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Viewpoint

Making the case for grid-connected photovoltaics in Brazil

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ABSTRACT

In the developed world, grid-connected photovoltaics (PVs) are the fastest-growing segment of the energy market. From 1999 to 2009, this industry had a 42% compound annual growth-rate. From 2009 to 2013, it is expected to grow to 45%, and in 2013 the achievement of grid parity – when the cost of solar electricity becomes competitive with conventional retail (including taxes and charges) grid-supplied electricity – is expected in many places worldwide. Grid-connected PV is usually perceived as an energy technology for developed countries, whereas isolated, stand-alone PV is considered as more suited for applications in developing nations, where so many individuals still lack access to electricity. This rationale is based on the still high costs of PV when compared with conventional electricity. We make the case for grid-connected PV generation in Brazil, showing that with the declining costs of PV and the rising prices of conventional electricity, urban populations in Brazil will also enjoy grid parity in the present decade. We argue that governments in developing nations should act promptly and establish the mandates and necessary conditions for their energy industry to accumulate experience in grid-connected PV, and make the most of this benign technology in the near future.

1. Introduction

1.1. Solar PV potential in a large-area and sunny country

The direct conversion of sunlight into electricity with grid-connected photovoltaic (PV) generators leads to a number of benefits to both the environment and the electricity system. The main technical advantage is the possibility of producing clean and renewable electrical power close to consumers or even at point of use, integrating PV generators on buildings or around urban areas. The peak shaving capability of distributed PV power systems reduces the strain on grid infrastructure (Perez et al., 1996, 2001; Jardim et al., 2008). A higher number of distributed units for the same installed capacity allow the deferral of a bigger network investment. This favours small- to medium-sized urban PV systems (Méndez et al., 2006). The traditional utility concept relies on a relatively small number of fairly large and centralized power plants, which quite often are distant from the urban centers where energy is consumed. In a large country like Brazil (8.5 millionkm^2), transmission and distribution (T&D) infrastructure and associated losses are considerable, adding value to distributed PV power that goes beyond the value of the kilo-watt-hour.

Hydropower generation plays a fundamental role in Brazil, in spite of the large distances from urban areas. The present installed capacity of some 75 GW corresponds to over 77% of the national electricity supply. Growing environmental restrictions, and the larger distances from urban centers to the remaining potential, however, will lead to an increase in end-user prices of electricity from new hydropower plants. The Brazilian interconnected electricity system is one of the largest and most complex in the world, with an installed capacity of over 108 GW. Detailed information on the Brazilian energy mix is available at https://ben.epe.gov.br/ (Balanço Energético Nacional – BEN). In 2001, with increasing demand due to favorable economic conditions, and a lack of investments in infrastructure, there was a shortfall and consequent rationing of electricity in some regions in the country, which exposed the fragility of the centralized generation and distribution model in a large country.

In this context, distributed grid-connected PV systems in urban areas can offer an attractive alternative to compose the energy mix in a developing country like Brazil. The high price of residential tariffs, ranging from 16 up to 23 Euro cents per kWh; the large solar radiation resource availability, ranging from over 1500 to nearly 2200 kWh/m^2/year (Martins et al., 2008), the complementary nature of solar vs hydro-availability (seasonality of hydrological cycles × solar availability), and the distributed nature of urban-scale PV must be taken into account in order to add value to this still costly energy source. The potential of solar thermal power plants is also considerable, and the potential of this solar energy technology in Brazil has been recently addressed elsewhere (Viana and Rüther, in press).

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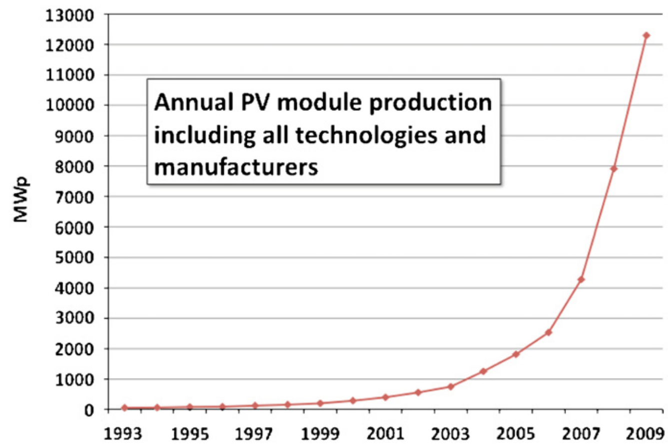

Fig. 1. Worldwide annual PV module production, including all commercially available PV technologies (mono- and multi-crystalline silicon, thin-film amorphous silicon, thin-film cadmium telluride and copper indium diselenide and related compounds).
Source: PHOTON International, 3 (2010a).

While most of the impressive growth in the PV market shown in Fig. 1 is related to grid-connected installations in developed countries, there is a huge potential for this application in sunny urban areas all over the developing world as well. Brazil is particularly well suited for the application of grid-connected PV due to the high solar resource availability, and to the high value that can be attributed to on-site generation of PV electricity in commercial areas of urban centers (Perez et al., 1996; Jardim et al., 2008; Rüther et al, 2008). Covering less than 0.04% of the Brazilian national territory with PV modules would generate more than the total annual electricity consumption (some 500 TWh/year) in the country.

2. PV added benefits in large-area and sunny developing countries

PV can contribute to a distribution utility's capacity if the demand peak occurs in the daytime period. Besides the advantage of peak demand reduction, PV systems should also contribute to a longer life of utility feeders (Jimenez et al., 2006). Commercial regions with high midday air-conditioning loads have normally a demand curve in a good synchronism with the solar irradiance (Perez et al., 2001; Jardim et al., 2008; Rüther et al., 2008). Another important factor in this analysis, is the comparison between the peak load values in summer and winter. The greater the demand in summertime in comparison with the demand in wintertime, the more closely the load is likely to match the actual solar resource. This is the typical picture of most capital cities in Brazil and many other sunny, developing countries, and the match between solar generation availability and power demands in urban areas is growing with the growing use of air-conditioning, made possible by the improving economic conditions in the last 10 years. Utility feeders in urban areas all over the country show distinct regions where commercial and office buildings dominate, and which present daytime peak demand curves, and residential regions where the peak demand values occur in the evening. To add value to the distributed nature of solar generated electricity, it is important to know the PV capacity of the different regions of a city when installing a PV power plant, in order to select the utility feeder with the greatest capacity credit. In this context, the concept of the Effective Load Carrying Capacity (ELCC) of PV was defined, to quantify the capacity credit of a strategically sited PV installation (Perez et al., 1996, 2001). In the near future, when the use of grid-connected PV becomes more widespread due to both cost reductions and the acknowledgment of the benefits of distributed PV, the assessment of ELCC will be of strategic value for utilities and investors, especially in large-area and sunny countries.

3. Incentives and the onset of solar grid parity

With the considerable cost reductions experienced and projected for the PV technology as shown in Figs. 2 and 3, and Table 1, it is widely accepted that grid-connected PV will reach economic competitiveness (Cody and Tiedje, 1996; de Moor et al., 2003; Yang, in press), and that it will be widely used in the future in most parts of the world, especially in sunny countries. Recent studies (Salamoni, 2009) indicate that sometime between 2015 and 2020 (perhaps even sooner, depending on the conventional energy price increases and the rate of PV price and interest rates decline) PV-generated residential electricity prices will achieve parity (i.e. become cost competitive, including taxes and charges) with conventional grid power in Brazil. These studies assume PV cost reductions in the 5 to 7%/year range, and residential tariffs increase in the 2 to 4%/year range in the present decade. These assumptions are well in line with cost trends in both industries.

It took over 20 years for a country like Germany to reach the state where PV generation plants feed considerable amounts of power to urban grids. Grid operators in Germany are only now becoming familiar with the peculiarities of grid-connected PV technology. Grid parity in Germany will likely occur at the same time as in Brazil, and Germany will be prepared when the time comes. It needs a long time to establish a professional market, gain experience and develop handling procedures by the electricity regulators, grid operators and utilities. Grid-connected PV experience in Brazil is still limited to a handful of small installations operating at universities and research institutes (Rüther and Dacoregio, 2000; Oliveira and Zilles, 2001). It is therefore important for the country, and for the whole of Latin America, to be prepared for the time when grid parity is reached, to develop a PV industry and to accumulate experience with grid-connected PV, in order to be able to make the most of the distributed benefits of this benign technology when it becomes cost-effective. Especially in the case of Brazil, where one of the largest quartz (SiO_2) reserves in the world is located (Moehlecke et al., 2010), the establishment of a PV industry is of strategic importance. A feed-in tariff support mechanism that takes into account the peculiarities of developing nations, where distributed, grid-connected applications are at an early stage of deployment of this emerging technology, might be a most appropriate and cost-effective way of bringing this energy generation alternative to mainstream (Midttun and Gautesen, 2007). Energy sector decision makers must have access to bona fide information

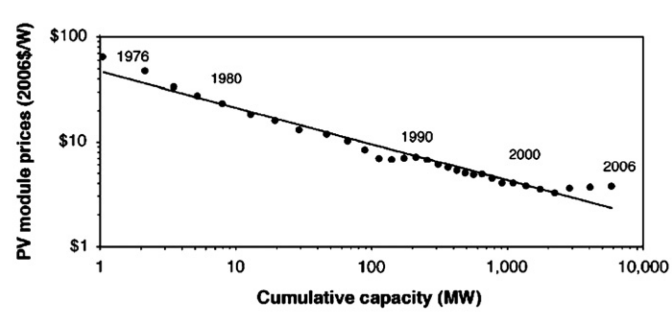

Fig. 2. Experience curves for PV modules prices from 1976 to 2006. .
Source: Nemet (2009)

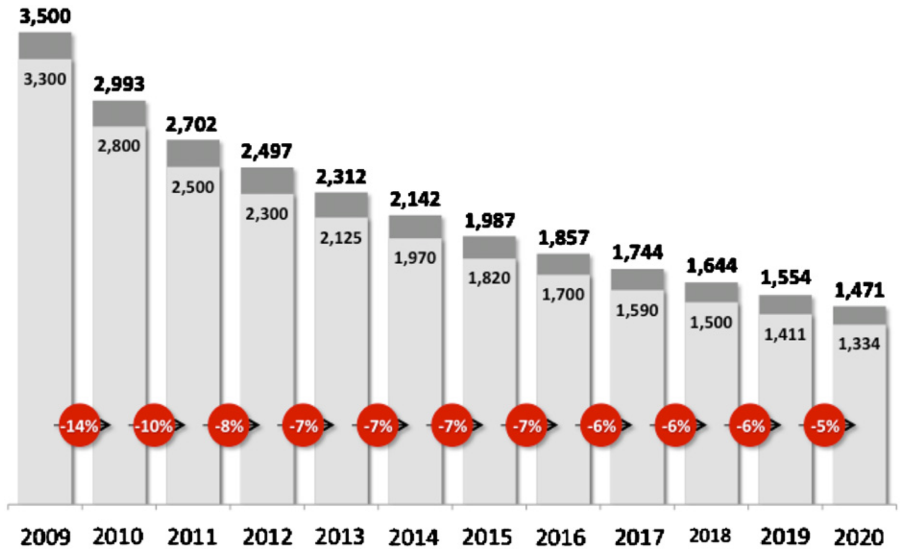

Fig. 3. Pricing capability range for large PV systems (2008 €/kW), and expected annual decrease (%).
Sources: EPIA 2009 – www.setfor2020.eu and National Renewable Energy Laboratory – A.T. Kearney analysis.

Table 1
German monthly spot prices for modules, from August 2009 to July 2010.
Source: PHOTON International, 3 and 9 (2010a,b).

Reference month	Modules from:	
	Europe and US (€/Wp)	China, India, Taiwan and Thailand (€/Wp)
August 2009	2.14	1.73
September 2009	2.09	1.69
October 2009	1.96	1.72
Novemeber 2009	1.94	1.69
December 2009	2.08	1.73
January 2010	1.85	1.52
February 2010	1.84	1.49
March 2010	1.81	1.45
April 2010	1.81	1.48
May 2010	1.45	1.56
June 2010	1.75	1.62
July 2010	1.71	1.62

and the foresight to acknowledge that PV will play a relevant role in the energy mix in the mid-term.

The German feed-in law and the associated costs, which are shared by the German society in the promotion of all renewable energies, and especially solar PV, are often criticized for leading to a so far negligible contribution of the PV technology to the energy mix at a high cost (Dusonchet and Telaretti, in press; Frondel et al., in press; Yang, in press). What these critics often fail to acknowledge, however, is that the impressive cost and price reductions shown in Fig. 2 and Table 1, and projected for the coming years as shown in Fig. 3, were only possible because of the production volumes related to the consistent support related to these incentive mechanisms, as well as to consistent and continuous R&D efforts. The German experience has shown that R&D and demonstration projects alone (e.g. the strong R&D component and demonstration targets of the 1000-Roofs Program and its successor programs) were not enough for the PV market to take off, and that volume markets were only established after incentive programs were launched in 2000 and 2004. There is a typical argument against the proposition of a feed-in tariff program for grid-connected PV in developing countries: as low-income citizens do not have access to the financing possibilities that might be made available for the acquisition of a PV rooftop system, it is in principle unfair to impose the cost-share burden of a feed-in tariff program to a large fraction of society that does not have the means to access the direct benefits of such a program.

An intrinsic characteristic of a dual society in developing countries is the fact that the elite and the poor differ fundamentally in their energy demands. The elite try to mimic the lifestyle prevailing in developed countries. Like so many developing nations, Brazil is a country of contrasts. There is one Brazil, where some 80 million inhabitants have access to goods and services in a standard very similar to the one experienced by western European or other industrialized countries; and there is another Brazil, where over 100 million inhabitants live in dire straits. A fraction (about 10%) of this second group does not even have access to electricity. In urban areas, where the national public electricity grid serves these two groups, there are two formal and distinct classes of residential consumers that officially reflect the abyss that exists in socio-economic levels. There are over 55 million urban residential consumer units (=over 55 million households connected to the public grid), out of which some 18 million are classified as "low-income residential consumers", who have access to subsidized tariffs. There is specific legislation that defines these low-income residential consumers, and establishes subsidies for their reduced tariffs. The cost of this subsidy is spread to all the other energy consumer classes. It is therefore straightforward to design a PV feed-in tariff program, where the cost of the premium tariff is spread to all consumers, except the low-income residential consumers.

In this context, we argue that a feed-in tariff program in Brazil could be especially tailored to bridge the period to grid parity, and at the same time establish the volumes, the professional market and the necessary experience for the sustainable and orderly introduction of this generation technology in the Brazilian energy mix. Differently from what has been typically recommended for developed countries, a feed-in tariff program in a developing country should be limited in time and size; it should be large enough to stimulate the establishment of a local market, but it should at the same time be small enough in order not to impose a large financial burden to consumers. A comprehensive exercise on these impacts can be found in Salamoni (2009), where it was shown that a 1 GWp over 10 years incentive program, paying premium tariffs attractive enough for residential consumers to be compelled to install PV, would lead to an impact on the residential tariff of some 0.3% on average. The 1 GWp figure was derived based on the expectation of being at the same time attractive enough for the PV industry to establish local production and a professional market, and for the electricity market to gain the necessary experience in urban grid-connected PV systems in the multi-megawatt range; and small enough in order not to result in a large surcharge on residential tariffs. The 10 year duration was proposed in order to bridge the period to grid parity, expected to be reached in the whole of the Brazilian national territory in the present decade under the PV cost reduction and conventional tariffs increase assumptions previously mentioned.

It has been argued that cost-effectiveness alone (=grid parity) may not be as powerful a driver for the PV market expansion (Yang, in press), and a successful introduction of PV should start with a carefully planned feed-in tariff program, followed by the appropriate mandates to support the continuous uptake of the PV technology after grid parity is reached. In Japan and in Hawaii, grid parity has already been reached, but unfamiliarity with the technology and high upfront costs still limit a more widespread adoption of grid-connected PV. A sustainable incentive program should address these issues.

4. Concluding remarks and caveats

In making the case for grid-connected PV in Brazil, we make the following important caveats: (i) it should be acknowledged that on top of establishing and promoting a feed-in tariff program, limited in size and duration, designed to assist the market in the transition to grid parity, political mandates to further induce and sustain the adoption of this technology are necessary, (ii) the cost of this especially designed feed-in tariff program should result in a very small burden to society, and it should be distributed only among that share of society which is outside the low-income residential consumer classification, (iii) the availability of raw materials (silicon and clean electricity) make Brazil an ideal candidate to become an important player in the PV production scenario (Krauter and Rüther, 2004), and these aspects should be part of the motivation for supporting the onset of a PV industry in the country, (iv) this especially designed feed-in tariff program should also be used to promote PV generators for mini-grids in the Amazon region, which constitute local and isolated distribution systems where PV is already cost-effective. These are all fundamental conditions for making good use of the considerable amounts of energy that shine on the country every day.

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