Energy Economics xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Climate policy scenarios in Brazil: A multi-model comparison for energy

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ARTICLE INFO

Article history:
Received 1 September 2014
Received in revised form 29 September 2014
Accepted 6 February 2015
Available online xxxx

JEL classification:
H23
C88
Q40
Q54
C61
C63
C68
O57

Keywords:
Climate policy
Low-carbon energy scenarios
Mitigation alternatives
Brazil

ABSTRACT

This paper assesses the effects of market-based mechanisms and carbon emission restrictions on the Brazilian energy system by comparing the results of six different energy-economic or integrated assessment models under different scenarios for carbon taxes and abatement targets up to 2050. Results show an increase over time in emissions in the baseline scenarios due, largely, to higher penetration of natural gas and coal. Climate policy scenarios, however, indicate that such a pathway can be avoided. While taxes up to 32 US\$/tCO_2e do not significantly reduce emissions, higher taxes (from 50 US\$/tCO_2e in 2020 to 162US\$/tCO_2e in 2050) induce average emission reductions around 60% when compared to the baseline. Emission constraint scenarios yield even lower reductions in most models. Emission reductions are mostly due to lower energy consumption, increased penetration of renewable energy (especially biomass and wind) and of carbon capture and storage technologies for fossil and/or biomass fuels. This paper also provides a discussion of specific issues related to mitigation alternatives in Brazil. The range of mitigation options resulting from the model runs generally falls within the limits found for specific energy sources in the country, although infrastructure investments and technology improvements are needed for the projected mitigation scenarios to achieve actual feasibility.

1. Introduction

The increase in greenhouse gas (GHG) emissions in the recent decade has been dominated by the emerging economies, explained mainly by the growth in their economic activity (Peters et al., 2012). In the case of Brazil, emissions up to 2010 have been dominated by land-use carbon dioxide (CO_2) and non-CO_2 gases, pinpointing the key role played by deforestation and agriculture in the country and placing it in fourth-place when it comes to ranking national contributions to observed global warming (Matthews et al., 2014). When accounting only for CO_2 emissions from fossil-fuel burning, cement production and gas flaring, however, Brazil is ranked as fifteenth (Boden et al., 2013).

Most of Brazil's deforestation takes place in the Brazilian Amazon, where its rate has decreased substantially in the recent years (from a 10-year deforestation average of 19,500 km^2 $year^{-1}$ in 2005 to 5843 km^2 $year^{-1}$ in 2013 — Nepstad et al., 2014). According to Aguiar et al. (2012), the reduction in deforestation rates in that biome alone leads to a drop in annual CO_2 emissions from more than 1.1 billion tons of CO_2 in 2004 to 298 million tons of CO_2 in 2011, assuming a direct conversion of lost biomass into carbon. Should deforestation stabilize at this new level, the energy sector will, in the near future, become the main source of emissions in Brazil.

Globally, Brazil is in a favorable position when it comes to the use of renewable energy sources. In 2013, over 40% of all primary energy produced in the country came from renewable sources (EPE, 2014), a value that is relatively high compared to the world average of around 13% (IEA, 2013). Most of the renewable sources used in the country come from sugarcane products (16.1%), hydropower (12.5%) and other biomass (8.3%). Wind, solar and other renewable resources still play a

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http://dx.doi.org/10.1016/j.eneco.2015.02.005

small role, with less than 5% of the total primary energy produced in Brazil (EPE, 2014).

However, socioeconomic development of the country will result in higher energy use that is not guaranteed to come from renewable sources. In spite of the current high share of renewables in the Brazilian energy mix, the country faces a situation where, on the one hand, it needs to increase its energy production to foster socioeconomic development, job creation and poverty alleviation. On the other hand, the country faces the near exhaustion of its environmentally feasible hydropower potential and is expected to increase fossil energy use, with the recent oil discoveries in the pre-salt[1] fields and the perspectives for increased coal-fired power generation (EPE, 2013; Nogueira et al., 2014; Saraiva et al., 2014).

Different policy options are available to foster a low-carbon economy. The evaluation of market based policies, such as a carbon tax or negotiable emission permits, has been widely conducted in worldwide and regional analyses (Clarke et al., 2012; GEA, 2012; IPCC, 2014). To date no study has analyzed the effects of different carbon policies, such as taxes and/or caps, on the Brazilian energy system by running and comparing different integrated assessment models (IAM).

As part of the Latin American Modeling Project and Integrated CLimate Modelling And CAPacity building in Latin America (LAMP–CLIMACAP — van der Zwaan et al., 2015a), six teams have generated profiles of the Brazilian energy system out to 2050 under different carbon tax and abatement target regimes using different IAMs. This paper compares the models' results[2] for Brazil in order to assess the possible effects of GHG mitigation strategies on the country's energy system. Based on the identification of key energy segments provided by this analysis, this paper provides a discussion of issues particularly relevant to Brazil.

This paper is organized as follows. Section 2 discusses the models and scenarios used in the study. Section 3 presents the basic assumptions and baseline results. Section 4 shows the results for climate policy scenarios. Section 5 discusses specific issues in the Brazilian energy system and relates them to climate change mitigation policies. Finally, Section 6 concludes the paper with some final remarks.

2. Participating models and scenario description

Within LAMP–CLIMACAP, six modeling teams assessed Brazil as an independent region and were, therefore, considered in this study. These groups have produced five scenarios for the Brazilian energy mix out to 2050 under different climate policy regimes. The models used in this study are: EPPA (Paltsev et al., 2005, 2013); GCAM (Calvin et al., 2011); MESSAGE-Brazil (IAEA, 2006; Lucena et al., 2010; Nogueira et al., 2014); Phoenix (Wing et al., 2011); POLES (Griffin et al., 2014; Kitous, 2010); and TIAM-ECN (Kober et al., 2014 and van der Zwaan, 2013). These models differ from each other in terms of their modeling approach (optimization or simulation), spatial resolution (national or global), sectoral scope (partial or general equilibrium), degree of foresight (myopic or perfect foresight) and representation of technological options (type, availability and costs). The models also differ in how they treat the potential for energy resources and represent technological change. A comparison of model features can be found in van der Zwaan (2015b) and Clarke et al. (in this issue).

A baseline scenario and four climate policy scenarios developed within the LAMP–CLIMACAP exercise are used in this paper and other studies within this special issue (Clarke et al.; van der Swaan et al.; Calvin et al.; van Ruijven et al.). The current climate policy in Brazil is limited to 2020 and there is not a clear picture or deep discussion in the country about a climate policy strategy beyond 2020. Considering this absence of discussions about possible future mitigation policy choices, testing standard mitigation instruments, such as carbon prices and emission targets, can provide useful information for climate policy making in the country, given that the model scenarios analyzed here for these instruments provide cost-effective mitigation options. Additionally, by using a standardized set of policy scenarios, it is possible to compare the effects of these policies across countries in Latin America (e.g. Clarke et al., in this issue).

The core baseline scenario is based on business-as-usual assumptions at the regional and global levels and is used as the reference for the climate policy scenarios. It does not include the Brazilian Copenhagen Pledge[3] or new climate or energy policies except those implemented prior to 2010. The four climate policy scenarios are divided into two different sets: two scenarios with CO_2 price paths applied to all GHGs — Low CO_2 price and High CO_2 price; and two others with emission reductions applied to all fossil fuel and industrial (FF&I) CO_2 emissions — 20% abatement (FF&I) and 50% abatement (FF&I). The scenarios are progressively stringent in terms of mitigation efforts. Both sets of policies begin in 2020 and all other assumptions are the same as in the baseline. Table 1, shows the CO_2 price paths and emission reductions assumed by the climate policy scenarios. For a more detailed description of the scenarios used in this study see van der Zwaan et al. (2015a), van Ruijven et al. (in this issue) and Clarke et al. (in this issue).

In this paper the results of the different models/scenarios are analyzed only for the industrial and energy sectors. For an analysis of land use and forestry emissions resulting from the LAMP–CLIMACAP modeling efforts see Calvin et al. (in this issue). Because the sectoral scope of the models is different – e.g. some models have endogenous land use modules – in the 20% abatement (FF&I) and 50% abatement (FF&I) emission reductions are applied to energy and industry only. Still, not all models include emissions from industrial processes. However, since these are relatively small compared to energy emissions, they do not significantly affect the model comparison (for simplicity, henceforth the term 'emissions from energy' will refer to emissions from energy and industry).

3. Basic assumptions and baseline scenarios

Model Projections are largely dependent on the basic assumptions guiding the evolution of the main drivers for energy production and consumption. Assumptions about technological development, costs, behavior, and trade, vary greatly across models (for more information on the technological specifications within the models used in the LAMP exercise, see van der Zwaan et al., in this issue). The models were not harmonized for Gross Domestic Product (GDP) and population growth, which creates a broad range of future pathways. The basic population and GDP assumptions used in each model are described in detail in van Ruijven et al. (in this issue). Some models are computable general equilibrium (CGE) models (Phoenix and EPPA) with endogenous GDP pathways that vary across the different scenarios prepared for this comparison exercise. In all other models, GDP is exogenous and is the same across scenarios.

The models generally assume that Brazil's population stabilize at different levels by 2050 (except GCAM) and, in some cases, population peaks in 2040 and then decreases. The assumptions for GDP vary greatly across models, ranging from a 2.5 to more than a 4-fold increase from 2010 to 2050. In per capita terms, the spread of GDP assumptions is also large, nearly doubling in the lower case and increasing by 3.6 times by 2050, when compared to 2010.

[1] The pre-salt oil fields are so called because of the 2000 m layer of salt above the oil. Estimated reserves in these fields range from 30 to 100 billion barrels of oil (OCD, 2009).

[2] The results database of the LAMP-CLIMACAP project can be found at https://secure.iiasa.ac.at/web-apps/ene/LAMPDB/.

[3] The Brazilian pledges were announced at the UNFCCC Conference of Parties in Copenhagen, 2009. These voluntary pledges set emission reduction targets of 36.1–38.9% compared to baseline emissions projected up to 2020 (Brasil, 2009). The extent to which these pledges are based on a realistic baseline is debatable (see, for example, Lucon et al., 2013; Clarke et al., this issue).