], as well as city-level studies such emissions inventory for the city of Cochabamba [22] or ministerial reports such as hydrocarbons [23], electricity demand forecasts [24] [25] and energy scenarios 2008–2027 [16].

The scope of this research is to explore and inform projections of future energy requirements for Bolivia. The model, developed using LEAP[2] [26], represents the first national level energy demand projections for Bolivia that use trends in demography, economy, technology and policy with a structure combining bottom-up and top-down methods. The results offer insights to explore and compare, in a scenario space future energy alternatives while, representing key data looking at forthcoming policy and investments in the supply side.

The structure of the paper proceeds as follows: Section 2 introduces some key considerations relating the modelling approach. Section 3 describes the model structure, scenarios and key assumptions with which the projections were prepared. Different paragraphs are used to describe the methodology used to model each sector and subsector. Section 4 presents the model results in 3 sub-sections: the first shows the Reference energy scenario results, the second presents a parameter sensitivity analysis of the energy model under three macroeconomic scenarios and the third subsection compares the results of the Reference energy scenario with three alternative energy scenarios to investigate the impact of various policies and measures. Section 6 discusses the strengths and limitations of the methods used. Finally, Section 7 concludes with the key findings of the model and scenarios.

2. Modelling approach

2.1. Energy models and indicators

Energy systems models are developed to support sustainable planning (policy and strategy) in a large selection of countries [9] with a planning horizon ranging from short-term −1 day to 1 year-to long term −5 years ahead. Such models have been defined as a comprehensive methodology for the analysis of complex problems such as the interaction between energy and economy, fuel or technology substitution using formal mathematical techniques [27]. To develop demand projections, energy models relate energy consumption patterns with other factors such as economics, industrial development, consumer behaviour and climate.

The literature is rich and diverse in methods for energy demand projections. Sughanti et al., classified 11 broad categories with 364 applied energy examples, ranging from classic model formulations including accounting, top-down, bottom-up (end-use) and econometric approaches, to soft computing techniques widely used in energy demand forecasting such as artificial/expert systems, genetic algorithms, particle swarm optimization and other hybrid models [28].

Notwithstanding the diversity of energy models available, the energy consumption in developing economies is growing fast and randomly. The later is due to the relative inequality in growth that affects different sectors of the economy. Thus, a single mathematical method cannot be generalised to perform well enough when modelling the entire energy demand.

In this study, specific bottom-up and top-down methodologies were applied to project long-term energy requirements for each sector. These methods are not mutually exclusive and can also be combined in a hybrid model [29] in which both methodologies interact with each other [30] [31].

Bottom-up models are data intensive, total energy consumption is obtained through aggregating various energy-using technologies defined by technical characteristics such as efficiency and life cycle [32], while top-down models analyse the energy systems from a higher/aggregated level with its interaction with the economy. Technologies are aggregates and modelled implicitly through average energy intensities. Both methodologies rely on exogenous parameters such as GDP, population, volume of production to calculate the projections. Since a lack of detail in energy end-use data restricts the use of a complete bottom-up demand model, for certain sectors of the economy, this work combines such approaches with top-down analyses which are soft linked with a Computable General Equilibrium (CGE) model.

[1] Economic and Social Development Plan (PDES in Spanish acronym).

[2] Long-range Energy Alternative Planning software.

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