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Estimating the potential for solar energy utilization in Chile by satellite-derived data and ground station measurements

Rodrigo A. Escobar [a,*], Cristián Cortés [b], Alan Pino [b], Marcelo Salgado [b], Enio Bueno Pereira [c], Fernando Ramos Martins [c], John Boland [d], José Miguel Cardemil [e]

[a] *Escuela de Ingeniería, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Santiago, Chile*
[b] *Fraunhofer Chile Research, Center for Solar Energy Technologies, Santiago, Chile*
[c] *Centro de Ciência do Sistema Terrestre—Instituto Nacional de Pesquisas Espaciais (Earth System Center—National Institute for Space Research), São José dos Campos, Brazil*
[d] *School of Information Technology and Mathematical Sciences, University of Southern Australia, Audelaide, Australia*
[e] *Universidad Diego Portales, Escuela de Ingeniería Industrial, Santiago, Chile*

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Abstract

The progress in solar energy resource assessment for Chile is reported, including measurements from a ground station network spanning more than three years of data, satellite estimations from the recently developed Chile-SR model including three full years of data, and simulations that evaluate the potential for solar thermal, photovoltaics (PV) and concentrated solar power (CSP) utilization.

The satellite estimation model adapts the Brasil-SR methodology with the combined use of visible and infrared (IR) satellite images, an enhanced treatment for altitude-corrected meteorological variables and an effective cloud cover computations that allows the estimation of the global horizontal and diffuse horizontal irradiation on an hourly basis. Direct normal irradiation (DNI) is computed from the direct horizontal irradiation by applying the Boland–Ridley–Laurent (BRL) model of diffuse fraction and proper solar geometry corrections. Comparison of the satellite-derived data with the ground station data shows good agreement and low error levels thus served for model validation. The results indicate that Chile is endowed with one of the highest levels of solar resource in the world in terms of annual irradiation for large portions of its territory. There is a small decrease in yearly levels of GHI and DNI with latitude that in practice indicate that most of the country shares exceptional conditions for solar energy. However, coastal regions have a large decrease in both GHI and DNI due to the persistence of seasonal cloud covers with daily cycles.

The use of irradiation data from the Chile-SR model for system simulation indicates that solar fractions over 80% are achievable for residential-sized solar thermal systems in most of the country, with PV systems yielding between 4.5 and 8 kW h/kWpv, and CSP annual yields of up to 240 GW h/year for a 50 MW parabolic trough plant. These results indicate that the country has the potential for ample utilization of solar energy conversion technologies in most of its territory when considering annual GHI and DNI, suitable terrain availability and energy (electricity and heat) demand from industrial, commercial and residential activities.

Keywords: Solar resource assessment; Chile; Ground measurements; Satellite estimation; Cloud cover estimation

* Corresponding author at: Escuela de Ingeniería, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Santiago, Chile. Tel.: +56 23545478.
E-mail address: rescobar@ing.puc.cl (R.A. Escobar).

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1. Solar energy in Chile

Renewable energy promotion in Chile has obtained government support by means legislations that mandate a renewable energy quota of up to 10% of the electrical energy generated, which must be met by 2024, with public announcements already being made that would modify this goal in order to achieve 20% of power generation by 2020 from renewable energy (Ministerio de Economía de Chile, 2007). This plan has sparked interest in introducing renewable energy systems to the country's electricity system. Solar energy is currently at the initial stages of market penetration, with several projects being developed including PV, CSP, and industrial heat supply plants. However, several barriers still exist and among them is the absence of a valid solar energy database available to the public, adequate for energy system simulation and planning activities. Even as the country is endowed with an exceptional solar potential, the contribution of solar energy to the energy mix in Chile is still small. As of June 2015, only 537 MW of PV plants have been deployed and are currently operating with 1849 MW being built and 8990 MW approved for construction in the environmental evaluation system. There are 110 MW of CSP plants under construction with another 870 approved (CIFES, 2014). Regarding solar heating and cooling systems, statistics from the *Solar Heat Worldwide* report from International Energy Agency indicate that as of 2013 there was 139,309 m^2 of installed solar thermal collectors for both the residential and commercial sectors (MAuthner et al., 2015). In terms of energy contribution, statistics from the government indicate that during 2014 a total of 458 GW h were produced accounting for 0.66% of the total Chilean electricity consumption, and that from January to May 2015 the contribution amounted to 484 GW h, or 1.65% of the national total for the period. There are currently no solar desalination projects in Chile. One of the several reasons that explain the difficulty in developing solar projects during the past years is the relatively scarce solar resource assessment activities that could allow reducing the risk associated to the evaluation of the energy yield of the solar plants in Chile. The efforts of our research team aim to produce and make available to the public and industry a proper set of solar radiation data able to allow project development with lower resource-related uncertainty.

Previous reports by the authors identified several databases of solar radiation that are publicly available for Chile and discussed their merits and shortcomings (Ortega et al., 2010; Escobar et al., 2014a). It has been found that significant deviation exists between sources, and that all ground station measurements display unknown uncertainty levels, thus highlighting the need for a proper country-wide long-term resource assessment initiative for the public domain. As the solar energy levels throughout the country are high according to all sources, it is thought that existing data is adequate for energy planning activities although not yet for proper power plant design and dimensioning. However, there are several commercial products that are not freely available to the public. As a general conclusion, although for Chile there are several databases of ground measurements, a weather simulation model, and satellite-derived data, none of these locally-produced data sources are completely valid and therefore a nationwide effort of resource assessment was needed at the time our research started (Ortega et al., 2010).

This report presents a summary of the solar energy resource assessment activities conducted by the Pontificia Universidad Católica de Chile (PUC) supported by its collaborators from the Instituto Nacional de Pesquisas Espaciais (INPE) of Brasil, University of Southern Australia, Universidad Diego Portales, and Fraunhofer Chile Research, briefly recounting what was already presented in Escobar et al. (2014a) and expanding on what was presented there and also at the ISES Solar World Congress 2013 (Escobar et al., 2014b). In short, a network of ground stations has been deployed in locations of scientific interest such as high altitude places, salt lakes, snow covered terrain, and others. A modification to an existing satellite estimation model has been developed, building upon the Brasil-SR model partially developed by researchers at INPE, and introducing different treatments for the meteorological variables and the effective cloud cover computations. The report presents results and comparisons for the described data sources. Validation of the Chile-SR model indicates that the model is properly estimating solar radiation for the range of climates present in Chile, which allows utilizing its data for an initial estimation that highlights the large potential energy yields of a variety of solar energy conversion systems in Chile. Finally, the Chile-SR data is used for simulations that estimate the potential in Chile for solar thermal, PV, and CSP projects.

2. The PUC-FONDEF ground station network

The network of ground stations was deployed starting on 2010, consisting of 13 stations, 4 of which are designed and operated under the Baseline Surface Radiation Network (BSRN) standards, and the remaining 9 are of three

Table 1
Ground station network.

Station name	Type	Start date of operation
1. Arica	RSBR	01/08/2011
2. Pozo Almonte	RSBR	04/04/2012
3. Patache	RSBR	16/01/2013
4. Sur Viejo	RSBR	07/07/2011
5. Crucero	RSBR	16/01/2012
6. Coya Sur	RSBR	05/07/2011
7. San Pedro	Sun tracker	03/12/2010*
8. El Tesoro	RSBR	01/01/2009
9. Diego de Almagro	RSBR	02/08/2011
10. Santiago	Sun tracker	22/12/2010
11. Curicó	Sun tracker	01/06/2012
12. Talca	Sun tracker	09/08/2012
13. Marimaura	RSBR	12/07/2012

* Decomissioned on dec 2011.

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