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Energy transition and path creation for natural gas in the Brazilian electricity mix

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ABSTRACT

Emerging economies will account for more than 90% of net energy demand growth to 2035. Although there is international consent about the need for reducing green-house gas (GHG) emissions, reduction targets have been left to governments' responsibility. Such opening lead to different energy policies and approaches among countries, specially comparing developing economies to developed ones. Technology development and new reserves found have set natural gas as the lead resource for transitioning energy mixes to lower carbon levels. However, hydropower has been the main source for the Brazilian electricity grid, and increasing dispatch of natural gas in fact increases GHG, which has been the core of current Brazilian energy policies. We estimated future Brazilian market shares of hydro, thermal, wind and nuclear power, through historical data analysis of power dispatch and installed capacity. The findings propose that current Brazilian administration is creating a new technological path, which will lead far from the desired GHG targets. If actual growth rate of thermal power continues, by the year 2022 thermal plants will be major suppliers of the Brazilian electricity grid, leaving hydro with the second largest market share. Furthermore, we propose several approaches for increasing adoption of renewable distributed generation and the development of other market niches for natural gas in Brazil, as alternative paths.

1. Introduction

International consent about reducing greenhouse gas (GHG) emissions has been achieved in the last decades. However, in order not to interfere in each country's sovereignty, reduction targets and approaches were left at national governments' responsibility (IPCC, 1990). Such decision has led to differences in energy policies and reduction achievements among countries (Laird and Stefes, 2009; Lipp, 2007). Moreover, fast developing economies as Brazil, China, India, Russia and South Africa present greater differences in targets and policies comparing to developed countries (IEA, 2013a; Rubio and Folchi, 2012), with much less consideration and effort regarding the reduction of GHG emissions, as it brings short-term economic constraints. Also, several studies on industrialized countries' energy transitions have been accomplished, although such transitions in emerging economies have not been covered with similar effort (Grubler, 2012). Such issue is a worldwide concern, since global energy demand is expected to move towards emerging economies in the next decades, which is expected to account for more than 90% of net energy demand growth until 2035 (IEA, 2013b).

Many societal problems, including environmental issues, result from social dilemmas. Although uniform cooperation would benefit everyone, each individual can benefit from free-riding (Hardin, 1968). Societies have found ways to overcome 'tragedies of the commons', and many studies have presented models and approaches which may mitigate such dilemma efficiently. Co-evolutionary games clearly show that coevolution is a promising concept to follow, as it constitutes the most natural upgrade of evolutionary games in the sense that not only strategies evolve in time, but so does the environment, and indeed many other factors that in turn affect back the outcome of the evolution of strategies (Perk and Szolnoki, 2010). For Grund et al. (2013), biological competition is widely believed to result in the evolution of selfish preferences. Assuming conditions promoting non-cooperative behavior, the authors demonstrate that intergenerational migration determines whether evolutionary competition results in a 'homo economicus', showing self-regarding preferences, or a 'homo socialis', having other-regarding preferences. Such approaches demonstrate the need for complementary economic theory

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embracing 'networked minds' (the 'homo socialis') and evolutionarily grounded theory of other-regarding agents, explaining individually different utility functions as well as conditional cooperation.

Regarding empirical data analysis, GHG emissions have currently been measured and compared to the first targets settled in 1990 (benchmark), as proposed by IPCC (Intergovernmental Panel on Climate Change) (IPCC, 1990, 2007, 2013), allowing cross-country comparisons of targets, achievements, and efficiency of policies bred. The results of such analysis shall provide knowledge through experience in order to correct previous projections for future emissions, after initiatives have already been enforced, which will in sequence alter either policies or targets, whatever suits better each country.

The electricity sector demonstrates different GHG emissions share among countries, which is a result of each particular energy mix. It is the major GHG emitter in many countries due to thermal power plants (IEA, 2013a; NREL, 2012). Recent technology development and new reserves found have set natural gas as the lead resource for transitioning electrical energy mixes to lower carbon levels throughout the globe, especially complementing renewables' intermittency (Mohareb and Kennedy, 2014; IEA, 2013b; NREL, 2012). Such assumption is true when we compare a thermal power plant fueled with coal or oil to one burning natural gas, since coal emits twice GHG levels than natural gas. On the other hand, the Brazilian electricity grid has been mainly supplied from hydropower for decades, and it seems that current policies are aiming to increase market share of natural gas, which in fact increases GHG levels of the grid. Installed capacity of different plants in the Brazilian National Integrated System (SIN) is demonstrated in Fig. 1, where the increase of thermal power share is visible in recent years. Despite such scenario, Brazilian per-capita CO_2 emissions is expected to increase by 50% to reach 3 tonnes of CO_2 in 2035, which is still only 70% of the world average (IEA, 2013b).

The discovery of offshore fields (Pre-salt) has set Brazil as one of the world's largest oil and gas reserves (Goldemberg et al., 2014; IEA, 2013b). Hence, increasing dispatches from thermal power plants in Brazil may be seen as technological path dependence stirred by the oil and gas industry, spurred by supply availability. Such tendency fosters technology adoption for these energy sources, directly supported by the government, since Petrobras, the major player in the market, is a company controlled by the State.

Thus, this paper demonstrates that current Brazilian policies regarding electricity generation and consumption are creating a new technological path, less sustainable, which will lead the administration far from the desired GHG emissions cut as advertised. Furthermore, we present historical data analysis obtained from Brazilian public agencies related to the power sector in order to compare predictions of future GHG emissions, according to the path currently being created, to administration targets. In spite of such future scenarios, we propose alternative policies for developing new paths for electricity generation and the smarter use of natural gas, keeping the Brazilian electricity mix mainly renewable.

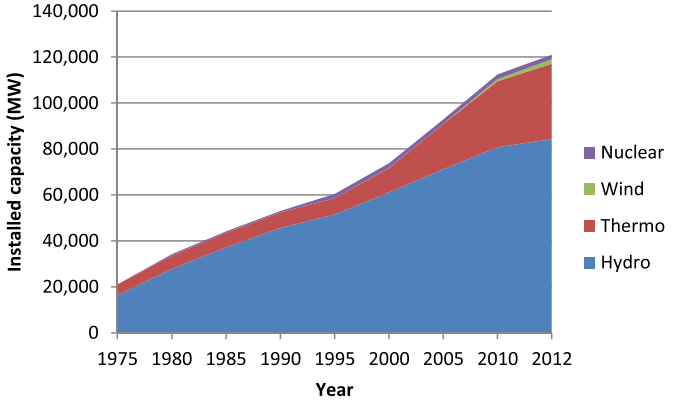

Fig. 1. Brazilian electricity generation installed capacity for different sources (EPE, 2013).

Section two presents the methods used in the study. Section three shows the background of technological path dependence and creation, as well as their relation to energy transitions and the development of national energy policies. Section four demonstrates results and discussion of the current Brazilian scenario regarding the electricity mix and possible future energy transitions, comparing the findings to predictions released by Brazilian administration reports. In section five, several approaches considering both supply and demand side management are presented as alternative policies in order to create an alternative new path.

2. Methods

Although some authors argue that energy transition evidence requires the analysis of long-term data for energy consumption (Verbong and Geels, 2007), the pace which it has occurred has varied greatly among countries, decades of difference, specially comparing developed economies to industrialized countries (Rubio and Folchi, 2012; Grubler, 2012; Solomon and Krishna, 2011). It also depends on the technological stage which the country is found, the diffusion rate of adoption and time. Such phenomenon can be understood through the evolution of energy sources market share (Rubio and Folchi, 2012), which demonstrates a country's energy mix in a given time.

Diffusion research does not necessarily have to be conducted after an innovation has diffused in a system. It is possible to investigate the diffusion of an innovation while the diffusion process is still ongoing, and data can be gathered during the diffusion process. This type of research design is similar to field experiments, where data are gathered before and after an intervention (Rogers, 1995), providing a suitable approach to analyze diffusion of new technologies before and after related policies are enforced.

Regression analysis has proven a reliable statistics tool for the investigation of relationships between variables. Regression techniques have long been central to econometrics, and have become useful to policy makers, widely used for prediction and forecasting (Freedman, 2005). Thus, we propose using regression analysis of historical data from several Brazilian institutions, which present reliable information about installed capacity and energy produced over the years, in order to analyze the adoption rate of new technologies for electricity generation and future energy transitions in Brazil. The regressions were taken with different timelines, representing different policy profiles and thus tendencies, in order to compare historical market shares, paths and embedded shifts. In this sense, path dependence of energy sources is compared to diffusion of innovations guided by national policies. Regression analysis is then a quantitative approach in order to evaluate current energy policies and their implications to future scenarios, making viable the prediction of their efficiency regarding GHG emissions targets and the actual paths being built. For such objective, the results were compared to the administration GHG emissions targets.

3. Path dependence and innovation diffusion in the energy industry

Path dependence leads the next generation of technologies towards historically shaped innovations, which is either pushed by research and development advances or by policies molding the