Renewable and Sustainable Energy Reviews 41 (2015) 1037–1051

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Potential residential PV development in Chile: The effect of Net Metering and Net Billing schemes for grid-connected PV systems

David Watts [a,b,*], Marcelo F. Valdés [a], Danilo Jara [a], Andrea Watson [c,d]

[a] Department of Electrical Engineering, Pontificia Universidad Católica de Chile, Chile
[b] Department of Applied Economics, The University of Wisconsin–Madison, USA
[c] U.S. Department of State Fulbright Scholar, Associated with Pontificia Universidad Católica de Chile, Chile
[d] Department of Engineering Management, University of Colorado-Boulder, USA

ARTICLE INFO

Article history:
Received 7 January 2014
Received in revised form
18 July 2014
Accepted 30 July 2014

Keywords:
Grid-connected photovoltaic
Residential PV system
Chile
Net Metering
Net Billing
Levelized cost of electricity

ABSTRACT

In recent years the global photovoltaic (PV) market has expanded rapidly due to a sharp decline in PV prices and increased attention to the importance of sustainable energy. Northern Chile has one of the highest irradiance levels in the world as well as one the highest electricity rates in Latin America. Because of these conditions, Chile is one of very few countries where several PV projects are being developed without government subsidies and consequently, the PV industry is experiencing rapid growth.

This paper reviews the opportunity to take advantage of these market conditions within the residential sector, modeling PV arrays across 10 cities in Chile. A detailed modeling of PV systems is performed to achieve an accurate analysis of energy production and electricity cost, using local resource data, optimal array orientation and inclination, and production losses.

A review of how Net Metering and Net Billing affect the value of the PV production is applied and a comparison using levelized cost of electricity (LCOE) is conducted. Net Metering is found to be a better policy choice to promote PV systems than Net Billing because energy injected into the electrical network is paid at the complete retail rate. However, in developed countries this kind of policy is unlikely to be supported because of it's economic unfeasibility. Under a Net Billing scheme a consumer will see an advantage when energy is recorded over longer time intervals and when installing a system with smaller capacity relative to household electricity consumption. This prevents excess generation from being injected into the network which would be bought by the utility at lower prices than the retail rate. Payback periods are found to be low, between 6 years in northern areas with high retail rates and 13 years in other areas with lower radiation and retail rates.

Contents

Abbreviations: LCOE, Levilized cost of electricity; GHI, Global Horizontal Irradiance; PV, Photovoltaic; PR, Performance Ratio; IR, Inverter Ratio

* Corresponding author at: Department of Electrical Engineering, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Macul, Santiago, Chile. Tel.: +56 2 3544281.
E-mail address: dwatts@ing.puc.cl (D. Watts).

http://dx.doi.org/10.1016/j.rser.2014.07.201
1364-0321/

1. Introduction

The development of solar PV market and the use of this technology worldwide has grown at annual rates of 35–40% [1]. This rapid expansion is due to a sharp decline in PV prices and increased attention to the importance of sustainable energy. Moreover, progressive, decreasing module prices which are coming from China (well below 1 US$/W) [2,3] have enabled the development of profitable PV systems at all scales.

Some counties in northern Chile have some of the world's highest irradiation levels, with average daily Global Horizontal Irradiance (GHI) above 7 kWh/m^2 [4] and Direct Normal Irradiation (DNI) above 9–10 kWh/m^2 [4]. As an example, the city of Calama has a GHI of 7.22 kWh/m^2 and is surrounded by desert. The location is of high potential for both large-scale and residential PV installations. Moreover, since northern Chile has one of the highest levels of solar radiation in the world and northern and central Chile have some of the highest electricity rates in Latin America, several areas of Chile offer optimal conditions for PV development [5] even without government subsidies.

It is the role of the government to understand the international context as well as local opportunities for solar development considering the high electricity rates that are reaching the level of crisis in the energy sector. Indeed, it is the government that can take a leadership role in helping to exploit these opportunities and enable a local solar PV development. In the Residential PV sector, the old electricity laws in Chile did not consider the prospect of customers selling energy into the grid and a new policy design was needed. The Net Metering and Net Billing debate started a few years ago, aimed at enabling small scale distributed generation in the country, especially PV, micro-hydro and micro-CHP.

Net Metering is an electricity policy which enables utility customers to own, operate and profit from a PV system (or other generation technology) offsetting some or all their electricity consumption and getting paid for excess energy injected into the grid. Typically a low-cost meter is used that is able to spin in both directions, showing the net consumption or the net excess during the billing period, which is finally valued at retail rate [6]. Net Billing is a variant from Net Metering, that uses two one-directional meters or one meter with two data-records, keeping the measured consumption from the grid and the excess injected into the grid in separate records, valuing them separately and at a different price. The difference between valued grid consumption and valued excess injections is billed to the costumers. The electricity injected back into the grid is valued at a price which is lower than the retail rate because only the energy component is paid out (whereas a typical retail rate also includes a distribution charge).

In Chile, a Net Billing scheme was approved for small generators with capacities up to 100 kW, through the law No. 20.571 in February 2013 [7]. However new changes to this law are in discussion, where a Net Metering scheme is suggested for consumers with capacities of up to 10 kW [8] (10 kW is consistent with the largest system reviewed in this study). In Net Billing, when only one meter is used, the definition of integration intervals that the meters use is essential to establish the cost-effectiveness of generation systems. Meters record high frequency readings, but can be programed to add those readings up over a specified time period (called an integration interval) and to compute one final reading which is stored as either net consumption or net production. The length of this integration interval proves to be important to the economic feasibility of PV installations under Net Billing because it establishes how much energy is valued at a high rate (consumer rate) and how much at a low rate (excess). We found this concept to be underexplored in energy literature.

This paper has three main contributions. The first contribution is to identify the production potential of PV systems based on radiation levels in 10 different cities of Chile. The second contribution is to establish optimal orientations and inclinations of PV modules to maximize the incident radiation and then estimate the PV production based on typical power losses. The third contribution is to identify the cities with the best PV potential under Net Metering and Net Billing tariff schemes, obtaining PV energy prices, which are compared by their levelized cost of electricity.

The paper is organized as follows: Section 2 provides a radiation analysis for 10 cities and determines the optimal photovoltaic system orientation and inclination and inverter sizing ratio. Section 3 presents the PV system production model. Section 4 explains Net Metering and Net Billing tariff schemes and how they are modeled considering consumption and compares the results of different integration intervals. Section 5 presents a levelized cost of energy, payback periods and IRR analysis. Finally, Section 6 presents the conclusions.

2. Residential scale PV analysis

2.1. Cities considered and their main characteristics

In order to understand a cross section of PV potential across Chile, 10 cities were studied. For each city, the following local resource and electricity rate data was used:

- The global horizontal irradiance (GHI) from year 2010 and the mean GHI from years 2003–2011.
- The temperature from year 2010.