Renewable and Sustainable Energy Reviews 52 (2015) 725–739

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Economic and environmental analysis of electricity generation technologies in Brazil

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ARTICLE INFO

Article history:
Received 13 April 2014
Received in revised form
24 March 2015
Accepted 30 June 2015
Available online 25 August 2015

Keywords:
Renewable energy
Solar
Wind power
Wave power
Hydroelectricity
Levelised cost of electricity

ABSTRACT

This study compares the economic viability of renewable energy technologies – wind, solar photovoltaic, concentrated solar thermal, biomass and wave power – to traditional generation technologies including hydroelectricity, nuclear power, coal power and gas power sources. The Levelised cost of Electricity (LCOE) for different generation technologies in Brazil are calculated by reviewing existing published literature and examining 13 case study projects. Initial results found that using a low (5%) discount rate, the hydroelectric plants had the lowest LCOE, but were only slightly cheaper than the wind power case studies. However, using a high (10%) discount rate, one of the wind power case studies actually had the lowest LCOE. Solar photovoltaic (PV) was found to be the most expensive technology followed by wave power and concentrated solar thermal power (CSP). It will be shown that grid connected distributed PV and concentrated solar thermal technology are largely undeveloped in Brazil due to the high price associated with importing solar power equipment into Brazil and also due to ineffective federal government policy. The environmental and social externality costs of fossil fuel plants and large scale hydroelectric dams (in the Amazon region) are also discussed. It will be demonstrated that wind power becomes the cheapest generation technology in Brazil, once all externality and transmission line costs are taken into consideration.

Contents

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http://dx.doi.org/10.1016/j.rser.2015.06.064
1364-0321/

1. Introduction

With the increase in fossil fuel prices and the global concern to reduce greenhouse gases there is a growing demand to shift away from CO_2 producing fossil fuels to renewable energy sources for electricity generation. In Brazil, wind, wave and solar power have enormous potential. However, the shift to these renewable technologies appears to remain almost at a standstill despite the enormous potential and their apparent viability in some locations.

In the past, poor economic viability together with a lack of reliable data and political willpower were obstacles that prevented large scale wind farms going ahead in Brazil [1]. But more recently, several large scale wind farm projects have been undertaken by private enterprise. These projects are now viable due to increasing fossil fuel prices, the local manufacture of wind turbines and the introduction of carbon credits through the Clean Development Mechanism [2,3]. The Northeast region (NE) of Brazil, in particular, has excellent solar energy potential. However, due to the high costs to import solar power equipment and the lack of government incentives, there are very few utility scale solar power projects installed in Brazil [2,4].

Despite the huge potential, there is still an apparent lack in the development of large scale wind, solar and wave power technologies. Therefore, the objective of this study is to analyse the economic and environmental viability of these developing renewable energy technologies in Brazil and compare them to more traditional generation technologies. Specifically, the Levelised Cost of Electricity (LCOE), which is used to benchmark the economic viability of different electricity generation technologies, is calculated for 13 different case study plants following the NEA-IEA-OECD [5] methodology. It is anticipated that the results of this study will assist energy planners to make more objective and informed decisions regarding new electricity generation projects.

All the case study plants will be connected or are already connected to the Brazilian electricity grid. Given the particular energy generation challenges faced by the Northeast region (NE) (see Section 1.2) and the region's enormous wind and solar energy potential (see Section 1.3), the majority of the case studies chosen are within the NE.

This work also aims to examine the environmental and social impacts of traditional generation technologies in Brazil by analysing those case studies that cause significant amounts of greenhouse gas (GHG) emissions, air pollution or that impact the environment in other ways. Where possible, the costs of these environmental and social externalities will be estimated in terms of health damage costs and greenhouse gas damage costs. Additionally the costs and energy losses of extended transmission line systems will be estimated for those case studies located in remote areas such as the Amazon. The advantages and disadvantages of small scale distributed renewable energy systems are compared to large scale centralised power plants with extensive transmission systems.

1.1. The Brazilian electricity sector

The electricity supply matrix for Brazil consists of 62.5% hydroelectricity, about 5.7% imported power which is mostly hydroelectricity, 8.6% biomass, and 3.9% wind power. Therefore, more than 80% of electricity generation is from renewable energy sources [4]. Brazil compares very well to the rest of the world, where on average renewable energy sources account for only 19.5% of electricity generation [6]. However, the capacity of hydroelectric generation is close to its maximum in most industrialized regions. There are unexploited water resources in the remote Amazon and Cerrado river basins. Nevertheless, large hydroelectric projects in these regions will have high environmental and transmission line costs, and relatively low energy density [7].

1.2. The Northeast region of Brazil

While Brazil overall has the world's largest water resources, the Northeast (NE) region is mostly semi-arid receiving only a small percentage of the annual total national rainfall. The region suffers from frequent droughts (the most recent in 2012), which can also affect the power supply, as the majority of the electricity matrix is supplied by hydroelectricity [3]. Additionally, by the second half of this century higher temperatures and reduced rainfall are predicted for the Brazilian North and NE regions due to Global Warming. These climatic changes will threaten hydroelectricity