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Photovoltaic energy generation in Brazil – Cost analysis using coal-fired power plants as comparison

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ABSTRACT

We make a brief analysis of the evolution of photovoltaic systems, highlighting the present situation worldwide and in Brazil. We compare costs of energy generation associated to photovoltaic and to coal-fired power plants. Coal-fired generation represents the eligible choice for the Brazilian State of Rio Grande do Sul, where thermal plants may use locally extracted coal. The production cost of the energy generated with coal is evaluated taking in account the effect of the invisible cost represented by externalities that affect human health. The price evolution of Photovoltaic modules is presented, as well as trends on decreasing costs for new installations. We also calculate the production cost of the AC energy generated by three photovoltaic plants, with different power, derived from a model. The model is used to make sensitive analysis based on the adjustment of some factors that directly affect Brazilian costs such as: insolation, module's custom and transportation taxes, effect of economy of scale, cost of money. A cost comparison is made between the two technologies and some government incentives are proposed to narrow the existing financial gap.

1. Introduction

The ongoing development of society reveals its strong dependence on electrical energy to sustain the incremental increase of the annual Gross Domestic Product – GDP. Government planners face the simultaneous challenge of ensuring the sustainable use of natural resources, while providing the necessary conditions for the development of national society.

The conversion of natural resources into energy generates collateral effects on the environment, represented by the huge stockpiling of unusable wastes and the diffusion of pollutants that have a profound effect on the quality of life.

To avoid the rapid depletion of limited natural resources, the use of renewable sources should be pursued and among them the radiation that the sun delivers to the surface of earth. Many different ways exist for exploring the radiation of the sun; one of them is the photovoltaic technology that transforms the insolation directly into electrical energy with no pollutant effects.

When seeking to compete with other established technologies, photovoltaics face the same competitive challenges, in the form of barriers, which must be overcome by any newcomer. Barriers may be political and economic, and the newcomer should formulate and propose some perceptible advantages to the prospective market. Photovoltaic technology involves relatively large initial investments and long payback times to recover the initial capital and does not have a record of affordability due to its relative novelty in the market. At this initial stage in its development, photovoltaics have not reached grid parity and the perceptible advantages rely mainly on its potential to support clean decentralized generation. To improve this situation, the governments of different countries worldwide, which believe in this technology and hope for beneficial side effects such as increased employment, provide economic support to the production chain, aiming to the point of self-sustainability where a mature market may guarantee the production flow.

Approximately half of the 194 GW new electric capacity, added worldwide in 2010, was based on the use of renewable sources and, out of this, an estimated 17 GW may be attributed to photovoltaic generation, so that PV continued to be the fastest growing energy technology. With that increase, the total existing capacity, in 2010, reached 40 GW, more than 7 times that of five years earlier [1].

Electric energy generation is sustained by several sources, some of them renewables and others not. Fig. 1, which represents the situation in the United States, is a good example of past distribution of the main energy sources and the forecast for the year 2035 [2].

To satisfy energy hunger, coal emerges, therefore, as one of the preferred sources of natural fossil fuel and planners tend to

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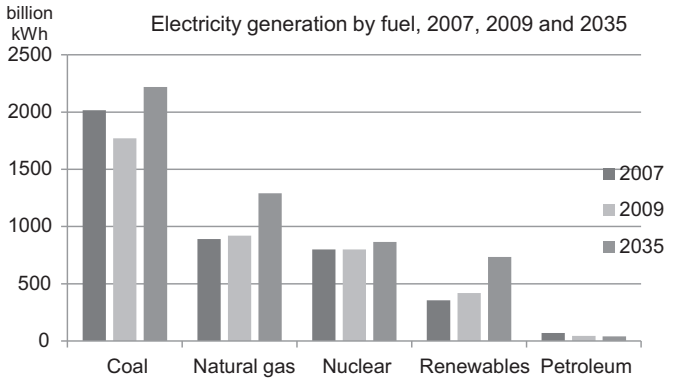

Fig. 1. Electricity generation in USA by fuel, past and future.

dedicate financial efforts, subsidies and political support, aiming toward the construction of new coal-fired plants.

Unfortunately, some unwanted effects, named externalities, must be considered, since they weigh heavily on the final cost of energy. An analysis made in the United Sates by the National Research Council [3] highlights the costs of diseases linked to the pollutants emitted by the 406 coal-fired energy plants: the cost of medical procedures to recover from related health problems corresponds to 39% of the average cost of kWh to the end user. This is a surplus cost that society does not see but pays in taxes.

Moreover, coal-fired plants are located close to the coal mines, to reduce the cost of transportation of raw material to the combustion plants and also the cost of its appropriate conditioning. Since such located coal-fired plants are installed far from the consuming centers, transmission lines are needed to make the energy available. Copper and aluminum conduits used to transmit the energy impede the passage of current, causing energy losses.

Photovoltaic generation, on the other hand, is a relatively new technology which is making giant steps in reducing manufacturing costs, developing new materials, optimizing the efficiency of the conversion devices, both from solar to DC current and from DC to AC and to the grid. The great and fast expansion of the market has leveraged the expansion of production with economy of scale and according to Baillie [4], it is foreseen by many authors that the parity with the grid will be reached before the year 2020 in many different locations around the world.

Brazil, a continental country, is favored by the existence of great rivers in its territory. In fact, the production mix for electricity generation in Brazil shows that approximately 71% is currently satisfied by renewables, primarily hydro generation small and large, while thermal accounts for approximately 27%. Table 1, updated to the year 2012 [5], shows the situation at the present time, later with the introduction of power plants under construction and in the future after planned construction.

Table 1
Electricity generation in Brazil per type – present, next and future.

Generation type	Present generation		Next generation		Future generation	
	MW	%	MW	%	MW	%
Hydro large	79.136	66.33%	18.283	66.66%	2.568	12.41%
Thermal biomass	9.736	8.16%	863	3.14%	1.860	8.99%
Thermal fossil	21.167	17.74%	4.862	17.73%	8.043	38.86%
Thermal other	1.505	1.26%	13	0.05%	67	0.32%
Hydro small	4.095	3.43%	578	2.11%	1.822	8.80%
Nuclear	2.007	1.68%	1.350	4.92%		0.00%
Wind	1.658	1.39%	1.480	5.40%	6.335	30.61%
Photovoltaic	1	0.00%		0.00%		0.00%
Total	119.305		27.428		20.695	

From Table 1 one can see that the next stage will maintain the percentage of 69% for hydro, while thermal will almost remain stable going from 27% to 26%.

In the future, hydro will decrease to 63% and thermal increase to almost 29%. Thermal will continue to represent the second biggest slice of the pie.

As suggested by Fig. 1, countries with coal reserves assign a great importance to them, for energy production. Brazil's coal reserves total 7 billion tons [6] concentrated in two states – Santa Catarina and Rio Grande do Sul, accounting respectively for 20 and 80% of the total Brazilian coal [7]. This amount corresponds to a life-expectancy of 400 years until its depletion given the present use for thermal fossil generation.

Unfortunately, Brazilian coal is low quality, with a heating value of approximately 13,000 kJ/kg as compared to traditional coals used for electricity generation which have an approximate heating value bigger than 25,000 kJ/kg [6]. Despite this weakness, the Brazilian coal-fired plants are supported by the government for several reasons, among them the benefits provided to the social environment of the region and its progress. Support can be described as the purchase of energy at a premium value for some older plants, to equalize the cost of their energy.

Among the different technologies presently used in Brazil for the generation of electricity, coal represents one of the highest costs as will be outlined in Fig. 2.

Worldwide, PV has the highest cost and it is worth comparing it with coal technology, which, not considering hydro, could be regarded as preferable for Rio Grande do Sul.

Besides that, there are two reasons for comparing PV and Coal technologies:

a by demonstrating that PV is cheaper than coal, it could be considered as a valid alternative to gas fuel cells, nuclear and coal itself, as shown in Fig. 2;
b if it is sound to economically support coal for political reasons, the same could be true for PV which is a fast growing new technology with real possibilities both technically and financially to improve its position toward parity.

Other technologies related to renewable sources like Biomass, Wind, Tidal are in their early stages of development and show-up as alternatives for future energy needs. Not discounting the merits of these technologies, this paper focuses on the PV alternative.

2. The potentiality of coal plants and their negative effects

Depletion of natural resources, considering the present usage pace, is predicted to happen in a few decades, taking into account that petrol and gas are primarily used for transportation and industrial use [8]. Coal reserves already mapped have an estimated period of availability of 130 years, not considering possible unknown reserves [9] and taking into account the present annual

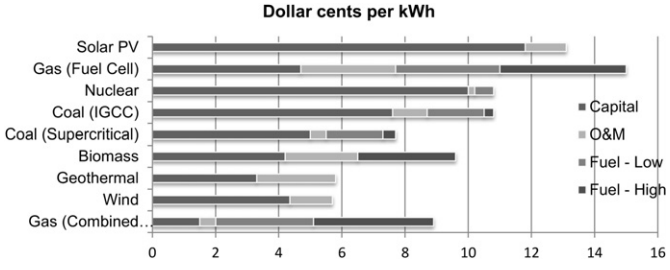

Fig. 2. Cost comparison between different production technologies.