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Electricity supply security and the future role of renewable energy sources in Brazil

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ABSTRACT

Hydropower is the backbone of the Brazilian electricity generation sector. Even though the use of this resource is advantaged in terms of greenhouse gas emissions, last years' severe droughts have exposed the country's huge dependency on hydroelectricity. Brazil's electricity supply system has shown to be vulnerable to electricity shortages and has demanded significant overhaul in order to address its challenges. The present paper provides a comprehensive review of the current status of the Brazilian electricity sector and discusses diversification of electricity generation mix as a strategy to improve electricity supply security in the country. An overview of the main features of the energy sources applied in Brazil is also presented through a review of the latest available generation data. The central section of this work is a discussion of the main causes of the current crisis and the future role of renewable energy sources in a 10-year perspective.

Contents

Abbreviations: ANEEL, Brazilian Agency for Electric Energy (Agência Nacional de Energia Elétrica); BRICS, Acronym for an association of five major emerging national economies: Brazil, Russia, India, China and South Africa; CCS, Carbon Capture and Storage; CCEE, Chamber of Electricity Energy Commercialization (Câmara de Comercialização de Energia Elétrica); CNPE, National Energy Policy Council (Conselho Nacional de Política energética); CRESESB, Reference Centre for Solar and Wind Energy Sérgio de Salvo Brito (Centro de Referência para Energia Solar e Eólica Sérgio Brito); EIA, Energy Information Administration; EPE, Company for Energy Research (Empresa de Pesquisa Energética); GDP, Gross Domestic Product; IBGE, Brazilian Institute for Geography and Statistics (Instituto Brasileiro de Geografia e Estatística); INCT, National Institutes for Science and Technology (Institutos Nacionais de Ciência e Tecnologia); INMETRO, National Institute of Metrology Standardization and Industrial Quality (Instituto Nacional de Metrologia, Qualidade e Tecnologia); LCOE, Levelized Cost of Electricity; MME, Ministry of Mines and Energy (Ministério de Minas e Energia); OECD, Organization for Economic Co-operation and Development; ONS, Brazilian Operator for Elecricity System (Operador Nacional do Sistema Elétrico); PDE, Brazilian Energy Expansion Plan; PLD, Settlement Price Differences (Preço da Liquidação das Diferenças); PROINFA, Program of Incentives for Alternative Electricity Sources (Programa de Incentivo às Fontes Alternativas de Energia Elétrica); SIN, National Interconnected System (Sistema Interligado Nacional); UNFCCC, United Nations Framework Convention on Climate Change; VCG, Variable costs of generation

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1. Introduction

Brazil has a population of 204.03 million and covers an area of 8.51 million km² [1]. The country has a per capita income of nearly US$ 11,208 a year and a total production of about US$ 2245.67 billion in terms of Gross Domestic Product (GDP) [2]. In 2014, Brazilian industry accounted for 26.4% of the domestic production, while agriculture accounted for an additional 5.5% and the service sector for 68.1% [3]. Most of the population is concentrated in urban areas, particularly in large cities. The country's urbanization rate is 84.36% but it can be as high as 96% in some regions, e.g., in state of São Paulo [4,5]. The country ranks 9th in the world in terms of energy consumption and the 4th largest among the BRICS [6].

Total primary energy consumption in Brazil has increased 57% from 2000 to 2013 [7]. Largest share of total energy consumption comes from oil and other liquid fuels (44%), followed by hydroelectricity (35%), and natural gas (8%) [8]. Brazil holds leadership position with regard to the use of renewable energy resources. On the whole, around 42% of the primary energy mix comes from renewable resources, which contrasts significantly with the global average of 13% and with the 8.1% average for OECD countries [7].

Brazil has one of the largest hydroelectric potential in the world and this corresponds to more than two-thirds of the total installed capacity in the country. The use of water resources brings many advantages, but its prevalence makes it electrically dependent on hydrological conditions. Intensive drought in the last years has damaged the main source of electricity generation and left reservoirs dangerously low. Brazil has barely escaped forced electricity supply shortages in 2015 and the diversification in electricity generation mix in order to increase the electricity supply security has become an issue. In addition, many problems need to be addressed, such as: how to further expand hydropower generation, how to boost development of other renewable sources and optimize intermittent power generation, and the role of oil, natural gas, and coal in a period when many countries seek to reduce the use of fossil fuels.

The objective of this work is to provide a diagnostic review on the positional gap of electricity generation and the main causes for the current crisis. Emphasis is also placed on a discussion of main features of electricity generation sources and the expected role of renewable and non-renewable energy as alternative sources for the increase of electricity supply security in the near-future.

The methodology applied in this paper includes an in-depth review of official reports and documents provided by the Brazilian regulatory authorities. After a review on the structure of the Brazilian electricity sector in Section 2, technical data on the supply of electricity are presented in Section 3 in order to provide an overview of the current status of electricity generation in Brazil. Section 4 includes a discussion of the main reasons for the current crisis in the electricity sector. In addition, based on data available in the Energy Expansion Plan for 2023, the future perspective of the main generation sources of electricity and the impact in terms of security of supply are discussed. The main conclusions of this work are summarized in Section 5.

2. Structure of the electricity sector

Brazil has been increasing its installed generating capacity and had 126.74 GW in 2013 as shown in Fig. 1. Overall, 53.07 GW has been installed since 2000, which represent an increase by 72%. In 2013, hydroelectric power plants accounted for 67.87% of the installed capacity, with increasing amounts coming from thermoelectric power plants (28.82%) and other forms of renewable energy such as wind and solar energy (1.74%). Nuclear sources corresponded to 1.57% of the installed capacity [7].

Fig. 2 displays the installed electricity generation capacity by region. Most of this electricity is generated in the Southeastern region (33.30%), followed by the Southern (23.36%), Northeastern (17.47%), Northern (13.31%), and Midwestern region (12.56%). Total electricity generated in 2013 was 570,025 GW h [7]. Public service power plants accounted for 483,863 GW h, while independent producers accounted for 86,162 GW h. Net imports of 39,867 GW h allowed a domestic electricity supply of 609,892 GW h. Final end-use consumption was 516,330 GW h, an increase by 3.6% compared with 2012. Industrial sector accounted for 210,083 GW h, while the residential and commercial sectors accounted for 124,896 GW h and 84,338 GW h, respectively. The remaining consumption was divided among the public sector (41,288 GW h), the energy sector (29,663 GW h), agriculture and livestock (24,129 GW h), and transportation (1884 GW h).

Almost 117,000 km of transmission line extensions interconnect the country through a National Interconnected System (SIN), reaching approximately 98.3% of coverage [9]. Few isolated systems (1.7%) that are not covered by the interconnected system are located in the Northern part of the country, especially in the Amazon region. Part of the transmission system is connected with the systems of Argentina, Uruguay, and Paraguay. These interconnections are used in case of excess of energy generation in one country and a lack of energy supply in another, or to attend to emergency cases.

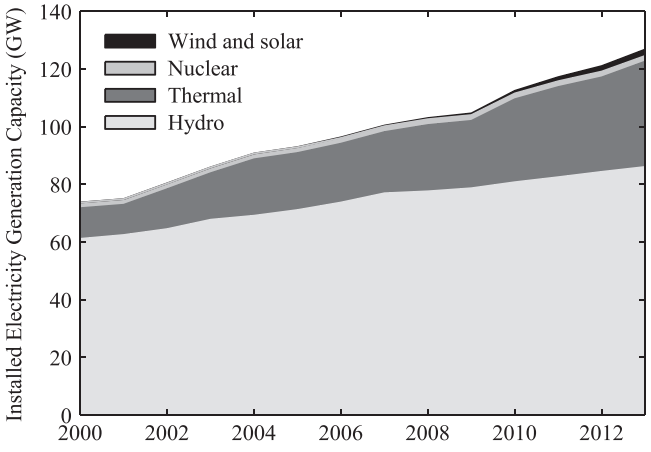

Fig. 1. Share of energy sources in the electricity generation sector. Data from [7].