Technological Forecasting & Social Change 98 (2015) 186–210

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Possible energy futures for Brazil and Latin America in conservative and stringent mitigation pathways up to 2050

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ARTICLE INFO

Article history:
Received 11 July 2014
Received in revised form 29 April 2015
Accepted 7 May 2015
Available online 29 May 2015

Keywords:
Latin America
Brazil
Climate change
Emissions
Integrated assessment models
Climate policies

ABSTRACT

Latin America has a unique position to address climate change impacts due to its many mitigation opportunities and its growing economy. This paper applied two global and one regional integrated assessment models to assess the energy and emissions trends in Brazil and the rest of the Latin American region up to 2050 based on a set of scenarios consistent with current trends and with the 2 °C global mitigation target. The models show that to achieve this target, deep CO_2 emission reductions are needed. The power sector offers the greatest mitigation opportunities. The implementation of CCS, in combination with fossil fuels and bioenergy, and hydro, biomass and wind energy are identified in this study as the most promising low-carbon options for the region. The realistic implementation of these options will depend, however, on their capability to overcome the present technical, economic, environmental and social challenges. Besides, an appropriate policy framework to stimulate the transformation of the energy system is also important. Brazil is the first country in Latin America to adopt a national voluntary mitigation goal by law. However, the assessment of the effectiveness of this goal up to now becomes difficult due to the vague targets established.

1. Introduction

The global energy system faces several key challenges, related to securing sufficient supply to support economic development, limiting energy security issues and mitigating the environmental impacts. Climate change represents a crucial challenge in this context: in order to limit global warming to less than 2 °C compared to pre-industrial levels (consistent with the Cancun Agreements), greenhouse gas emissions associated with energy use need to be reduced all around the world. To understand global response strategies better, it is important to look at regional trends. While several studies have looked at trends in Asian regions (Calvin et al., 2012; Johansson et al., 2014; Lucas et al., 2013; van Ruijven et al., 2012), much less studies have looked at trends in the Latin American (LAM) region. LAM is on the one hand vulnerable to climate change, given the key role of natural systems (IPCC, 2014a; R. Schaeffer et al., 2013), but it also has a unique position in addressing the issue. Many countries in the region may profit in their response strategies from the abundance of natural resources and their growing economies. With this in mind, several countries have elaborated low-carbon plans: e.g., Brazil, Colombia, Mexico, Bolivia, Chile, Costa Rica, and Peru. Brazil, in particular, has an important position in mitigation initiatives worldwide, launching comprehensive programs such as the National Plan on Climate Change (Ministry of Environment Brazil, 2007).

In 2010 the LAM region accounted for about 11% of global greenhouse gas (GHG) emissions (Vergara et al., 2013b). Interestingly, the 2010 emissions were about 11% below the

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http://dx.doi.org/10.1016/j.techfore.2015.05.006
0040-1625/

2000 emissions, largely caused by a decline in land-use (LU) related emissions. The latest IPCC report showed the LAM region among those with the highest abatement potential across different scenarios (IPCC, 2014b). The great mitigation potential of the region is attracting interest among the international community to explore low-carbon development opportunities further (de la Torre et al., 2009; IADB, 2013; IEA, 2013; Vergara et al., 2013a,b). However, only a limited amount of studies have assessed and quantified the implications of high and low mitigation commitments in the long-term in the LAM region, in general, or in Brazil in particular, often using very different assumptions (Borba et al., 2012; IEA, 2013; IPCC, 2007a; La Rovere et al., 2013; Nogueira et al., 2014a; Vergara et al., 2013a,b).

This study aims to address the current lack of scenario analysis in LAM by looking into a set of long-term pathways developed by three different integrated assessment models (IAMs) for Brazil and the rest of LAM region (henceforth referred to as RLAM). The use of multiple models allows a better assessment of the uncertainties involved and has been a major tool in exploring the role of different technologies over time under various assumptions such as climate policy or different socio-economic developments (Eom et al., 2013; Grübler et al., 2007; Kriegler et al., 2014b; Riahi et al., 2013; M. Schaeffer et al., 2013). This paper, in particular, explores the potential development of the energy sector and its emissions with and without stringent climate policy. By doing this, the study addresses the following questions:

1) How does the future for the energy system and CO_2 emissions look like in Brazil and the RLAM in these scenarios?
2) What are the key challenges to implement the required mitigation strategies in LAM, according to the models?
3) How do the identified mitigation pathways, according to the models, compare to current policies in Brazil?

The article is structured as follows. Section 2 describes the methodology and the input data used. Section 3 presents the results for a variety of variables from the models utilized in the analysis. Section 4 discusses the outcomes, the limitations of the study and how the main findings relate to the challenges faced by the region as well as to the climate policy context in Brazil. Finally, Section 5 presents the conclusions.

2. Methodology

2.1. Model description

This paper employs the results of two global IAMs (IMAGE and AIM-Enduse) and one regional IAM (MESSAGE-Brazil) to assess possible emissions pathways up to 2050 in Brazil and the RLAM (including the Caribbean and Mexico). Comparing the global projections with national insight provides a better understanding of the implications of climate change and energy responses at more refined scales, improving the quality of projections. The models are used for the development of a set of future climate scenarios. Each model uses different approaches including partial equilibrium, techno-economic and hybrid approaches. The diversity of approaches is important since it allows understanding structural uncertainties among the models as well as identifying which findings are more robust across the various methodologies. The models also differ with respect to the representation of greenhouse gas emissions, sectors and the timeframe (Table 1). A short description of the participating models is presented below. For further technical description of the models, see Appendixes A, B and C.

The Integrated Model to Assess the Global Environment (IMAGE 2.4) framework (Bouwman et al., 2006), developed by the Netherlands Environmental Assessment Agency, consists of a set of linked and integrated models that describe fundamental elements in the long-term dynamics of global environmental change, such as air pollution, land-use change and climate change. The main components are the global energy model TIMER 2.0 (Bouwman et al., 2006), the land use and the land cover submodel and the climate policy model FAIR–SiMCaP (Den Elzen and Lucas, 2005). The energy model TIMER describes the demand and supply of 12 different energy carriers for 26 world regions. The IMAGE land-cover submodels simulate the change in land use and land cover driven by demands for food, timber and biofuels and changes in climate. The FAIR module distributes the global emission reduction across the different regions, gases and sources in a cost-optimal manner by using information on marginal abatement costs. The SiMCaP pathfinder module uses an iterative procedure to find multi-gas emission paths that correspond to a pre-defined climate target (Van Vuuren et al., 2007).

The AIM-Enduse model (Asia-Pacific Integrated Model) is an inter-temporal dynamic optimization, techno-economic model for mid- to long-term climate policy assessment. The world is divided into 32 regions over a time horizon up to 2050 and covers both the energy and non-energy sectors (e.g., agriculture, waste, and fluorinated gases) (Kainuma et al., 2003a, 2013). It simulates flows of energy and materials in an economy, from supply of primary energy and materials, to conversion and supply of secondary energy and materials and to satisfaction of end-use services. AIM-Enduse models these flows of energy and materials through detailed representation of technologies. Consequent emissions are modeled elaborately. Selection of technologies takes place in a linear optimization framework where system cost is minimized based on the exogenously given energy price under several constraints like satisfaction of service demands, availability of energy and material supplies, and limiting GHG emissions to a specific level.

MESSAGE is a perfect-foresight, mixed integer linear optimization model developed by the International Institute for Applied Systems Analysis (IIASA) and the International Atomic Energy Agency (IAEA) to evaluate alternative energy supply options under economic, environmental or technical constraints, among others. MESSAGE-Brazil (MSG-BR) is a regional variation of the global MESSAGE model developed by the Centre for Energy and Environmental Economics (CENERGIA) of COPPE/UFRJ in Brazil. The Brazilian regional model has been adapted to the Brazilian case with global input variables (e.g., population, GDP, land use, trade) set exogenously; and the country divided into three regions. The current version of MSG-BR was initially developed as part of a study of the IAEA (IAEA, 2006b). Since then, it has been constantly improved to model the Brazilian energy system's adaptation to possible long-term climate change scenarios (de Lucena et al., 2010) and the integration of wind or solar options (Malagueta et al., 2013) into the country's electric power grid. The most recent version includes: fossil fuel power plants with carbon capture and storage (coal and natural gas); improvements to Brazil's petroleum refinery infrastructure