



Methodology for biomass energy potential estimation: Projections of future potential in Colombia



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ABSTRACT

This paper presents a novel method to estimate the future biomass energy potential in countries with domestic markets unable to influence international markets. As a study case, the biomass energy potential in Colombia is estimated for the period 2010–2030.

The prediction model is a scenario-based optimization algorithm that maximizes the yearly profit of locally producing and importing commodities in a country subject to certain constraints (domestic demand, limited area, etc.) as well as to demographic, macroeconomic and market data (e.g. domestic and international prices of commodities). The bioenergy potential associated to the production of commodities is calculated according to a methodology presented by the same authors. In order to provide a modeling framework consistent with other state-of-the-art projections, global scenarios for analysis are selected from the literature rather than formulated. Selected global scenarios highlight the influence of global biofuel use on agricultural prices, production and demand.

Results predict a theoretical bioenergy potential in Colombia 56%–69% larger in 2030 than in 2010 (1.31–1.41 EJ). A sensitivity analysis shows that while a higher global biofuel use leads to a higher local bioenergy potential, its influence is less pronounced than that of agricultural yields, demand and specific energy of biomass resources.

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1. Introduction

Global interest on bioenergy as the largest renewable resource today [1] with the potential to reduce dependency on fossil fuels and decrease greenhouse gas emissions continues to grow. While most R&D activities on bioenergy have been so far carried out in industrialized countries and in few large economies, the largest growth in biomass to power and biofuel production is actually expected in emerging economies and developing countries [2–4]. Despite a vast potential, developing countries face several challenges to use sustainably bioenergy resources. Hurdles include limited industrial experience, constrained investment in R&D and absence of support policies. Strategic planning is therefore required to ensure that appropriate measures are taken to exploit bioenergy.

This paper deals with one of the critical challenges of strategic planning: how to estimate future bioenergy potential in a country.

Assessing the future bioenergy potential is important not only to understand the magnitude and significance of bioenergy to the future energy mix of a country, but also to analyze associated changes in land use and ecological impacts. Ultimately, it is critical to design sound policies that ensure sustainable operation and environmental benefits. Several reviews have recently compared approaches, methodologies, key drivers and results of future bioenergy potential assessment for different countries [5–8]. Most reviews agree that while there is lack of a widely accepted and systematic approach to estimate future bioenergy potential, an ideal approach should consider demographic data, market data (food, energy, others), land use, macro-economic effects and environmental impacts [5–12]. Regarding the country of analysis, the majority of bioenergy assessments target industrialized countries and emerging economies (e.g. BRICS) while a limited number of studies aim at developing countries. Compared to industrialized

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Nomenclature		Symbols	
<i>Abbreviations</i>		<i>A</i>	area
BRICS	Brazil, Russia, India, China & South Africa	<i>c</i>	production cost
CIF	Cost, insurance and freight	<i>D</i>	domestic demand of commodities
COL	Colombian peso	<i>I</i>	volume of imported commodities
FAPRI	Food and Agriculture Policy Research Institute	<i>I1</i>	volume of imported commodities subject to tariffs
FAO	Food and Agriculture Organization of the United Nations	<i>I2</i>	volume of imported duty free commodities
FOB	Free on Board	<i>k</i>	price sensitivity coefficient
FTA	Free Trade Agreement	<i>M</i>	profit
GDP	Gross Domestic Product	<i>P</i>	domestic production of commodities
IEA	International Energy Agency	<i>PIC</i>	price index for Colombia
IIASA	International Institute for Applied Systems Analysis	<i>Y</i>	yield
LDPS2	Livestock Development Planning System v2	π	price “Free On Board” (FOB)
MUV	Manufactures Unit Value	π^*	price “Cost Insurance and Fright” (CIF)
OECD	Organisation for Economic Co-operation and Development	<i>Subscript</i>	
R&D	Research and Development	<i>i</i>	<i>i</i> -th time step, year
TRQ	Tariff Rate Quota	<i>j</i>	<i>j</i> -th commodity
UPME	Mining and Energy Planning Unit	<i>Superscript</i>	
USD	U.S. dollar	<i>D</i>	domestic production
WB	World Bank	<i>E</i>	exports
WEO	World Energy Outlook	<i>I1</i>	imports subject to tariffs
		<i>I2</i>	duty free imports
		<i>Max</i>	maximum

countries, studies for developing countries are often less comprehensive and offer a limited level of detail in data and analysis [5].

The aim of this paper is to present a methodology to estimate the future biomass energy potential in countries with domestic markets unable to influence international markets. The proposed methodology is a combination of resource-focused and demand-driven approaches in which the bioenergy potential is influenced by the demand and land use under different global scenarios selected from the literature. The fundamental driver of land use and trade is the maximization of the profit that can be perceived by local actors. Competition is considered at three levels: food vs. biofuels, residues for energy vs. other uses and local production vs. imports, although an exhaustive representation of all economy sectors and international trade is beyond the scope of this investigation.

Potential advantages of this methodology include a simple approach that is easy to implement and relies on official statistics and public data. Simultaneously, it offers a significant level of detail in terms of land use, production of commodities and biomass categories compared to existing studies for developing countries. These features are expected to be particularly relevant for countries like Colombia, where no future bioenergy assessments are available.

This paper is structured as follows: Section 2 describes the proposed methodology, modeling approach and optimization algorithm to evaluate future bioenergy potential; assumptions, model validation and results for the particular case of Colombia are presented in Section 3; finally Section 4 present the conclusions and recommendations.

2. Methodology

2.1. Bio-energy production in Colombia

The formulation of the methodology starts from a literature review of state-of-the-art approaches to estimate the future bioenergy potential. Detailed comparison of approaches, methodologies, key drivers and results of state-of-the-art bioenergy

assessment are provided by Batidzirai et al. [5], Berndes et al. [8], Heistermann et al. [10], Van Schroyen et al. [11] and Gnanounou [12]. In general, three types of approaches are identified: resource-focused, demand driven and integrated [5, 8].

Resource-focused approaches estimate the overall bioenergy resource and competition between different uses [8]. Two main types of methodologies are employed in resource-focused approaches [5]:

- Statistical analysis: it relies on statistical data to estimate the availability of biomass for energy production and other uses. Advantages include simplicity, transparency, reproducibility and low cost. However, it offers limited considerations for macro-economic impacts, environmental and social aspects.
- Spatially explicit analysis: it combines spatially explicit data and land use to assess bioenergy. The main advantage is the ability to evaluate distribution of bioenergy and impacts at a local and regional level. Drawbacks include lack of reproducibility, labor intensiveness and high complexity that does not necessarily provide more accurate results.

Demand-driven assessments investigate the cost competitiveness of bioenergy systems and evaluate biomass supply to meet exogenous targets [8]. Two main types of methodologies are employed in demand-driven assessments [5]:

- Cost–supply analysis: it combines a bioenergy technical estimation with a cost evaluation of the biomass supply chain. It is a simple, transparent, reproducible and inexpensive method. However, competition is not accurately modeled as it does not allow matching demand and supply through prices.
- Energy-system modeling: it simulates the behavior of energy markets and the competitiveness of bioenergy systems through application of economic optimization. Benefits include suitability to evaluate costs and effectiveness of policies. However, it lacks validation of land availability and agricultural yields and it uses economic correlations based on expert judgment.

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