Preliminary Economic Evaluation of the First Grid-connected Photovoltaic System in the Aysén Region Under the Current Law of Distributed Generation in Chile

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Abstract

Chile has a law of distributed generation that came into effect in October 2014. Nevertheless, in the Aysén Region, which has solar resources similar to other areas with higher installation ratios, the first grid-connected photovoltaic system under this law was installed two years after it was enacted. In order to analyse the existing barriers to the implementation of photovoltaic technology in this area, a preliminary economic evaluation was conducted for this study after the first system installed in the region had been in operation for one year. In economic terms, the results reveal an unfavourable situation for the large-scale installation of these types of systems intended for home consumption compared to other areas of the country with similar radiation levels. We therefore suggest analysing options that consider multiple interrelated factors to be able to model scenarios with high penetration of local distribution grid-connected photovoltaic technology on a residential scale.

Keywords: Economic Evaluation, Grid-connected PV, Local Distribution Grid, PV costs, PV for Buildings

1. Introduction

Photovoltaic (PV) technology is key to the sustainable energy transition (Child and Breyer, 2017). In 2016, PV systems of residential prosumers reached a share of 25-30% of the PV solar energy installed globally (REN21, 2017). According to Breyer et al. (2017), in one scenario of energy demand in the global power sector, the primary generation of PV electricity in 2050 may reach 69%, 31% of this contribution coming from PV prosumers.

The high penetration of photovoltaic systems in power grids has therefore been identified as essential to the transition towards sustainable energy systems (IEA-PVPS, 2014). Still, under some circumstances, impediments have been detected that hinder their integration into local distribution grids, even varying within the same country. In the case of Chile, Law 20571 –known as "Citizen Generation" and whose aim is to promote the self-consumption of electricity– was passed in 2012 and came into effect in October 2014 under a net-billing scheme. Thanks to this Law, a total of 2059 grid-connected PV systems were installed by the end of 2017; only four of them in the Aysén Region (CNE, 2018), located in the south of the country. The first grid-connected PV system installed in this region –1.56 kWp and a total investment of 5774.9 USD_{2016} (VAT included)–, was financed with public funds and began operating in October 2016 in the city of Coyhaique, the capital of the region undergoing study.

In 2016, the project *"Elaboración de un Índice de Precios de sistemas FV conectados a la red de distribución comercializados en Chile"* ("Development of a Price Index of Grid-Connected Photovoltaic Systems Marketed in Chile") (ME and GIZ, 2016) was conducted. It did not include the Aysén Region as, at that time, there were no systems installed under Law 20571. In addition, considering that this region has areas with average solar radiation levels of up to 4.50 kWh m^{-2} per day, similar to those of the centre-south of Chile (ME, 2018), it follows that the main barrier to the large-scale penetration of residential PV systems in the region has to do with factors associated with its initial investment; affecting the time of recovery.

In order to elucidate some of the causes that have hindered the implementation of grid-connected PV systems in

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the territory in question, this study presents a preliminary economic assessment based on the first PV system under Law 20571. The initial investment in the system is compared to the price index (PI) of the country's PV systems; the prices of the residential tariff and the feed-in tariff in the territory under consideration are compared to the prices of the tariffs in areas with similar solar resources, and; the time for return on investment in the system is calculated for different ranges of self-consumption and energy injected into the grid. The results indicate that the Aysén Region exhibits disadvantages, in economic terms, for the implementation of grid-connected PV systems.

In short, in addition to revealing the unfavourable situation of the area under consideration to expand access to grid-connected PV systems, this study contributes with the detection of factors and aspects to consider for the development of models of scenarios with high penetration of PV technology on a residential scale, also serving as a reference for other similar studies.

2. Method

First, considering the total investment costs of the PV system installed –turnkey–, the Wp price in USD without VAT was calculated and compared to the PI of grid-connected PV systems with a range of installed capacity of 1-5 kWp, according to information from ME and GIZ (2016). Subsequently, based on the data published by electricity supply companies in cities with solar radiation levels similar to those of Coyhaique (Temuco and Osorno), a comparison was conducted of the average prices of tariffs in 2017. These included both those corresponding to energy consumption for residential customers –due to the fact that it is the price of the kWh saved through energy self-consumption –, as well as those of valuation of feed-in tariff. Then, with the real electricity production data of the 1.56 kWp PV system, recorded in 2017, the times for return on investment were calculated using eq. 1 with different self-consumption ($\boldsymbol{F_{SC}}$) and grid injection ($\boldsymbol{F_{GI}}$) factors –both of them simultaneously varying between 1.00 and 0.00–, under different scenarios. In the equation, $\boldsymbol{Pt}$ is the payback time, $\boldsymbol{I}$ is the initial investment, $\boldsymbol{E}$ is the monthly energy production of the PV system, $\boldsymbol{T_{SC}}$ is the price of the self-consumption savings tariff and $\boldsymbol{T_{GI}}$ is the feed-in tariff, the latter varying monthly.

$$Pt = \frac{I}{\sum_{i=1}^{n=12}\left[E_i\left(T_{SC,i} \cdot F_{SC} + T_{GI,i} \cdot F_{GI}\right)\right]} \qquad \text{(eq. 1)}$$

3. Results and Discussion

3.1. Price index comparison

According to ME and GIZ (2016), grid-connected PV systems in Chile with an installed capacity in the range of 1-5 kWp have average and median prices of 2.76 USD Wp^{-1} and 2.56 USD Wp^{-1}, respectively. The installation price of the PV system in the Aysén Region had a value of 3.11 USD Wp^{-1}. This suggests that the system under consideration is 11.3% more expensive than the national average and 17.7% more expensive than the national median.

As the lowest prices have been shown to be in the Metropolitan region –the centre of Chile– (ME and GIZ, 2016), it is possible that one of the causes that the price per installed Wp is higher in the area under consideration is the fact that the Aysén Region is isolated from the rest of the country. This may cause the investment cost to increase due to factors related to the transport of equipment and in a range higher than that of other regions. It is therefore suggested to analyse the budgetary breakdown of investment in systems with the same installed capacity for a more objective comparison and, in turn, to detect items for cost reduction and/or subsidy options since the latter, at the residential level, do not exist in Chile.

3.2. Tariff comparison

As can be seen in Tab. 1, the average price of self-consumption savings tariffs among the cities compared to the one under consideration is insignificant. This would not entail a large difference in the recovery of investment in a setting of 100% self-consumption of the energy produced if the total cost of PV systems were the same for each territory. However, as explained in section 3.1, the initial investment in the city of Coyhaique is above the national average. Nevertheless, with the enactment of the Tariff Equity Law –at the end of 2017–, the price of tariffs changed for residential customers across Chile, thus leading to a variation in the times for return on investment. This last point will be necessary to consider in future studies.

Tab. 1: Comparison of annual average tariffs, 2017

City [latitude]	T_{SC} (USD$_{2017}$ kWh^{-1})	T_{GI} (USD$_{2017}$ kWh^{-1})
Temuco [-38.74º]	0.239	0.109
Osorno [-40.57º]	0.239	0.127
Coyhaique [-45.57º]	0.237	0.100

In addition, if follows from Tab. 1 that in the city of Coyhaique 8.3% and 21.3% less per kWh injected into the grid is appraised than in Temuco and Osorno, respectively. These differences have significant effects on the time for recovery of investment, depending on the amount of energy injected into the grid. It is likely that the differences in feed-tariff are due to the fact that the electricity systems in the Aysén Region, on the one hand, are isolated from the interconnected systems of the rest of the country and, on the other, are classified as medium-sized electricity systems (below 200 MW). It is therefore suggested in future studies to analyse tariff regulation under the Law of distributed generation.

3.3. Estimation of time for investment recovery

Tab. 2 shows a summary of the results obtained with eq. 1. In 2017, the PV system in question produced a total of 1951.7 kWh; 1509.7 kWh was self-consumed and 442 kWh was injected into the grid. Considering these data as $F_{SC} = 0.77$ and $F_{GI} = 0.23$ for the calculation of annual return, it was found that the recovery of the investment would be completed in 14.4 years. This would be 13.0 and 12.8 years for the cases of Temuco and Osorno, respectively.

Tab. 2: Time for investment recovery with different factors

City [latitude]	$F_{SC} = 0.77$ $F_{GI} = 0.23$ (years)	$F_{SC} = 1.00$ $F_{GI} = 0.00$ (years)	$F_{SC} = 0.15$ $F_{GI} = 0.85$ (years)	$F_{SC} = 0.00$ $F_{GI} = 1.00$ (years)
Temuco [-38.74º]	13.0	12.7	22.6	27.4
Osorno [-40.57º]	12.8	12.7	20.3	23.6
Coyhaique [-45.57º]	14.4	12.7	25.0	30.0

In one scenario of residential self-consumption in the area under consideration, it was found that the most favourable situation is produced with $F_{SC} = 1.00$ and $F_{GI} = 0.00$, where the investment would be recovered in 12.7 years. It was also found that the more generated energy is injected into the grid, the greater the time for return on investment. For the PV system in Coyhaique, its maximum limit is with $F_{SC} = 0.15$ and $F_{GI} = 0.85$, since, in this situation, the investment would be recovered in 25 years. In other words, it becomes unviable. Using these same self-consumption and injection values, the investment in Temuco and Osorno would be recovered in 22.6 and 20.3 years, respectively.

3.4. Final Considerations

In summary, grid-connected PV systems in the Aysén Region have higher investment costs than the rest of the country and the feed-in tariff is lower than in other areas with similar solar radiation. The investment therefore takes longer to recover, causing the implementation of this type of system to be less attractive in the area under consideration. This may explain why it took two years for the first grid-connected PV systems to be installed and may be the main reason it is the region of Chile with the least amount of this type of system in operation.

Even so, along with analysing the budgetary breakdown of the initial investment, it is necessary to perform a deeper economic assessment. To do so, it is proposed to consider real profiles of residential consumption, as well as the calculation of parameters including: Levelized Cost of Energy, to compare it to the price of the tariff for residential customer energy consumption; and socket parity. In addition, bank financing and state subsidy options may also be assessed.

It will also be necessary in future studies to review and analyse techno-regulatory factors that influence the implementation of decentralised PV systems. Furthermore, it is suggested to consider aspects such as the socio-economic benefits and environmental externalities associated with this type of system, all with a view to model scenarios with high penetration of PV technology on a residential scale in local distribution grids.

4. Conclusion

From the results obtained in the preliminary economic assessment conducted of the first grid-connected PV system in the Aysén Region, it has been concluded that the territory has disadvantages in economic and probably regulatory terms compared to other areas of the country, thus impeding the widespread use of grid-connected PV systems. Furthermore, with the enactment of the Tariff Equity Law, it will be necessary to reassess the economic viability of grid-connected PV systems, not only in the Aysén Region but throughout the country. In turn, it proves necessary to analyse PV energy production data and compare them to profiles of residential consumption in order to foresee the real viability of the systems. In addition, it is also necessary to consider public incentives or subsidies for residential customers –until now non-existent in Chile–. Finally, for future analyses of high penetration grid-connected PV systems, along with conducting a broader economic assessment, it is suggested to consider factors such as technical and regulatory limitations of the local distribution grids as well as social and environmental externalities in order to envision options that contribute to the decentralisation and democratisation of energy through PV technology.

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6. Appendix

6.1. Abbreviations

PV	Photovoltaic
USD	United States Dollar
VAT	Value Added Tax
PI	Price Index

6.2. Variables

Pt	Payback time
I	Initial investment
E	Monthly Energy Production
T_{SC}	Price of the self-consumption savings tariff
F_{SC}	Self-consumption factor
T_{GI}	Feed-in tariff
F_{GI}	Grid injection factor