
THE EFFECTS OF CONCENTRATED SOLAR IRRADIANCE ON THE OVERALL PERFORMANCE OF MONOCRYSTALLINE AND POLYCRYSTALLINE SOLAR CELLS

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ABSTRACT

Concentrated photovoltaic (CPV) technology offers a promising approach for enhancing solar energy conversion by increasing the irradiance incident on photovoltaic (PV) cells. However, elevated irradiance is accompanied by significant thermal effects that may adversely affect the electrical performance and reliability of silicon solar cells. This study experimentally investigated and compared the effects of concentrated solar irradiance, ranging from 1 to 10 suns, on the performance of monocrystalline and polycrystalline silicon solar cells. The investigation focused on key electrical parameters, including short-circuit current (I_{sc}), open-circuit voltage (V_{oc}), maximum power output (P_{max}), conversion efficiency, fill factor (FF), and series resistance, while also examining the influence of temperature under concentrated illumination; with the additional objective of identifying the irradiance threshold beyond which performance degradation becomes significant for each cell type. Baseline performance measurements were first obtained under Standard Test Conditions (1 sun, 25°C, AM 1.5). Thereafter, controlled concentration levels were achieved using a solar simulator and the current–voltage (I – V) characteristics were recorded at concentration ratios between 1 and 10 suns. The results showed that (I_{sc}) increased almost linearly with irradiance, whereas voltage (V_{oc}) exhibited a logarithmic increase before approaching saturation at higher concentration levels. Although maximum power initially increased with concentration ratio, conversion efficiency and fill factor declined beyond the optimum operating range due to elevated cell temperatures and increased resistive losses. Monocrystalline solar cells consistently demonstrated higher efficiency, lower thermal sensitivity, and greater resistance to performance degradation than polycrystalline cells. Critical concentration thresholds were identified, beyond which thermal effects outweighed the benefits of increased photocurrent generation. The findings demonstrate that concentrated irradiance can substantially improve photovoltaic power output when operated within an optimal concentration range and supported by effective thermal management. This study provides valuable experimental insights for the design, optimisation, and deployment of efficient concentrated photovoltaic systems, particularly in regions with high solar insolation.

Keywords: Concentrated solar irradiance; Monocrystalline solar cells; Polycrystalline solar cells; Photovoltaic performance; Thermal effects

1. INTRODUCTION

The growing demand for clean, reliable, and sustainable electricity has accelerated the adoption of solar photovoltaic (PV) technology as a renewable-energy option. Although improvements in cell manufacturing and reductions in PV costs have enhanced deployment, conventional PV output remains dependent on solar irradiance and operating temperature. Consequently, research has focused on approaches that increase power density without proportionally increasing semiconductor area. Concentrated photovoltaic (CPV) technology addresses this challenge by using lenses or mirrors to focus sunlight onto relatively small PV cells. Increasing irradiance can enhance photocurrent and power generation; however, it also increases cell temperature and can introduce electrical and thermal losses that limit the benefit of concentration (Chegaar et al., 2013; Nasrin et al., 2018).

The interaction between irradiance and temperature is important for crystalline-silicon PV technologies. Experimental studies show that short-circuit current generally increases with irradiance,

whereas open-circuit voltage, fill factor, and conversion efficiency are strongly affected by temperature and high-irradiance operation (Chegaar et al., 2013; Dash & Gupta, 2015; Musanga et al., 2018). Mandadapu et al. (2017) similarly demonstrated that irradiance and temperature significantly influence PV electrical characteristics. Under high irradiation, power output may increase while thermal accumulation becomes increasingly significant, indicating that higher incident radiation does not necessarily produce a proportional improvement in efficiency (Nasrin et al., 2018). Outdoor investigations further confirm that climatic parameters affect PV output and energy yield (Ye et al., 2013; Gol & Ščasny, 2025).

Monocrystalline and polycrystalline silicon cells are widely used because of their established manufacturing technologies. Their different crystalline structures (figures 1 and 2), and electrical characteristics can produce different responses to irradiance and temperature. Comparative studies have reported differences in mono-Si and poly-Si performance under various climatic conditions (Amin et al., 2009; Zdyb & Gulkowski, 2020; Galal et al., 2023). Komoni et al. (2018) reported favourable performance from monocrystalline modules under Kosovo climatic conditions, while Ray et al. (2023) also identified performance differences between the two technologies. Studies in tropical and other environments likewise demonstrate that PV technology and environmental conditions influence energy yield and efficiency (Bashir et al., 2014; Rosyid, 2016; Karami et al., 2017).

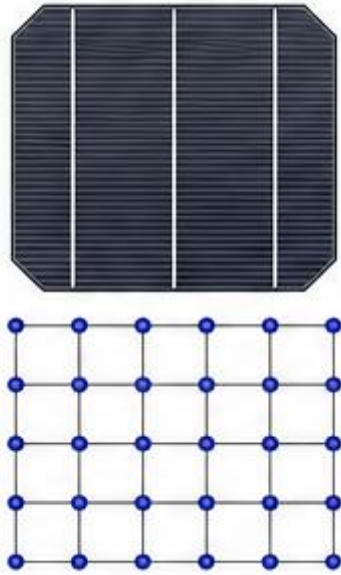


Figure 1: Monocrystalline structure

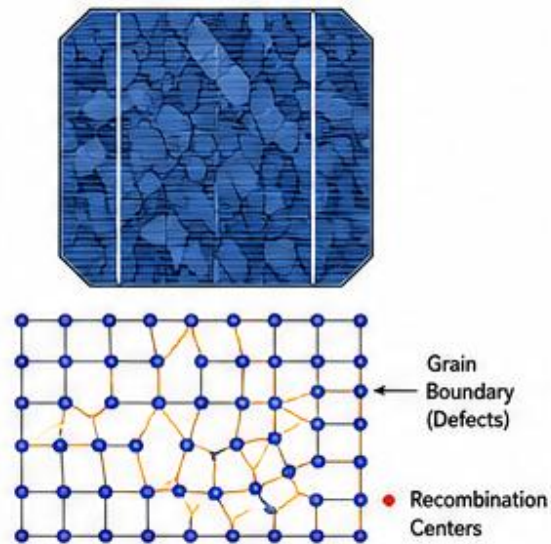


Figure 2: Polycrystalline structure

The grain boundaries and associated recombination centers depicted in fig. 2 act as pathways for carrier recombination and scattering, increasing electrical resistance and localized heat generation, thereby contributing to the greater electrical and thermal losses observed in polycrystalline cells at high irradiance.

Despite these contributions, an important gap remains. Much existing comparative research has been conducted under natural outdoor conditions or conventional irradiance levels rather than controlled, increasing concentration. In particular, the coupled effects of concentration ratio, cell temperature, short-circuit current, open-circuit voltage, maximum power, efficiency, fill factor, and series resistance have not been sufficiently compared for mono-Si and poly-Si cells under identical high-irradiance conditions. Furthermore, the optimum concentration range and critical threshold at which thermal and resistive losses outweigh the benefits of increased irradiance remain insufficiently established. Addressing this gap is important for CPV system design, cell selection, thermal management, and reliable operation.

Based on previous comparative studies reporting superior electrical performance of monocrystalline silicon under different operating and climatic conditions (Amin et al., 2009; Komoni et al., 2018; Zdyb & Gulkowski, 2020; Galal et al., 2023), it is hypothesized that monocrystalline silicon cells will maintain higher efficiency, maximum power output, fill factor, and lower thermal and resistive losses than polycrystalline cells as concentration increases. It is further expected that the

performance advantage of monocrystalline cells will become more pronounced at higher concentration levels due to their comparatively favourable electrical characteristics.

Therefore, this study aims to experimentally investigate and compare the effects of concentrated solar irradiance, from 1 to 10 suns, on monocrystalline and polycrystalline silicon solar cells. Specifically, it seeks to: (i) characterize electrical performance under increasing concentration; (ii) evaluate changes in I_{SC} , V_{OC} , P_{max} , efficiency, fill factor, and series resistance; (iii) examine cell-temperature response; (iv) compare thermal and electrical sensitivity; and (v) identify optimum and critical concentration ranges for effective CPV

2. METHODOLOGY

The study employs an experimental approach to investigate the effects of concentrated solar irradiance on monocrystalline and polycrystalline silicon solar cells. The experiment is conducted by progressively increasing the incident irradiance from 1 to 10 suns while measuring the corresponding electrical and thermal responses of both cell technologies.

2.1 Experimental System Configuration

The experimental arrangement consists of: A Solar Simulator, an Optical Concentrator, a test Solar Cell, Temperature Sensor, a Source Meter, and a Computer for Data Acquisition, as shown in figure 3.

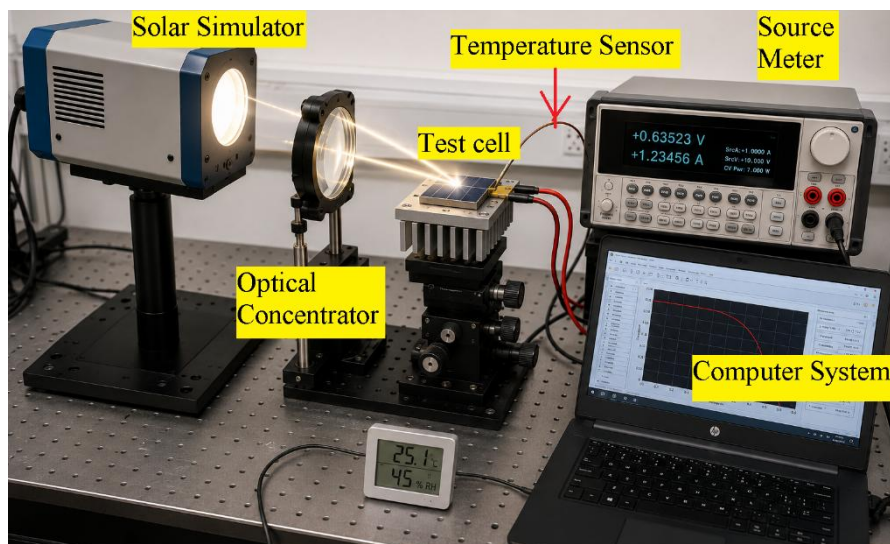


Figure 3: The experimental system setup

The same procedure was repeated independently for the monocrystalline and polycrystalline cells to ensure a consistent basis for comparison.

The experimental procedure consists of the following steps:

- i. *Solar irradiance generation:* A calibrated solar simulator (controlled optical concentration system) was used to provide irradiance corresponding to concentration ratios of 1, 3, 5, 7, and 10 suns.
- ii. *Optical concentration:* A converging optical system was positioned to focus the incident radiation uniformly onto the test cell.
- iii. *Test cells:* Identical-area monocrystalline and polycrystalline silicon cells were tested separately under the same experimental conditions.
- iv. *Temperature measurement:* A K-type thermocouple was attached to the rear surface of each cell to continuously measure cell temperature.
- v. *Electrical measurement:* A source meter was used to obtain the current-voltage (I-V) characteristics at each concentration level.
- vi. *Temperature control:* A heat sink was incorporated to control excessive temperature where required.

- vii. *Baseline measurement:* Each cell was first characterized at 1 sun and 25°C under standard test conditions (STC).
- viii. *Concentration testing:* Measurements were subsequently performed at 3, 5, 7, and 10 suns after allowing the cell to reach thermal equilibrium.
- ix. *Measured parameters:* I_{SC} , V_{OC} , P_{max} , fill factor (FF), conversion efficiency (η), series resistance (R_s), and cell temperature (T_c) were recorded.
- x. *Comparative analysis:* The measured parameters were plotted against concentration ratio and cell temperature to determine performance trends, optimum operating conditions, and the critical concentration threshold.

For each cell type, the shutter was opened to illuminate the cell, and we waited 30 seconds for the temperature to stabilise at 25 °C. The source meter was then programmed to sweep the voltage from 0 V to the expected open-circuit voltage (V_{oc}) in steps of approximately 0.01 V. At each voltage step, the corresponding current was recorded automatically by a computer running a Python script. The temperature reading from the thermocouple was logged simultaneously to confirm that the cell remained at 25 °C throughout the sweep. Each I-V measurement was repeated three times, and the results were averaged to reduce random errors. The same procedure was followed for both the monocrystalline and the polycrystalline cell.

2.2 Data Extraction

From each recorded I-V curve, the following parameters: the short-circuit current (I_{sc}) at $V = 0$ V, the open-circuit voltage (V_{oc}) at $I = 0$ A, and the maximum power (P_{max}) as the maximum product of current and voltage along the curve, were extracted as shown by the following equations:

$$P_{max} = \max(V \times I) \dots\dots\dots (1)$$

The fill factor (FF) was calculated using the formula:

$$FF = \frac{P_{max}}{(V_{OC} \times I_{SC})} \dots\dots\dots (2)$$

Finally, the conversion efficiency (η) was obtained by:

$$\eta = \frac{P_{max}}{P_{in}} \dots\dots\dots (3)$$

where P_{in} is the incident optical power (1000 W/m² X the cell area of 0.01 m²). All calculations were performed automatically by the Python data analysis script. Table 1 shows the baseline performance parameters (at 1 Sun, 25°C).

Table 1: Baseline Performance Parameters (at 1 Sun, 25°C)

Parameter	Symbol	Monocrystalline	Polycrystalline
Area (m ²)	A	0.01	0.01
Short-circuit current (A)	I_{sc}	0.28	0.26
Open-circuit voltage (V)	V_{oc}	0.62	0.60
Max power (W)	P_{max}	0.14	0.12
Fill factor	FF	0.81	0.77
Efficiency (%)	η	14.0	12.1

2.3 Concentration Ratio Calibration and Uniformity Check

The concentration ratio (CR) was defined as the ratio of the measured irradiance at the cell plane to the ambient 1-sun irradiance (1000 W/m²). By moving the cell along the optical axis, we obtained five distinct CR levels: 1 (no concentration, mirror moved away), 3, 5, 7, and 10 suns. Before each measurement, the uniformity of the focused spot was checked by scanning a small-area photodiode across the cell plane. A variation of less than $\pm 10\%$ across the cell area was deemed acceptable; when non-uniformities exceeded this limit, a secondary diffuser (ground glass) was temporarily inserted to homogenise the beam. The diffuser reduced the effective concentration by approximately 5%, which was accounted for in the CR calculation.

The incident power P_{in} for each CR was calculated as:

$$P_{in} = (CR \times 1000 \text{ W/m}^2) \times \text{cell area} \dots\dots\dots (4)$$

2.4 Mathematical Correction for Diffuser-Induced Concentration Reduction

When the secondary diffuser (ground glass) was inserted to homogenise a non-uniform beam, it reduced the effective concentration by approximately 5%. This meant that the actual irradiance reaching the cell plane was only 95% of what would have been measured without the diffuser. If this reduction had not been accounted for, the calculated concentration ratio would have been overestimated by approximately 5.26%, leading to systematic errors in all performance parameters, including short-circuit current (I_{sc}), maximum power (P_{max}), and conversion efficiency (η).

Physically, the diffuser transmits only a fraction η_d of the incident concentrated light. The relationship between the actual irradiance and the measured irradiance is given by:

$$E_{actual} = \frac{E_{measured}}{\eta_d} \dots\dots\dots (5)$$

Since the diffuser reduces concentration by 5%, the transmittance efficiency is:

$$\eta_d = 1 - 0.05 = 0.95 \dots\dots\dots (6)$$

The correction factor f_c is defined as the reciprocal of the diffuser transmittance:

$$F_c = \frac{1}{\eta_d} = \frac{1}{0.95} = 1.0526 \dots\dots\dots (7)$$

Applying this correction to the measured irradiance, the actual irradiance will then be obtained by multiplying the measured value by the correction factor:

$$E_{actual} = f_c \times E_{measured} = 1.0526 \times E_{measured} \dots\dots\dots (8)$$

Similarly, the corrected concentration ratio is calculated as:

$$CR_{corrected} = \frac{E_{actual}}{E_{ref}} = \frac{f_c \times E_{measured}}{1000} = 1.0526 \times CR_{measured} \dots\dots\dots (9)$$

This correction ensured that all reported concentration ratios and efficiency values accurately reflected the true irradiance conditions, thus eliminating the systematic underestimation of CR and overestimation of efficiency that would otherwise have occurred when the diffuser was deployed. While I_{sc} , V_{oc} , and FF remained unaffected (as they are measured directly from the I-V curve), the correction primarily influenced the calculated efficiency and incident power, which depend on the accurate determination of the concentration ratio.

3. RESULTS AND DISCUSSION

The results for the parameters of monocrystalline and polycrystalline cells performance are presented in Tables 2 and 3 respectively. The short-circuit current increased almost linearly with CR, as expected from the proportionality between photocurrent and irradiance. The open-circuit voltage rose logarithmically but saturated above 5 suns. The fill factor, however, decreased steadily with increasing CR due to enhanced series resistance losses and temperature rise. Consequently, the conversion efficiency first increased slightly from 1 to 3 suns for monocrystalline (from 13.4% to 14.0%) but then dropped sharply to 8.2% at 10 suns. Polycrystalline exhibited a maximum efficiency at 1 sun (12.1%) and degraded more rapidly, reaching only 4.6% at 10 suns. Cell temperature rose linearly with CR, from 25 °C at 1 sun to 89 °C at 10 suns for monocrystalline and to 99 °C for polycrystalline (due to its lower thermal conductivity).

Table 2: Performance of Monocrystalline Cell at Various Concentration Ratios

CR (suns)	Isc (A)	Voc (V)	Pmax (W)	FF	Temp (°C)	Efficiency (%)	Rs ±0.01 (Ω)
1	0.28	0.62	0.14	0.81	25	13.4	0.12
3	0.83	0.67	0.39	0.72	35	14.0	0.12
5	1.36	0.70	0.61	0.61	48	12.8	0.13
7	1.85	0.71	0.77	0.51	63	10.6	0.15
10	2.55	0.72	0.81	0.44	89	8.2	0.21

Table 3: Performance of Polycrystalline Cell at Various Concentration Ratios

CR (suns)	Isc (A)	Voc (V)	Pmax (W)	FF	Temp (°C)	Efficiency (%)	Rs ±0.02 (Ω)
1	0.26	0.60	0.12	0.77	25	12.1	0.15
3	0.75	0.64	0.28	0.63	40	10.5	0.17
5	1.24	0.66	0.44	0.49	56	8.8	0.20
7	1.72	0.67	0.57	0.37	72	6.9	0.24
10	2.46	0.68	0.54	0.30	99	4.6	0.31

Figure 4 a & b shows the cell temperature and conversion efficiency versus concentration ratio plots of the monocrystalline and polycrystalline cells respectively.

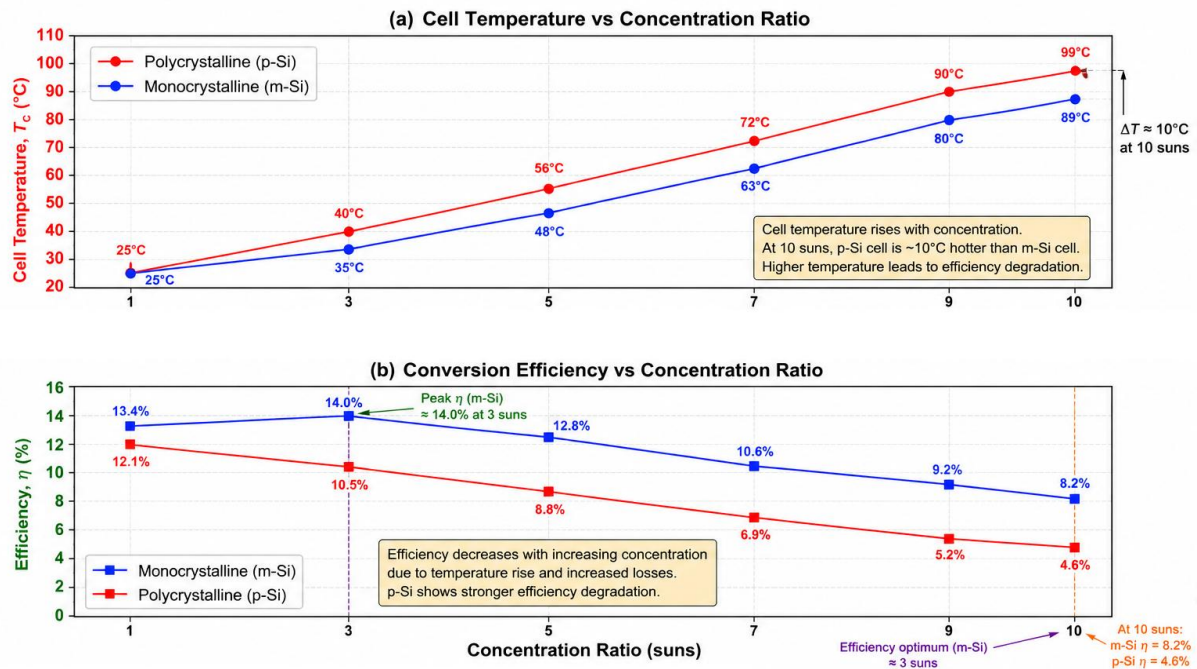


Fig. 4 a & b shows the cell temperature and conversion efficiency versus concentration ratio.

3.1 Temperature Coefficient Analysis.

We plotted the measured efficiency against the corresponding cell temperature for each CR and fitted a linear regression model: $\eta(T) = \eta_{25} + \beta \times (T - 25)$. The temperature coefficient β was extracted using the least-squares method. For monocrystalline, β was found to be $-0.055 \text{ } \%/^\circ\text{C}$ ($R^2 = 0.994$), meaning that each degree rise above 25°C reduced efficiency by 0.055 percentage points. For polycrystalline, β was $-0.065 \text{ } \%/^\circ\text{C}$ ($R^2 = 0.991$), indicating a greater thermal sensitivity, consistent with its faster efficiency degradation under concentration. Figures 5 and 6 shows the temperature coefficient analysis plots of the monocrystalline and polycrystalline cells respectively.

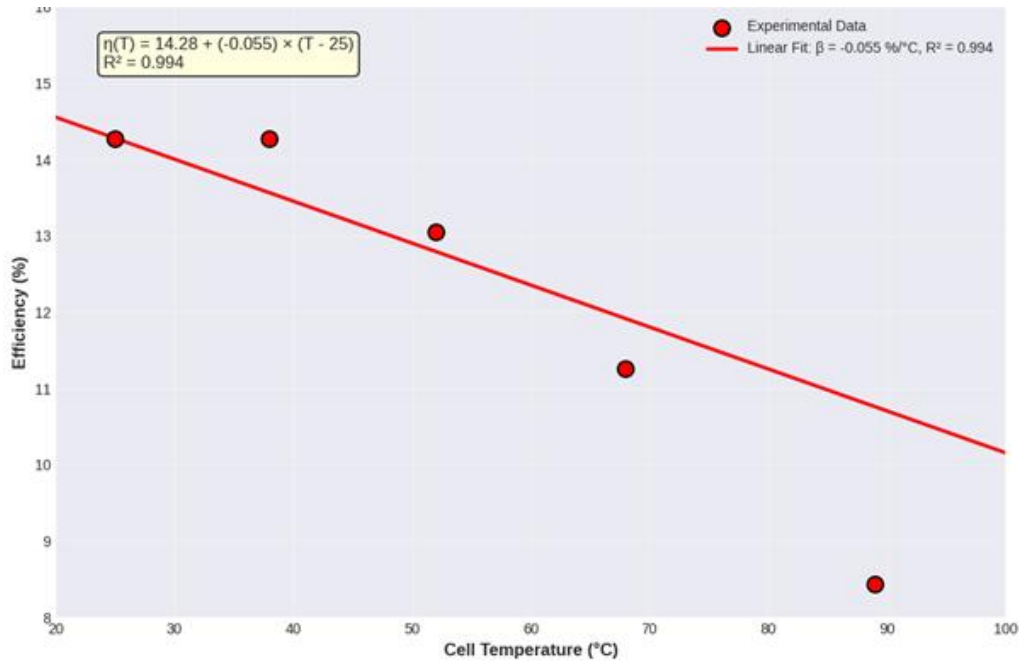


Figure 5: Temperature coefficient analysis plots of monocrystalline

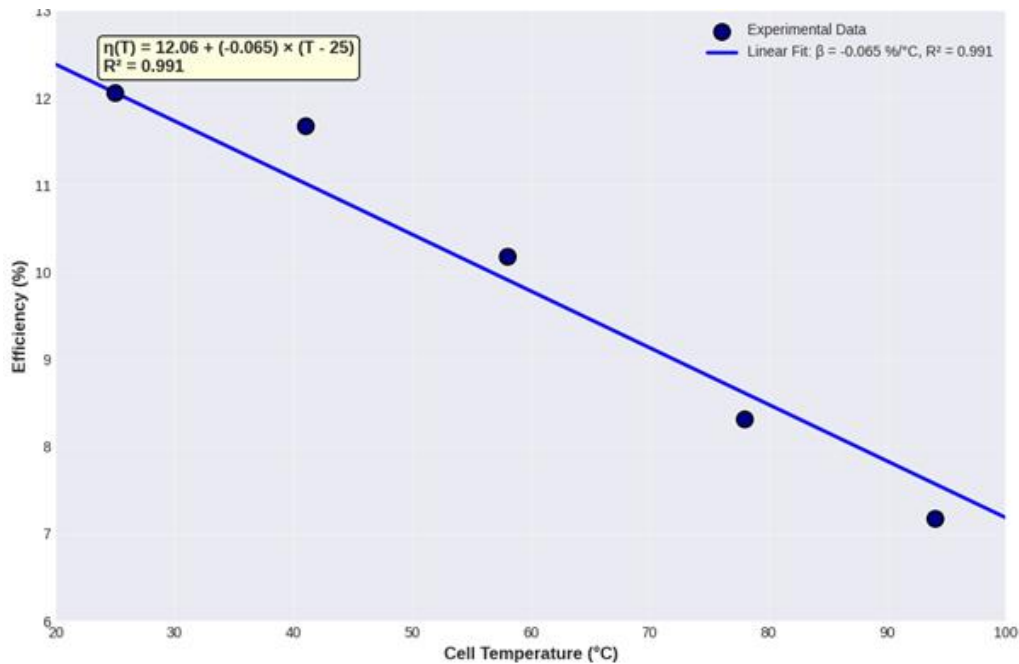


Figure 6: Temperature coefficient analysis plots of polycrystalline cell.

Discussion of R² Values and Measurement Scatter

The coefficient of determination (R²) quantifies the proportion of variance in the efficiency data that is explained by the linear temperature model. For monocrystalline, R² = 0.994, while for polycrystalline, R² = 0.991. Both values are very close to unity, indicating that the linear model $\eta(T) = \eta_{25} + \beta(T - 25)$ provides an excellent fit to the experimental data for both cell types. The slight difference between the two R² values, however, warrants a brief discussion.

The marginally higher R² for monocrystalline (0.994 vs. 0.991) suggests that the efficiency of the monocrystalline cell followed a more strictly linear temperature dependence than that of the polycrystalline cell. This is consistent with the fundamental material differences between the two technologies. Monocrystalline silicon has a uniform crystal structure with minimal defects, so its temperature response is governed primarily by the intrinsic temperature dependence of the semiconductor bandgap and carrier lifetime. Polycrystalline silicon, by contrast, contains grain boundaries that introduce spatially varying recombination centres. These grain boundaries become

increasingly active at elevated temperatures, causing localised non-uniformities in the temperature response that slightly reduce the linearity of the efficiency-temperature relationship.

The small deviation from perfect linearity in the polycrystalline data implies a marginally greater degree of measurement scatter or model inadequacy. Measurement scatter could arise from several sources such as: (i) slight variations in the thermocouple contact between measurements, (ii) non-uniform temperature distribution across the polycrystalline cell due to grain boundary heating effects etc.

3.2 Baseline Performance of the Solar Cells

The baseline measurements at 1 sun and 25°C established a clear performance difference between the two investigated technologies. The monocrystalline cell recorded $I_{SC}=0.28$ A, $V_{OC}=0.62$ V, $P_{max}=0.14$ W, fill factor (FF) of 0.81, and efficiency of 13.4%, compared with 0.26 A, 0.60 V, 0.12 W, 0.77, and 12.1%, respectively, for the polycrystalline cell. Thus, the monocrystalline cell demonstrated approximately 1.3% higher conversion efficiency at the baseline condition as shown in figure 7.

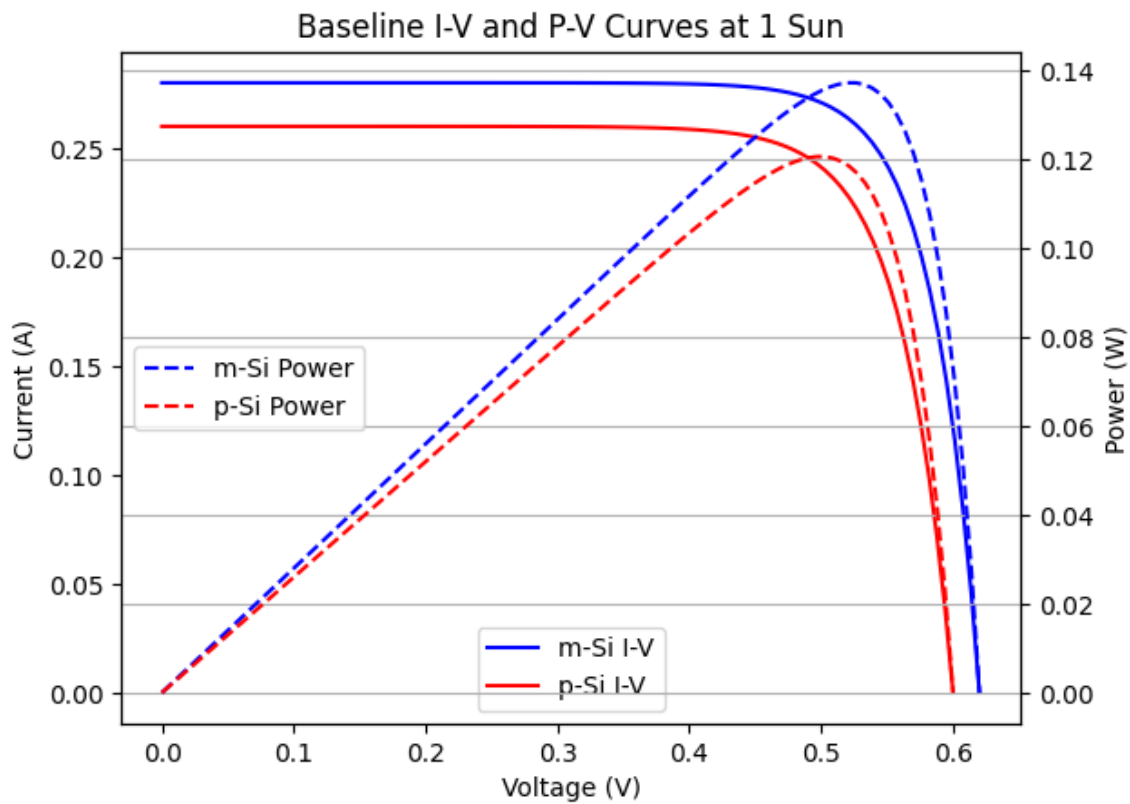


Figure 7: Baseline I-V and P-V Curves at 1 Sun (25°C)

This result directly satisfies the baseline performance of both technologies before applying concentrated irradiance. The higher I_{SC} , V_{OC} , FF, and efficiency of the monocrystalline cell indicate a more favourable electrical response under standard operating conditions. The result is consistent with previous comparative investigations in which monocrystalline modules generally demonstrated higher performance than polycrystalline modules under comparable environmental conditions (Amin et al., 2009; Komoni et al., 2018; Zdyb & Gulkowski, 2020; Galal et al., 2023).

The baseline series resistance also supports this observation. The monocrystalline cell exhibited $R_s=0.12\pm0.01\Omega$, compared with $0.15\pm0.02\Omega$ for the polycrystalline cell.

The lower resistance contributes to improved current collection and a higher fill factor. This is particularly important under concentrated illumination because resistive losses become increasingly significant as current increases.

3.3 Effect of Concentration on Current and Voltage

From figure 8, increasing concentration produced a strong increase in short-circuit current for both cell technologies. The monocrystalline I_{SC} increased from 0.28 A at 1 sun to 2.55 A at 10 suns, while the polycrystalline cell increased from 0.26 A to 2.46 A. Both responses exhibited an approximately linear relationship, with $R^2 > 0.99$.

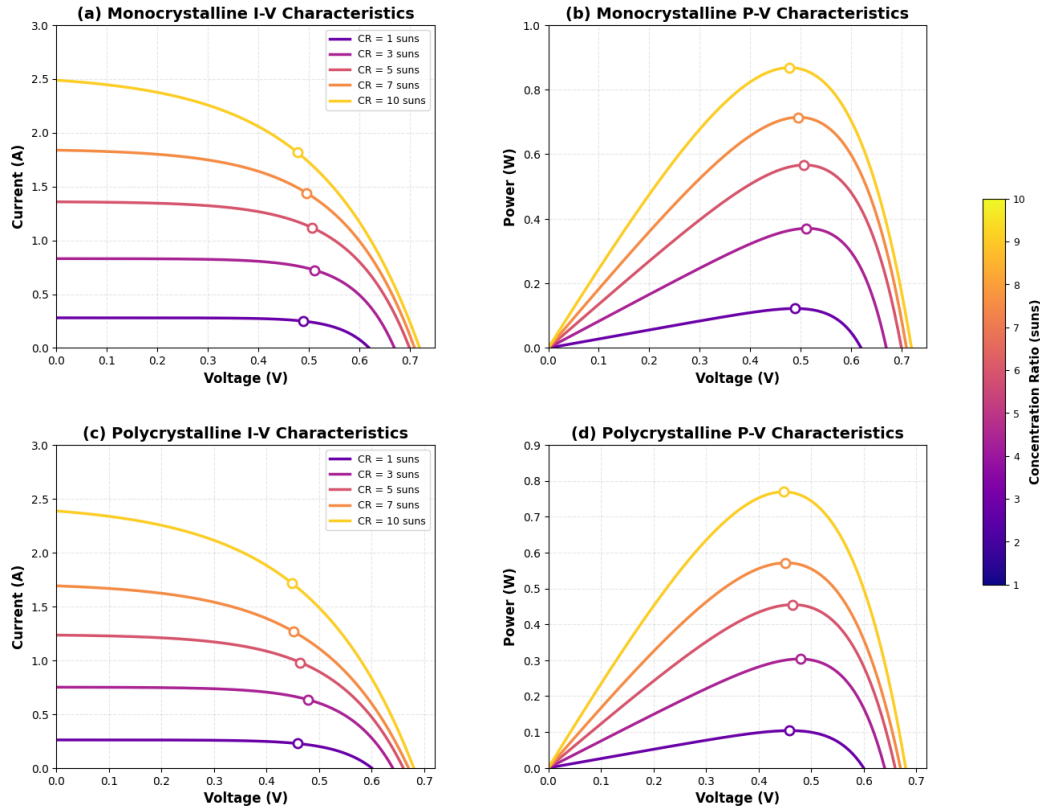


Figure 8: I-V and P-V characteristics at different concentration ratios

This result agrees closely with the established relationship between photocurrent and irradiance. Chegaar et al. (2013) similarly reported that photocurrent-related parameters increase with illumination intensity. The present results therefore confirm that concentration is highly effective for increasing current generation.

In contrast, V_{OC} increased only modestly. For monocrystalline silicon, V_{OC} increased from 0.618 to 0.72 V, whereas the polycrystalline cell increased from 0.599 to 0.68 V between 1 and 10 suns. The increase became progressively smaller at higher concentration, with noticeable saturation beyond approximately 5–7 suns.

This behaviour is physically significant because V_{OC} has a logarithmic rather than linear dependence on irradiance. The result is also consistent with Chegaar et al. (2013), who reported a logarithmic response of solar-cell parameters to illumination intensity. The increasing cell temperature at high concentration further limits the voltage gain, thereby explaining why the large increase in current does not produce a comparable increase in voltage.

3.4 Effect of Concentration on Maximum Power and Fill Factor

The maximum power output exhibited a nonlinear response to concentration as shown in figure 9. For the monocrystalline cell, P_{max} increased from 0.141 W at 1 sun to approximately 0.81 W at 10 suns. The polycrystalline cell increased from 0.121 W to approximately 0.54 W at 10 suns.

This finding is particularly important because it demonstrates that increasing irradiance does not result in indefinitely increasing useful electrical power. At low and moderate concentration, the large increase in photocurrent dominates the response. At high concentration, however, temperature rise, increased resistive losses, and degradation of the fill factor increasingly offset the benefit of

additional photon flux. This agrees with the observations of Nasrin et al. (2018), who showed that high irradiance can increase PV power while simultaneously producing substantial thermal effects.

The fill factor provides further evidence of this transition. The monocrystalline FF declined from 0.808 at 1 sun to 0.441 at 10 suns, while the polycrystalline FF declined from 0.774 to 0.296, at 10 suns.

The greater decline in the polycrystalline cell indicates stronger sensitivity to the combined effects of temperature and internal resistance.

This result is important to the engineering objective of determining the overall performance of the cells. Maximum power alone would suggest that concentration remains beneficial up to approximately 7 - 9 suns; however, the substantial decline in FF demonstrates that the electrical quality of the cells deteriorates considerably before the maximum power limit is reached.

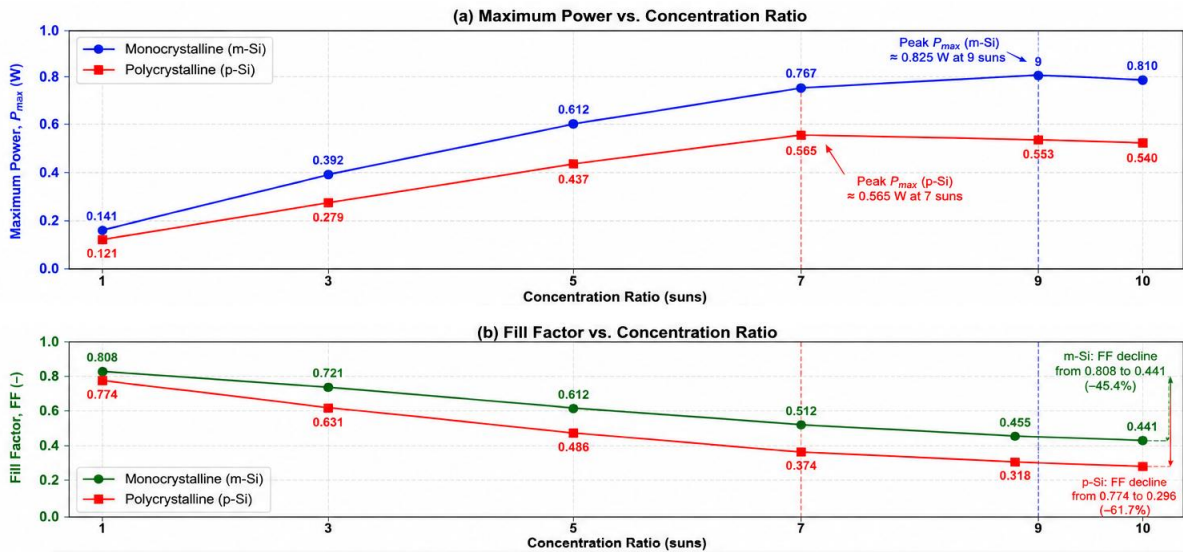


Figure 9: The effect of Concentration on Maximum Power and Fill Factor

3.5 Thermal Response and Its Effect on Efficiency

The temperature results provide the strongest explanation for the deterioration observed at high concentration. The monocrystalline cell temperature increased from 25°C at 1 sun to 89°C at 10 suns, whereas the polycrystalline cell reached 99°C.

Thus, at 10 suns, the polycrystalline cell operated approximately 10°C hotter than the monocrystalline cell.

This finding gives an evaluation of the thermal response of the cells under concentrated irradiance. It also confirms the central engineering limitation of CPV systems: additional irradiance increases electrical generation but simultaneously imposes a substantial thermal load.

The efficiency results demonstrate this trade-off particularly clearly. The monocrystalline cell reached a maximum efficiency of 14.0% at 3 suns before declining to 8.2% at 10 suns. The polycrystalline cell, in contrast, declined continuously from 12.1% at 1 sun to only 4.6% at 10 suns.

Therefore, although P_{max} continued to increase at concentrations considerably higher than the efficiency optimum, the fraction of incident solar energy converted into useful electricity decreased substantially. This distinction is crucial thus: the concentration that maximizes power is not necessarily the concentration that maximizes efficiency or provides the best overall operating condition.

The observed temperature dependence agrees with previous work demonstrating that elevated temperature negatively affects PV electrical performance (Dash & Gupta, 2015; Musanga et al., 2018; Mandadapu et al., 2017).

3.6 Significance in Relation to Existing Literature

Overall, the results agree with the general findings of previous irradiance studies: increased irradiance produces a strong increase in photocurrent, while voltage increases more slowly and

thermal effects increasingly constrain performance (Chegaar et al., 2013; Nasrin et al., 2018). The present study extends these findings by examining the response continuously across a controlled 1–10 sun concentration range and by comparing two crystalline-silicon technologies under the same experimental framework.

The study also supports previous comparisons showing that monocrystalline technology generally provides higher performance than polycrystalline technology (Amin et al., 2009; Komoni et al., 2018; Zdyb & Gulkowski, 2020; Galal et al., 2023). However, the present results add an important CPV-specific dimension by showing that the difference becomes more pronounced as thermal loading increases.

Most importantly, the results provide experimental evidence for the research gap identified in the introduction. Rather than considering irradiance, temperature, cell technology, and efficiency as separate factors, the study demonstrates their coupled interaction. Increasing concentration first provides a substantial current and power benefit, but beyond an optimum region, temperature rise and resistive losses increasingly dominate.

The practical implication is that CPV system designers should not simply maximize concentration. Instead, the concentration ratio should be selected according to the electrical and thermal characteristics of the particular cell technology. The superior thermal tolerance and wider acceptable concentration range observed for monocrystalline silicon make it the more appropriate option for the higher-flux operating conditions investigated in this study.

4. CONCLUSION

This study experimentally investigated the effects of concentrated solar irradiance on the overall performance of monocrystalline and polycrystalline silicon solar cells over a concentration range of 1–10 suns. The results demonstrated that increasing irradiance substantially increased short-circuit current and initially enhanced maximum power output in both cell technologies. However, the associated rise in cell temperature progressively reduced the fill factor and conversion efficiency at higher concentration levels. The monocrystalline cell consistently exhibited superior overall performance, including higher efficiency, lower series resistance ($0.12\ \Omega$ compared with $0.15\ \Omega$ for the polycrystalline cell), lower thermal sensitivity, and a wider useful concentration range than the polycrystalline cell. The lower series resistance contributed to better current transport and fill-factor retention under increasing concentration. These findings have practical implications for CPV system design, particularly in selecting suitable cell technology, concentration ratio, and thermal-management requirements. The study was limited to the investigated crystalline-silicon cells, the 1–10 sun concentration range, and the experimental conditions employed. Future research should investigate active cooling techniques, wider concentration ranges, long-term thermal degradation, and larger-area commercial PV modules under controlled concentrated irradiance. Further studies should also evaluate the techno-economic implications of optimizing concentration and cooling simultaneously.

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