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Analysing the performance values of PV technologies in Östersund, Sweden.

Comparing the performance values of PV panels against PVGIS databases.

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Sammanfattning / Abstract

Solar power is a promising technology to convert the current state of electricity production to the renewable sector. The margins for solar projects in unproductive regions like northern Sweden are slim, so the overall viability of projects depend on using the most efficient technology and estimating realistic values. This paper analyses a series of performance values between different PV technologies in the city of Östersund. The methodology is based on statistical analysis of the quarterly performance values and how they perform against each other and the European PVGIS databases. CIS (Copper Indium Selenide) thin-film technology showed significantly higher yearly production and specific yield than conventional crystalline silicone types. Furthermore, the PVGIS database estimates are similar to all the other technologies in the report apart from the CIS. This indicates that the PVGIS is a useful tool for estimating realistic values, and even more so that CIS is a good choice of technology for this specific region. It is therefore recommended that any potential solar power projects in the area use CIS thin film panels to maximise their production output. However more research is needed to conclude whether the solar potential is enough to warrant new projects.

Nyckelord / Keywords:

Solar power, analysis, CIS, thin-film, crystalline silicone, specific yield, PVGIS, Sweden

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1 Introduction

1.1 Background

There is a big demand for readily available renewable energy technology. According to (IPCC, 2022), over the last few decades greenhouse gases have been rapidly increasing and it has become clear that there needs to be a shift towards low-emission power production. The demand for power is continuously increasing, with population growth and higher standards of living raising the global power consumption per capita.

Solar power is a promising technology to move the electricity production into the renewable sector. Considering sunlight is a globally available resource, developing efficient and low-cost solar technology could potentially have a large impact on the global energy sector.

1.2 Observation and Problem description

There are many contributing factors in a PV performance and potential analysis. In low insolation regions like northern Sweden, the margins for solar projects are slim and it might not be productive enough to warrant installations. So, the overall viability of projects depend on using the most efficient technology and estimating realistic values. This report will address that issue by looking at different performance values.

1.3 Literature Review

Solar PV potentials have been analysed in most regions of the world. Various methods have been used, some more in-depth than others. According to (Avtar et al., 2019),(Quiroga-Ocaña et al., 2021), GIS, satellite data and remote sensing are among the most efficient ways of analysing data concerning renewable energy analysis. This is confirmed by many other researchers aswell, (Tapia et al., 2022), (Mavsar et al., 2019) and (Melius et al., 2013).

According to (Boyle & Everett 2018) the photoelectric effect is used to extract power from the electromagnetic radiation from the sun. There are different semiconducting materials used in PV cells. Crystalline silicon is the most commonly used material, where polycrystalline is considered easier and cheaper to manufacture but has a lower efficiency than monocrystalline. Other technologies like thin film have been developed recently. They need less material than conventional crystalline cells but are currently also more difficult to manufacture.

The PV panel needs to be angled correctly for the direct radiation to hit the panel and maximise the voltage potential (Despotovic & Nedic, 2015). It's a matter of compromise since the orientation of the sun changes throughout the day and year. Additionally, (Armstrong S. & Hurley W.G., 2010) mentions that high latitudes regions receive higher amounts of diffusive radiation compared to direct radiation, due to frequent cloud cover, and that affects the performance of the panels. (Boyle G. & Everett B., 2018) brings up that the current produced from the panel is directly proportional to the intensity of the irradiance. The irradiance varies throughout the day and systems like maximum power point tracking has been developed to try to optimise performance during changing conditions. Such a system maximises current by adjusting the resistance of the circuit depending on the output voltage.

Much research has also been done in material science to diminish the potential losses from variable irradiance due to cloud cover. According to (Taraba et al., 2019) thin film technology performs better in low light conditions due to the construction of the material. They consist of depositions of different materials that can absorb a greater proportion of the EM spectrum. (Kiseleva et al., 2018) also confirms this, and adds that thin films have a lower temperature coefficient than crystalline silicone, so they perform comparatively better when the temperature is higher. Thin films do however have slightly lower production per square meter so larger areas are needed to achieve higher production.

1.4 Aim

The aim of the study is to contribute to a deeper understanding of the performance of PV panels in Östersund**.** This study could provide a basis for further research in the subject.

1.5 Research question

How do performance values differ between PV technologies in the city of Östersund?

1.6 Theory

Solar power is produced by the Photovoltaic effect. The system relies on the absorption of light (Electromagnetic radiation) by a material to create a bound electron-hole pair (exciton) that gets dissociated, moves through an electrical circuit and induces a current. Many factors that affect the efficiency of materials for solar power belong to the realm of condensed matter physics: structures of solids, surfaces and interfaces; light absorption; electron- and hole trapping and charge transfers (Martsinovich, 2016).

2 Method

2.1 Delimitation

The study area is the city of Östersund. The object of study is the PV system on the roof of the Miun university. The system is made up of 4 different models, poly-, monocrystalline and thin-film by 4 different manufacturers (REC (Poly), Solar Fabrik (Poly), Renesola (Mono) and Solar Frontier (CIS Thin-film). They've been installed with identical positioning and have nearly identical system efficiency and peak power output.

The goal of the study is to notice differences between the performances of the technologies and to highlight the most productive type. A broader view is added by comparing them against a reference dataset from the European PVGIS database (re.jrc.ec.europa.eu, 2023). The methodology of comparing the performance against a database means that the data can be assessed against a standard dataset and that could be relevant for other analysis projects.

Quarterly and yearly values of the PVs were analysed. Any technology that performed better than the PVGIS database could be considered a good alternative for further installations. Likewise, if any performed worse, it could be an indicator that it is not a suitable model for the study area. Furthermore, if the PVGIS database values are similar to all the measured values from the system, it can indicate that the PVGIS database is a reliable option when assessing further PV potential in the area of Östersund.

PVGIS offers multiple alternatives for PV technology during its analysis but after testing, it was found that there was less than 1% discrepancy between the measured values of the different technologies. Thus, only the values of the silicone technology were used for the sake of clarity. PVGIS also offers two different solar radiation databases, ERA5 and SARAH2. The website measured the irradiance, optimised both slope and azimuth to 45° and 0° respectively. A recommended system loss of 14% was set, with an installed capacity of 7,25 kWh.

Emphasis in this method is put on maximum performance because it is such a critical factor in a low insolation area like Östersund. Due to the basic methodology, many ethical factors are not given much attention like land and material usage that are equally important from a larger perspective. However, they could be research topics on their own as the report would be quite extensive if those were included also.

2.2 Data collection

The performance data of the installed PV was given from the university and had been collected between 2016-2019. An information sheet of the installed technologies was also given from the university and all the necessary data, like installed capacity was taken from there. The data from the PVGIS database was collected from the European PVGIS website. (re.jrc.ec.europa.eu, 2023).

2.3 Data analysis

MATLAB was used for the analysis. The irradiance data of the city of Östersund was plotted, to establish a general potential.

The mean was taken from the quarterly performance values of each technology and charted against the mean of the ERA5 and SARAH2 databases respectively. The idea behind the quarterly values was to visualise potential differences between the types over the seasons.

$$Mean_{quarterly,type} = \frac{Sum\ of\ performance\ from\ specific\ quarter}{Total\ amount\ of\ specific\ quarter}$$

The total yearly production of the mean values was then summarised into a table:

$$Production_{yearly,type} = \text{Sum of } Mean_{quarterly,type}$$

Finally, the total yearly production (kWh) was divided by the peak power capacity (kWp) of each type, creating a specific yield value:

$$Specific\ yield_{type} = \frac{Production_{yearly,type}}{\text{kWp}}$$

The highest specific yield value relates to the highest functioning efficiency. Specific yield is a valuable variable to look at when comparing performances because it adjusts each performance by dividing with its installed capacity, thus creating an equal level of comparison.

3 Result

The irradiance data in Fig. 1 shows a slight difference between the separate databases. SARAH2 shows higher values during the summer months with a peak just above 160 kWh/mˆ2 in June. ERA5 shows higher values than SARAH2 throughout the year aside from the summer months, with the yearly peak just below 160 kWh/mˆ2 occurring in May.

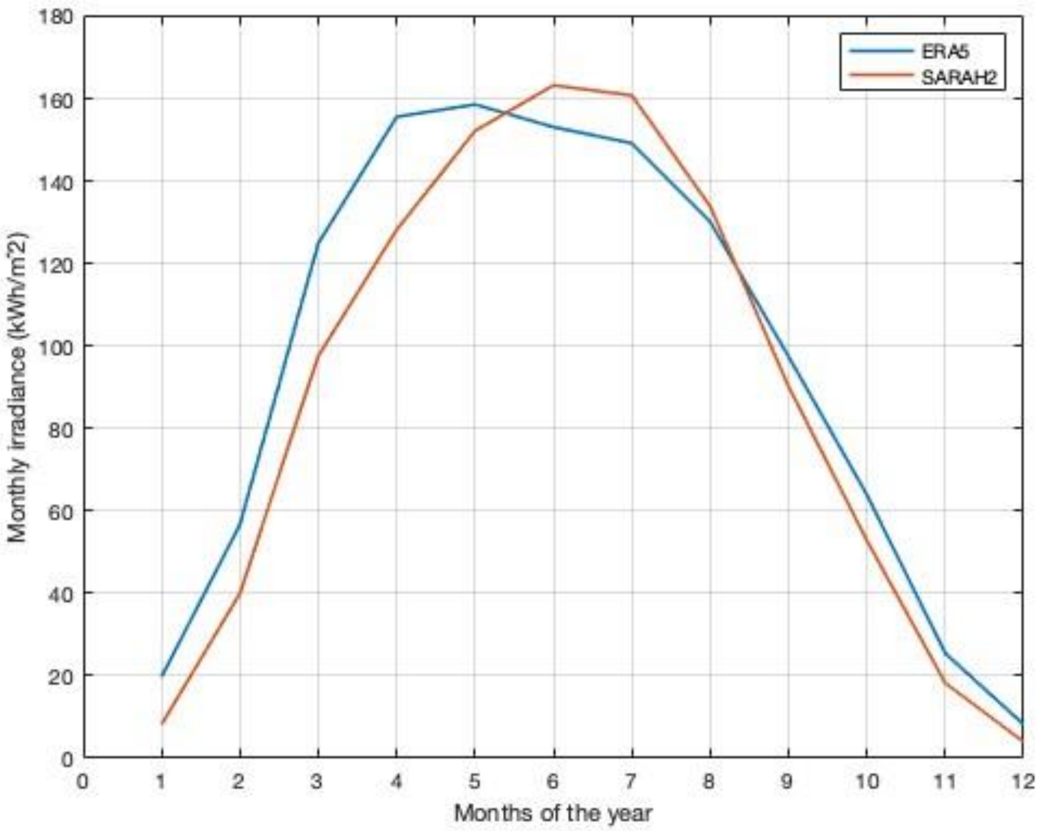

Figure 1. Monthly in-plane Irradiance data from the city of Östersund. Collected from the European PVGIS database (re.jrc.ec.europa.eu, 2023).

In Fig. 2 it is noticeable that the thin film CIS technology has a higher performance than all the other materials and databases. Furthermore, every type of technology performs better than the databases during spring and summer, but equal or worse during autumn and winter.

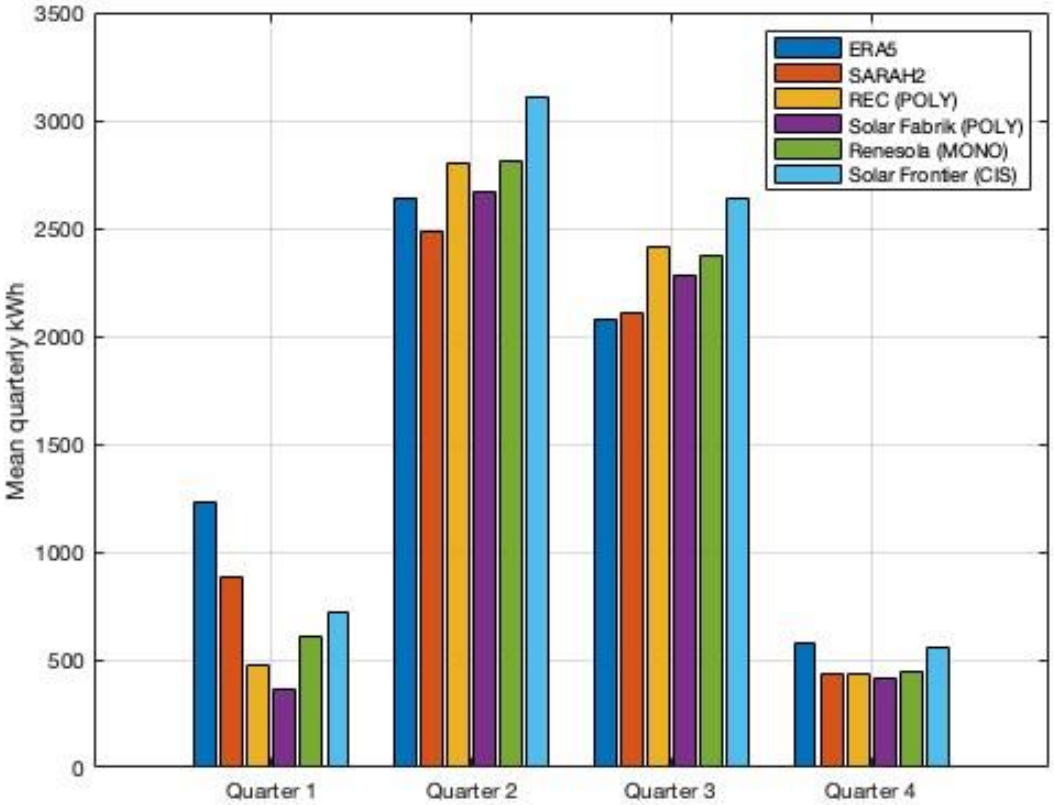

Figure 2. Quarterly performance values between type of technology and database. Database values collected from the European PVGIS database (re.jrc.ec.europa.eu, 2023).

The CIS thin-film technology has the highest yearly production (Table 1). The other types have values that are closer to each other. It should be mentioned that there's a variation between the REC and Solar Fabrik, even though they are both Polycrystalline silicon.

Table 1. Yearly production values between type of technology and database.

	Total Yearly Production (kWh)
ERA5	6523
SARAH2	5912
Rec (Poly)	6136
Solar Fabrik (Poly)	5739
Renesola (Mono)	6255
Solar Frontier (CIS)	7031

The CIS thin-film technology has a higher specific yield value (Table 2) than the other types. The difference in specific yield value between the REC and Solar Fabrik is not as large as the yearly production in Table 1. The slight increase in specific yield can be attributed to the lower installed capacity (kWp). The database values are slightly higher and lower than the crystalline silicone types.

Table 2. Installed capacity (kWp) and specific yield (kWh/kWp) between type of technology and database.

	kWp	kWh/kWp
ERA5	7,25	899
SARAH2	7,25	815
Rec (Poly)	7,28	842
Solar Fabrik (Poly)	7,0	819
Renesola (Mono)	7,25	862
Solar Frontier (CIS)	7,31	961

4 Discussion

The results show that the CIS thin film technology performed better than all the other types and databases. Since these are actual measurements from the performance data over a few years, it is very indicative that thin film is the most suitable option for solar power in Östersund. That it happened in conditions that experiences a larger share of diffusive radiation due to cloud cover, is not all that surprising since it has been documented and explained by other researchers (Taraba et al., 2019). Similar results have also been found by (Ahsan et al., 2018), where CIS thin film outperformed crystalline silicone in partially shaded conditions. The higher performance is attributed to a monolithic structure that allows for better redistribution of voltages and current within the module, and a lessening of thermal hotspots. A factor contributing to the higher measurements for CIS thin film during summer could also be the lower temperature loss coefficient, as explained by (Kiseleva et al., 2018). Exactly which one is the key factor is not analysed further.

The crystalline silicone type values are all fairly similar to each other compared to the thin film type. Although monocrystalline did perform slightly better than polycrystalline, it's not quite significant enough to make a noticeable difference in the yearly production. Additionally, a mean value taken from the database values would be very close to the actual production from crystalline silicone panels. Since they are still the most common types of solar panels it is indicative that it's an effective tool when measuring solar power potential in the region.

The performance values between the types of technologies investigated differ. CIS thin film has higher performance values and is therefore the recommended type of technology for installations in Östersund.

Although thin film has higher performance, this study hasn't made any investigations into the pricing and availability of the different types. Those factors will surely have an impact on future deployment and might limit the growth of thin film installations in the area. Additionally, whether PV power is a suitable method for power production in the region hasn't been considered in this study.

Because of the regions low irradiance, any large-scale solar plant projects should definitely consider using CIS thin film if at all financially possible. Although land restrictions are not as tight in the region of Östersund as many other places in the world, it should be considered that thin film tend to have a higher space requirement for equivalent power output than crystalline silicone, as mentioned by (Ahsan et al., 2018). It is therefore suggested that homeowners should be a little apprehensive towards solar power installations unless they can attain optimal positioning and have sufficient space availability for thin film.

Further topics could be to investigate the potentials between solar plants and roof installations in the area. Establishing the most productive systems is a necessary step to maximise solar power production. Maximum productivity could be looked at by comparing available rooftop areas to an equal amount of land, and calculating whether economies of scale could benefit projects. After such a project it would be easier to definitively conclude whether solar power is a potential renewable energy source in the region, or whether resources should be put into other sources.

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