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Solar Photovoltaic Modules Degradation Rate Comparison and Data Analysis

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Solar Photovoltaic Modules Degradation Rate Comparison

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Abstract

The increase of solar power users, despite the expense of photovoltaic (PV) module installation, is due to the high estimation of Return on Investment (ROI). However, most ROI estimation neglects the decline in efficiency of power generation over time (degradation rate). As use of solar power grows, accurate prediction of PV module efficiency is important. The Engineering Technology Department at Queensborough Community College has installed monocrystalline, polycrystalline, and thin-film PV modules by four manufacturers on the roof of the Technology Building. The goal of this research is to estimate each PV module's degradation rate and compare the changes of the efficiencies over seven years in New York's climate. Knowing how each type of PV module degrades will provide crucial information to potential solar power users in New York.

Keywords

Research, Renewable energy, Solar PV efficiency

Introduction

As part of the state's NY-Sun initiative, use of solar power in New York State has grown 575% from 2012 to 2015 according to the New York State Energy Research and Development Authority (NYSERDA).[1] Growth of solar power in New York City is even more remarkable. There are more than 5,300 solar power installation projects across the five boroughs in 2016 in comparison with 186 projects in 2011 and the number keeps rising.[2] The increase of solar power users in spite of the relatively high upfront cost of solar photovoltaic (PV) module installation (for a single-family house it runs between $20,000 and $50,000) is due to the high estimation of Return on Investment (ROI).[3] However, most of ROI estimation neglects the functional decline of efficiency of power generation over time, also known as the degradation rate. As use of solar power is growing, the accurate prediction of power delivery over time in PV modules is important. The total power delivery to the electric system with the same amount of solar radiation depends on both how efficiently a solar PV module converts sunlight into power and how this relationship changes over time.

There are three major types of solar PV modules: monocrystalline, polycrystalline, and thin-film PV. Each type converts sunlight into power at a different efficiency rate, therefore, the cost varies. The power conversion efficiency of solar energy is relatively low, at an average of about 15%, according to the U.S. National Renewable Energy Laboratory (NREL).[4] If modules degrade 10 –

15% after a certain time period, PV module efficiency is considered a failure.[5] The performance of PV modules over long periods of time have been unclear, therefore, estimation of accurate net efficiency that take degradation rate into account is important. The Engineering Technology Department in Queensborough Community College (QCC) has installed these three major types of PV modules by four different manufacturers, as shown in Table 1, on the southeast roof of the Technology Building (Figure 1). These PV modules have been converting sunlight to power and have been providing electricity directly to the building since 2010.

Table 1 Solar panels by different Manufacturers and types installed in Technology Building, QCC

Manufacturer	Type of Cell	*Qty*
Sun Tech	Monocrystalline silicon	2
Evergreen	Thin-film	2
Sharp	Polycrystalline silicon	2
Sanyo	Hybrid (monocrystalline silicon surrounded by ultra-thin amorphous silicon)	2
Trina Solar	Polycrystalline silicon	1

Figure 1 Picture of installed solar modules on the roof of the Technology Building at QCC

Literature Review

The risk management company DNV GL performed laboratory testing of the PV modules from 17-20 manufacturers on four reliability test categories. The objective of their testing was to understand PV equipment's aging behavior and make data available publicly. The reliability test was implemented with controlled physical parameters over a time frame of a few months. Controlled physical parameters were thermal cycling, damp heat, humidity-freeze, and dynamic mechanical load. The result showed that thermal cycling (ambient temperature and irradiance fluctuation) was the factor that most affected PV decline. Damp heat (high ambient temperature and humidity) resulted in the largest range of degradation rates (-0.6% to -58.8%) between manufacturers. However, the test has the limitation that laboratory-based results with controlled factors cannot be extrapolated to precisely predict field degradation rate.[6] Similar experiments were performed on the solar PV modules at QCC with available measured meteorological data in this study.

Data

Locally measured meteorological data from National Weather Service (NWS): solar irradiance, air temperature, humidity, precipitation and the UV index, were considered as independent variables to see if meteorological parameters are related to degradation rate and which variables highly trigger the degradation of solar PV modules.

Daily and hourly power data in kWh (kilowatt hours) is available from eight solar modules through the online-based software Enphase (https://enlighten.enphaseenergy.com). In this study, the degradation rate for about six years was computed for each operating PV module type and manufacturer.

Analysis and Results

We calculated the efficiency of each solar panel by dividing each panel's monthly power output by the product of the area of that panel and incident solar irradiation (Equation 1).

$$\eta(efficiency) = \frac{P_{month\_ave}(average\ power\ output)}{Incident\ solar\ irradiation \times Area\ of\ panel} \times 100\% \qquad \text{Equation 1}$$

Figure 2 shows a plot of the eight different solar panels' efficiencies from February, 2012 to July, 2017. All the solar panels show similar patterns by season: high efficiencies in the winter months of December, January and February, and lower efficiencies in the summer months of June, July, and August. There are slight differences in efficiency between manufacturers. In 2012, the Trina solar panel performed with the highest efficiency, with a maximum above 30%. It maintained the highest performance until 2016, then it degraded greatly in 2017, performing with the lowest efficiency among all of the brands that were studied. The two solar panels from Sanyo were the second-most efficient to the Trina panel and became the most efficient when the Trina panels declined. These Sanyo panels are of the hybrid type, which is monocrystalline silicon surrounded by ultra-thin amorphous silicon. The two solar panels from Suntech, which are monocrystalline, generated power with the next-highest efficiency. Solar panels from Sharp, which are polycrystalline, performed with similar efficiency to the Suntech brand in winter months, but they showed noticeably less efficiency in the summer months.

Learning that the efficiency varies with seasons, we plotted solar panel efficiency with respect to four different meteorological factors to see if any of these factors affect efficiency more than the others. The result shows that high solar irradiance leads to poor performance of the solar panels. This result explains how we got a low efficiency in the summer months in Figure 2. Temperature does not show clear relationships with efficiency but efficiency does not reach more than 20% when the temperature is higher than 70°F. UV dose shows a similar result. With a higher UV dose, efficiency is low. Humidity does not have an effect on the efficiency.

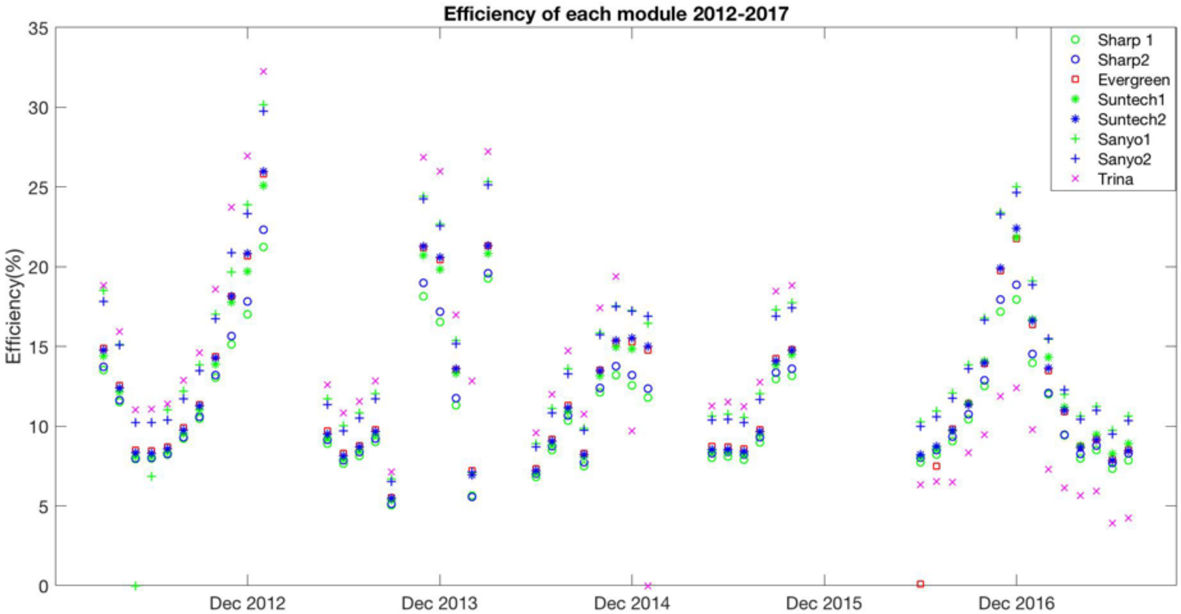

Figure 2 Efficiency of each module comparison over time (2012-2017)

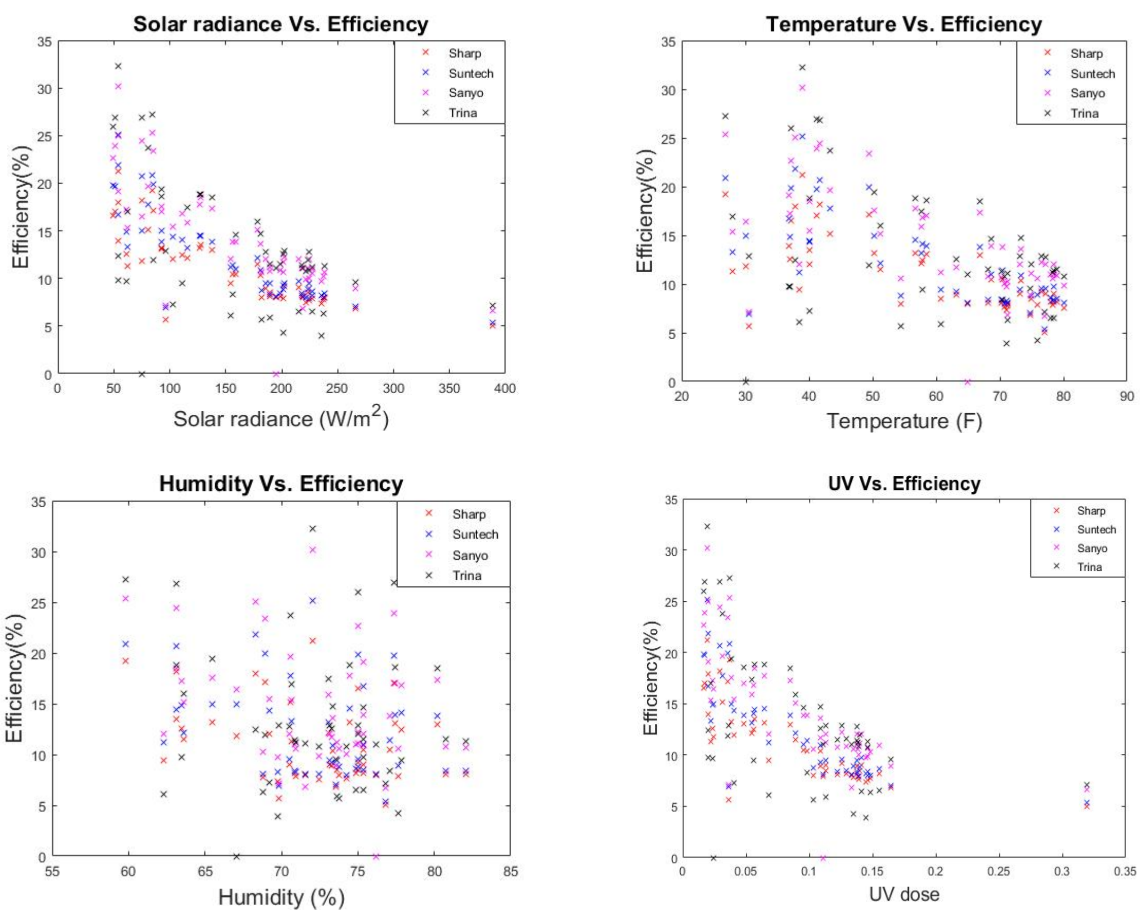

Figure 3 Relationship between meteorological factors-solar radiance, air temperature, humidity and UV dose and efficiency

Conclusions

In general, as was expected, solar panel efficiency has degraded over time, though there were some increases in efficiency in 2016. The absence of data from November 2015 to May 2016 makes this unusual uptick difficult to track. All panels were more efficient in winter than in summer, perhaps indicating that there are declining returns from higher solar radiances. The most reliable panels on the roof of the Technology Building at Queensborough Community College were hybrid (monocrystalline silicon surrounded by ultra-thin amorphous silicon) panels made by Sanyo. The only type of solar panel on the roof that is represented by more than one manufacturer is polycrystalline silicon, represented by Sharp and Trina Solar, which had very different results. Trina's efficiency started off as the best, but had a steep decline from 2015 to 2016. Sharp's efficiency was never near the top but did not have that steep decline despite being the same type of panel. Further investigation will be done into the loss of data for certain months as well as the effect that cleaning has on the efficiency of our solar panels.[5]

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