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The environmental paradox in generation: How South America is gradually becoming more dependent on thermal generation

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ABSTRACT

There has been an increasing focus on global warming, emission of green house gases (GHG), and the problems this might create. In this article, we review the trend in sustainable and renewable electricity generation in South America, where the generation portfolio increasingly depends on thermal generation, in particular gas. South America is a region that has relatively low emissions, but the current development is not desirable in environmental terms. We analyze the underlying reasons for this development, which is related to security of supply, deregulation, and the cost of renewable energy. We review and discuss the policies to promote renewables in the region. We analyze the potential advantages and drawbacks of different types of market interventions, such as direct subsidies that create potentially strong market distortions, more sophisticated market interventions that might be less intrusive but not necessarily as effective as, e.g. firm energy markets. We also review market-based solutions such as the Clean Market Mechanism and its potential, and the use of renewable electricity in non-interconnected zones, which might be one of the most economically attractive applications of renewables. However, without a stronger and more aggressive intervention from the governments in the region it is unlikely that the increase in thermal generation can be stopped.

Contents

1. Introduction

During the last decade there has been an increasing focus on global warming, the emission of CO_2 and other greenhouse gases (GHG), and in general the impact that human activities have on the climate and the problems this might create. There has been a series of international agreements such as Kyoto, and more recently the Johannesburg, Rio, and Copenhagen meetings, where the international community, with more or less success, has agreed to reduce emissions. Thus, there is a general consensus about the need to reduce emissions, but there is less agreement on how it should be done, who should do it, and what it will cost [1,2].

One of the major contributors of GHG emission is the generation of electricity, or more specifically the use of thermal generation capacity, based on oil, coal, and gas. Generation capacity based on coal is normally considered the worst polluter, followed by oil and then gas; however, even gas contributes significantly to emissions [3]. Other generation technologies not contributing to emissions include nuclear, as well as alternative

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energy sources such as wind, solar, and hydro plants (both large and small-scale plants). There are well-known environmental problems relating to nuclear plants (such as radioactive waste) and large-scale hydro plants (local environmental problems with dams), which we do not deal with in this paper. For a country trying to reduce emissions the use of renewable resources for generation should ideally be the first choice both for capacity expansion and when replacing existing generation.

In Europe and the US there has been an increasing focus on the use of renewable technology, in particular wind, which has reached a significant level of contribution to the generation of electricity in some countries [4]. Other technologies, such as photovoltaic, are expected to contribute more over the next decade [5]. However, there is one current problem with most of the renewable technologies: they are still relatively expensive compared to conventional thermal solutions, thus, "*The growing interest in the establishment of a minimum share of renewable sources in the world energy matrix, after the Johannesburg World Summit for Sustainable Development (WSSD), has raised the question about the means for such new technologies to compete with the traditional ones*" [6]. Renewable technologies have other advantages, not least the lower dependence on imports of oil and gas, and the financial uncertainty that is tied to oil in particular; however, this might not be enough of a benefit to compensate for the increasing cost to many developing countries.

We are focusing on South America, an area that has had a number of economic crises during recent decades, making the economic development rather uneven at times [7]. The region also has a high potential for development, and in periods like the present, we can observe rapid growth in most of the countries, if not in all. Economic progress, including the increase in GDP, requires continuous expansion of electricity generation, and energy sources become a strategic variable for sustain development [8]. Thus, in order to sustain the economic growth we ask the question: which technologies should be used for the expansion of the capacity, i.e. thermal, hydro, or renewable, while taking into account both environmental and economic considerations? The answer to this question will help us to understand the future emissions from electricity generation in South America, and is of interest as South America traditionally has been a relatively "clean" region, with the predominant "fuel" having been water.

In this paper we review the past development, and consider the future use, of renewable energy including hydro, in South America. As discussed above, the traditional renewable sources and technologies are relatively expensive even for developed countries; how can they then be used in developing countries such as those in South America? Furthermore, South America has for some time had, a relatively large hydro-based capacity. We are interested in the development and sustainability of this hydro-based generation over the past two decades, and the pressure from increasing demand for electricity in the future, as the economies expand. South America has had not only relatively low emission from electricity generation, but also has some of the world's largest absorbers, in the Amazon rain forest, which is also under increasing pressure from human development.

The paper is organized in the following way. We begin with an overview of electricity generation in South America, after which we consider in more detail four of the largest South American countries: Argentina, Brazil, Chile, and Colombia. We then highlight some of the incentives as well as problems for electricity generation using renewable resources, followed by a detailed discussion and conclusion.

2. The electricity sector in South America

South America has been the most progressive area in the developing world promoting deregulation in the electricity sector [9]. The countries of the region are similar on many dimensions, such as culture, language and generation technology, which provide an opportunity for comparing and contrasting choices made in the individual countries. The region has been, and still is dominated by hydro-generated electricity [9,10], which has led to relatively low CO_2 emission compared with the rest of the world.

Table 1 shows an overview of South America in terms of macro-economic indicators, energy consumption, and emissions by country. There is a wide variation in the region, from a GDP per Capita of US$ 1089 for Bolivia to US$ 8692 for Argentina, with an average of approximately US$ 4000/Capita. It also shows the relationship between economic growth and energy consumption, an important relationship for understanding the effect of future economic growth on the demand for electricity. The correlation is 0.83 between *GDP/population* and *electricity consumption/population*, emphasizing the close relationship between electricity consumption and development. Finally, the electricity consumption in South America is only 4.1% of the total world electricity consumption while the population is 5.8% of world population [11].

During the decades of the seventies and eighties, the electricity sector expanded via major infrastructure projects to promote economic growth and social development [12], while in the nineties the focus moved to improve efficiency through market mechanisms. Most of the countries in South America moved from monopolies to some degree of open and competitive markets,

Table 1
Main macro-economic indicators, energy consumption and emissions of South America.

Country	Population (Million)	GDP (Billion $)	GDP/population ($/Capita)	TPES (Mtoe)	Electricity consumption (TWh)[a]	CO_2 emissions[b]	Elect. Cons/population (kWh/Capita)
Argentina	39.13	340.15	8692	69.10	102.53	148.73	2620
Bolivia	9.35	10.19	1089	5.85	4.53	12.75	485
Brazil	189.32	765.13	4041	224.13	389.95	332.42	2060
Chile	16.43	96.17	5853	29.78	52.70	59.84	3207
Colombia	45.56	105.55	2316	30.21	42.05	59.39	923
Ecuador	13.20	21.42	1622	11.24	10.02	25.02	759
Paraguay	6.02	8.34	1385	3.97	5.42	3.56	900
Peru	27.59	70.60	2558	13.55	24.81	27.93	899
Uruguay	3.31	23.16	6997	3.19	6.77	6.14	2042
Venezuela	27.02	146.64	5427	62.22	85.79	149.20	3175
S. America	*376*	*1587*	*3998*	*453*	*724*	*824*	*1707*
World	*6536*	*37,759*	*5777*	*11,740*	*17,377*	*28,003*	*2659*

Source: [11].
[a] Gross production + imports − exports − transmission/distribution losses
[b] CO_2 emissions from fuel combustion only. Emissions are calculated using the IEA's energy balances and the Revised 1996 IPCC Guidelines.