Summary of the Master Thesis

Analysis of the Technical Potential and Profitability of Photovoltaic in Costa Rica

Toni Weigl

Lehrstuhl für Energiewirtschaft und Anwendungstechnik
Technische Universität München

This thesis carried out an in depth study about the feasibility of using photovoltaic (PV) systems for the electricity generation in Costa Rica. It was conducted in cooperation with the Gesellschaft für Internationale Zusammenarbeit (GIZ), the Cámara de Industrias de Costa Rica (CICR) and the Asociación Costaricence de la Energía Solar (ACESOLAR) with the goal to enhance the usage of solar resources in Costa Rica. Therefore the lack of trustworthy irradiation data and non-transparent pricing had to be resolved in this study and the benefits of PV to be carved out. For the first time the irradiation conditions in Costa Rica were analyzed accurately enough to calculate the yield and the impact of PV systems distributed throughout the country. Furthermore, with these yield estimations, the profitability of each system was calculated using the market price for PV installations and current electricity prices.

Costa Rica is a politically very stable and emerging country which aims to produce its electricity only from renewable sources by 2021 and to become the first CO_2 neutral country [1]. Therefore it uses its excellent environmental conditions for the electricity production from renewable energy sources. Water power is the main source for the electricity generation in Costa Rica at the moment, followed by wind power, geothermal heat and fossil fuels whose usage was constantly rising in recent years. The share of solar power is still largely underrepresented in the electricity mix, considering the location of Costa Rica in the tropical belt and irradiation values up to 2 000 kWh/m²/year. Even though the biggest energy provider ICE had introduced a pilot plan for net metering in 2010, solar systems still produced less than 0.1 % of the nation's electricity in 2014 [2].

The large altitude differences present in Costa Rica create micro climates that require a very precise prediction of the solar irradiation to calculate the PV output for a specific location. To obtain an accurate result, a dense measurement grid with high quality was required. Therefore a broad data acquisition was carried out, which in Costa Rica is far more difficult and time consuming than in industrialized countries like Germany or the USA. This study has obtained and analyzed different datasets, including ground measurement data from the National Metrological Institute (IMN), two universities (EARTH and ITCR) and satellite data from SolarGIS and the NASA. The comparison of the different datasets and the validation with measurements from existing PV systems were used to validate the data sources. Yield estimations from the pvPlanner using the SolarGIS data resulted in an average deviation of only 3 % compared to the PV systems installed in the Central Valley and proved SolarGIS to be the most accurate source. Lowest irradiation values of 1 250 kWh/m²/year were identified on the mountain tops while in the north-western part of the country an average of 2 000 kWh/m²/year was measured in the horizontal plane. In the Central Valley, where the demand is highest, the irradiation is approximately 1 700 kWh/m²/year, and on the Caribbean coast 1 600 kWh/m²/year. The country's average specific annual yield of nearly 1 400 kWh/kWp/year is 40 % higher than the average output in Bavaria.

Besides the spatial fluctuations within the small country, also the temporal fluctuations were investigated. The Pacific Region and the Central Valley have the highest outputs during the dry season (December to April) and 20 % lower irradiation in the rain season. In the northern part of the country and on the Caribbean coast the weather conditions are reversed, and solar systems produce more electricity from March to October than in the winter months. This contrary behavior leads to very low fluctuations between the two seasons and less than 10 % deviation to the counties average.

Another common prejudice about PV was the high levelized cost of electricity. Solar electricity was believed to be far too expensive to be competitive in the market without subsidies, as installation prices of 9 USD/W were spread by the press and the natural gas lobby. To verify this, a market research was carried out with the result that installation costs of PV systems in Costa Rica vary from 1.8 to 3.1 USD/W depending on the system size. With the high specific yield obtainable in Costa Rica, specific electricity generation costs of 7 to 13 US cents can be achieved for a lifetime of 20 years. These calculations showed that the good irradiation conditions and the high electricity prices have already established grid parity on the consumer side in Costa Rica without subsides.

With the validated yield estimations from SolarGIS, PV systems for residential and commercial buildings could be dimensioned precisely for the first time. The costs associated to the PV systems were compared with the savings from the electricity bills in different tariffs using temporal correlations of production and consumption. Depending on the electricity tariff and the consumption of the consumers the return on investment varied between 5 and 12 years. Clients in the “General tariff” are paying the highest electricity prices and have therefore the fastest payback times. They can achieve also the highest internal rates of return of more than 25 % on a PV system.

With a large penetration of PV electricity, from decentralized systems, also the energy mix and the electrical grid would be influenced. Solar electricity could replace the petroleum derivatives in the electricity matrix for their lower the generation costs and minimize the carbon footprint of Costa Rica significantly. The installation of 600 MW homogeneously distributed PV capacity would be sufficient to produce the same amount of electricity as the fossil fuels contributed to the electricity mix in 2012. The water storage basin of Lake Arenal, with its three hydro power plants, would be the perfect counterpart for solar electricity to balance production and demand. In the dry season where lots of solar electricity is available, the operation of the hydro power plants could be reduced to save water in the storage basin for the transition months. Daily fluctuations are balanceable by the run of river power plants which have basins to shift their production by a few hours.

The high electricity yields and the low investment costs of large scale PV systems make it viable also for electricity generation companies to invest in large scale PV parks. As Costa Rica is a very stable country, also international investors would be able to inject money on low interest rates if they get the political framework to have secure returns from their investments by means of power purchase agreements and speed up the development. Therefore the energy department of the government is working on the implementation of this framework at the moment. Furthermore, this thesis was often-quoted in the local press [3] [4] and several follow up studies were initiated to enhance the usage of solar electricity in the upcoming years.

[1] Gobierno de Costa Rica, „Plan Nacional de Desarrollo 2006-2010,“ San José, Costa Rica, Costa Rica. Ministerio de Planificación Nacional y Política Económica., 2007, pp. 81, 83.

[2] U. Luis Diego Tapia Carmona, „Plan Piloto Generación Distribuida para Autoconsumo, Proyectos Hidroeléctricos a Pequeña Escala para Autoconsumo,“ 2011.

[3] K. Murillo, „El poder del sol que no aprovechamos,“ El Financiero, 27 October 2014.

[4] J. P. Arias, „Industriales vuelven la mirada hacia la energía solar para abaratar costos,“ La Nation, 2 September 2014.