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Title: Soiling of Photovoltaic Modules: Impact on Performance and Mitigation Strategies

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PRESENTATION CONTENT

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INTRODUCTION

Photovoltaic solar energy has diverse applications, with innovations like flexible or translucent cells. It is used in various settings, from small devices to large buildings, and is especially useful in areas without access to the electrical grid. Systems are divided into off-grid and grid-connected, with advantages such as low environmental impact, long lifespan, and modularity. However, it has disadvantages like high initial costs, the need for storage, and limited efficiency. Additionally, dirt accumulation on modules significantly reduces efficiency, prompting research on how to address this issue. Studies show that dirt can reduce module efficiency by up to 70%, highlighting the importance of regular panel cleaning and maintenance.

Fig.1 JaSolar modules of 410 W, dirty vs clean
[Own source]

INTRODUCTION

The performance of a photovoltaic module depends on the amount of sunlight it receives and its technological ability to harness it. Factors such as the season, time of day, geographical location, and ambient temperature affect its efficiency. Moreover, extreme environmental conditions like sandstorms, pollution, snow, hail, and intense UV radiation also impact its performance. The actual efficiency of modules often differs from the specified values due to local factors like shading, temperature, and irradiance at the installation site.

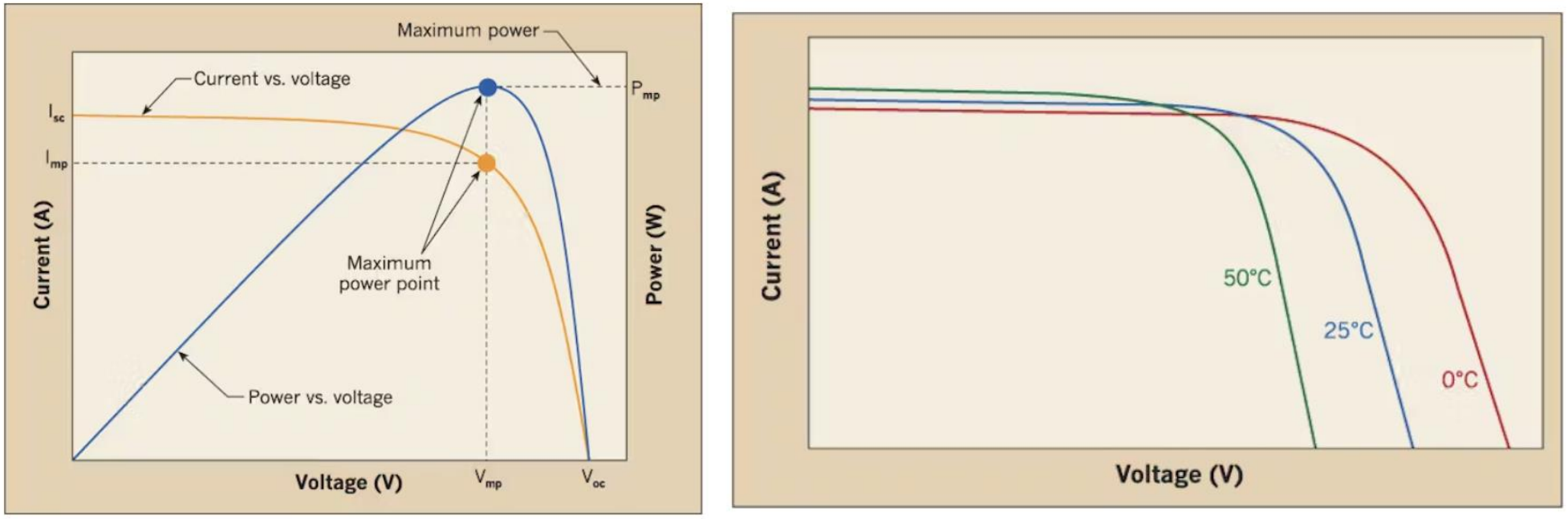

Fig. 2 The current-voltage curve of a PV module varies with sunlight intensity, with current changing significantly while voltage remains stable. Temperature also impacts the curve, mainly affecting voltage. [https://www.ecmweb.com/renewables/article/20896643/the-highs-and-lows-of-photovoltaic-system-calculations]

INTRODUCTION

Factors that influence the operation of a photovoltaic module.

Accumulated dust on solar panels affects their efficiency, and its adhesion depends on factors such as:

- Particle size,
- Panel orientation, and the surrounding environment.

Panels in arid regions experience greater dust buildup due to the lack of rain. This can reduce efficiency by up to 30%, impacting energy conversion and potentially causing long-term damage, such as hot spots. Additionally, dust accumulation increases the temperature of the cells, which can shorten their lifespan. Regular cleaning is essential, but both the cleaning process and dust buildup generate significant economic costs, with annual losses potentially exceeding $700,000.

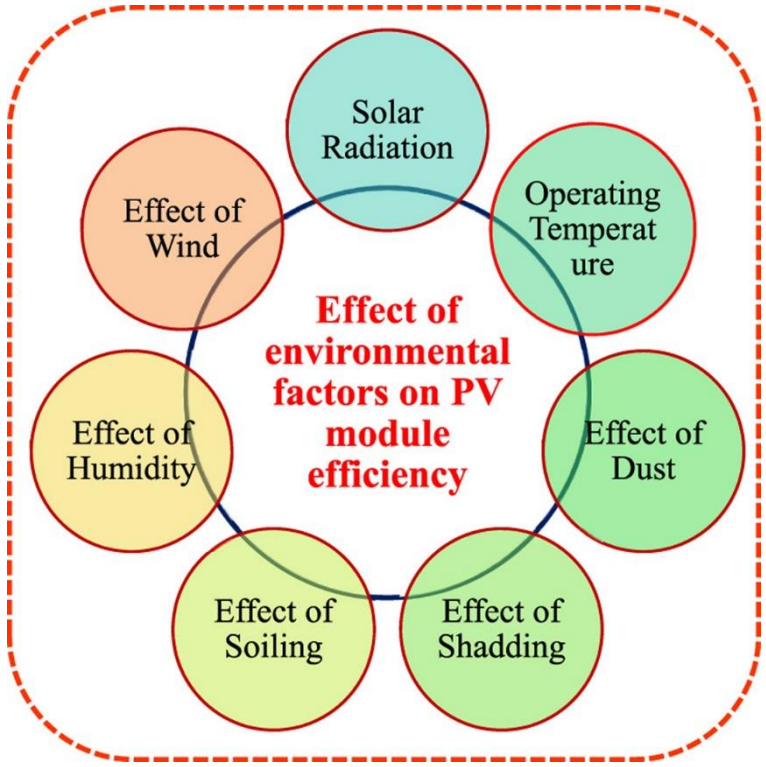

Fig. 5 Environmental factors influencing performance of photovoltaic panels (https://doi.org/10.1016/j.envpol.2023.121474)

INTRODUCTION

Cleaning photovoltaic modules is essential to ensure optimal performance. There are two main methods: dry cleaning and wet cleaning.

•**Dry cleaning** uses brushes or vibration without water, but it may not be as efficient and can cause surface damage due to friction.

•**Wet cleaning** uses water or aqueous solutions to remove dirt, and is more effective. However, it should be done outside peak solar radiation hours to prevent thermal stress that could damage the panels.

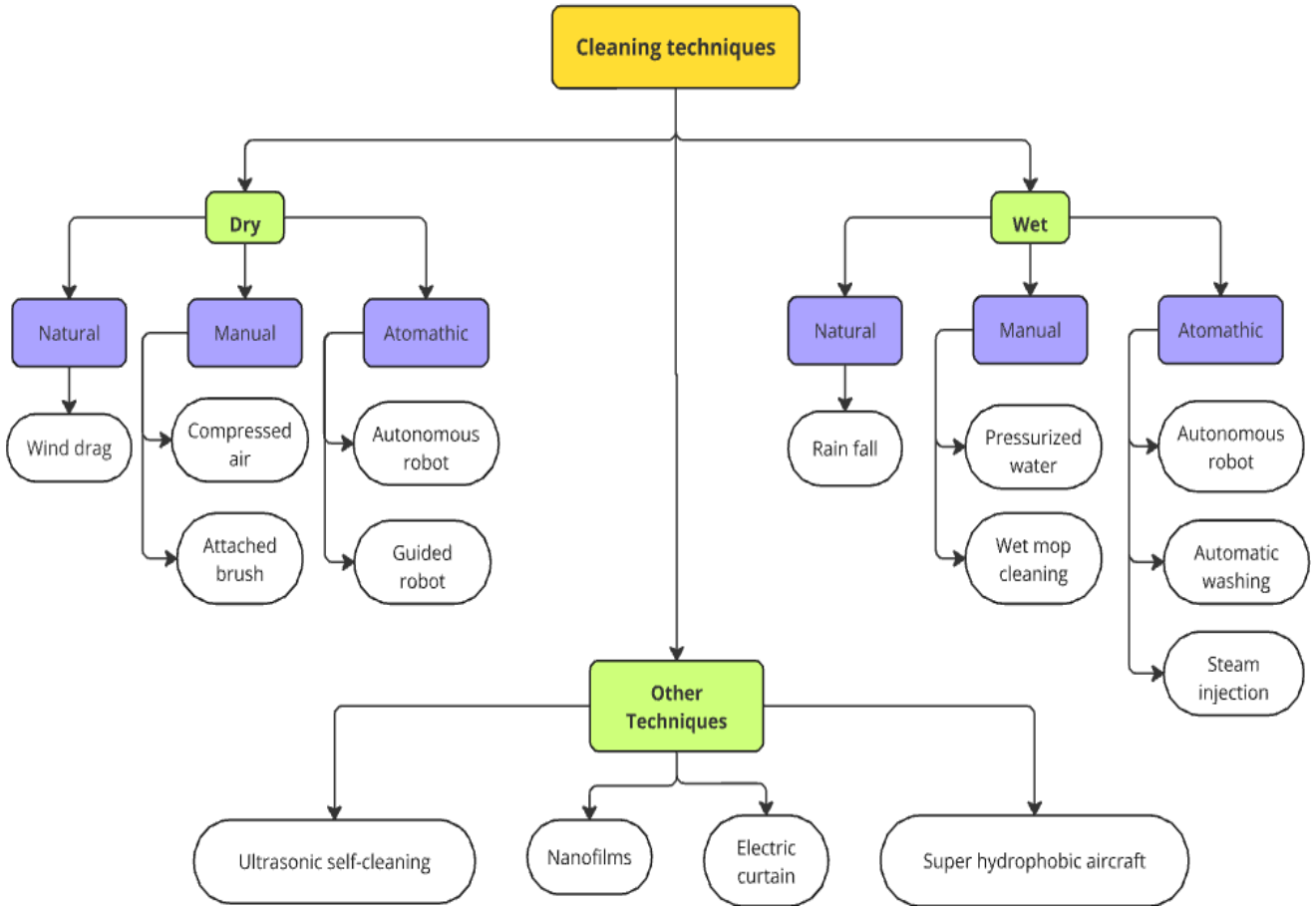

Fig. 4 Classification of cleaning techniques for photovoltaic modules. [Own source]

METHODOLOGY

To evaluate the effectiveness of the two types of cleaning, dry cleaning and wet cleaning, we experimented with the application of both cleanings on photovoltaic modules of the same technology. In the case of wet cleaning, an automatic washing prototype was used, while a cleaning prototype with nylon brush coupling was used to apply dry cleaning.

Fig. 5 Wet cleaning prototype [Own source]

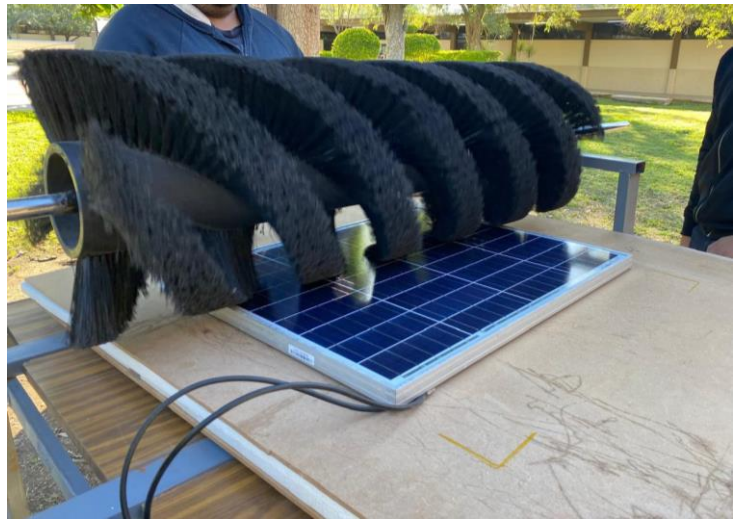

Fig. 6 Dry cleaning prototype [Own source]

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METHODOLOGY

For the analysis, 3 photovoltaic modules were used, one of which was kept clean, another was wet cleaning and another was piled dry cleaning. The application of cleanings was carried out repeatedly to obtain an average of the efficiency of each module subjected to cleaning, for this the modules were soiled and cleaned on multiple occasions using the corresponding prototypes and the values obtained were compared with the values generated by the module that was kept clean.

Fig. 7 Cleaning applied to photovoltaic modules with wet cleaning prototype.

Fig. 8 Cleaning applied to photovoltaic modules with dry cleaning prototype.

RESULTS

Regarding the comparison of the efficiency of the modules after being cleaned with the wet cleaning and dry cleaning prototypes

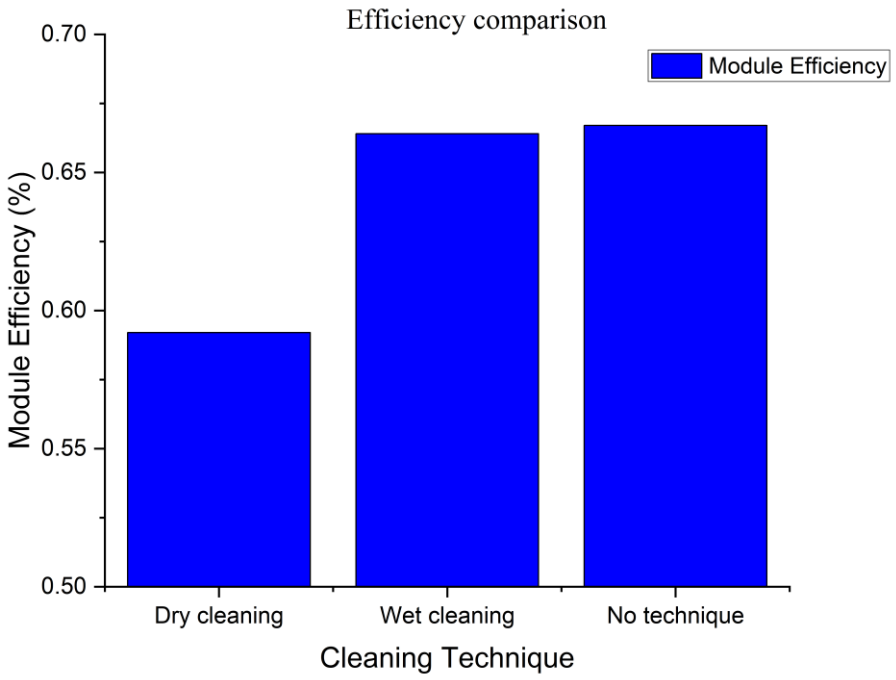

Fig. 9 PV module efficiency comparison using wet and dry cleaning.

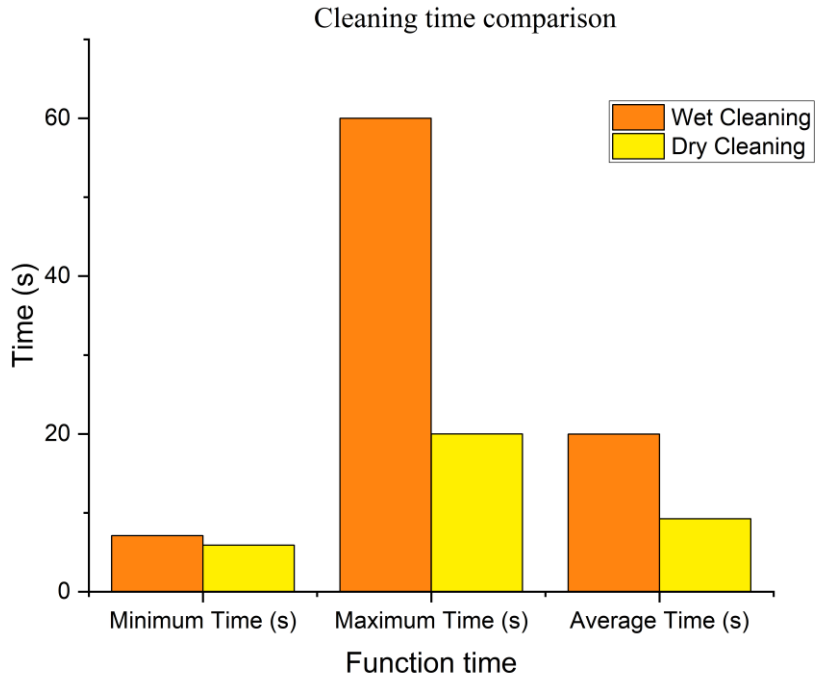

Fig. 10 Wet and dry cleaning application time comparison.

RESULTS

Regarding the comparison of the efficiency of the modules after being cleaned with the wet cleaning and dry cleaning prototypes

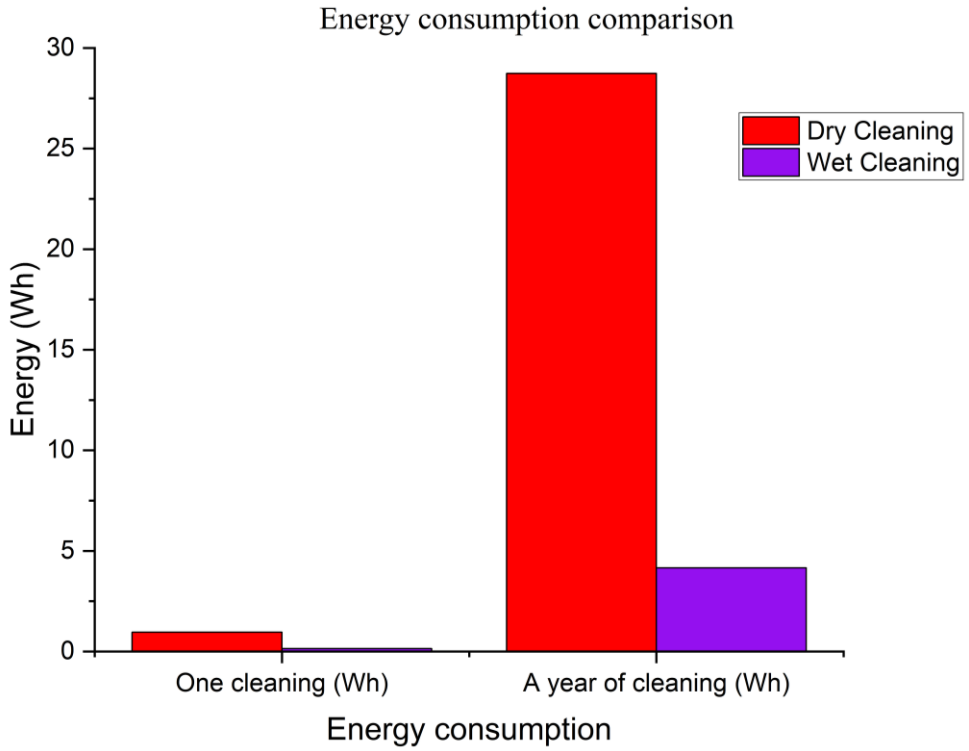

Fig. 11 Comparison of the energy consumed by wet and dry cleaning prototypes.

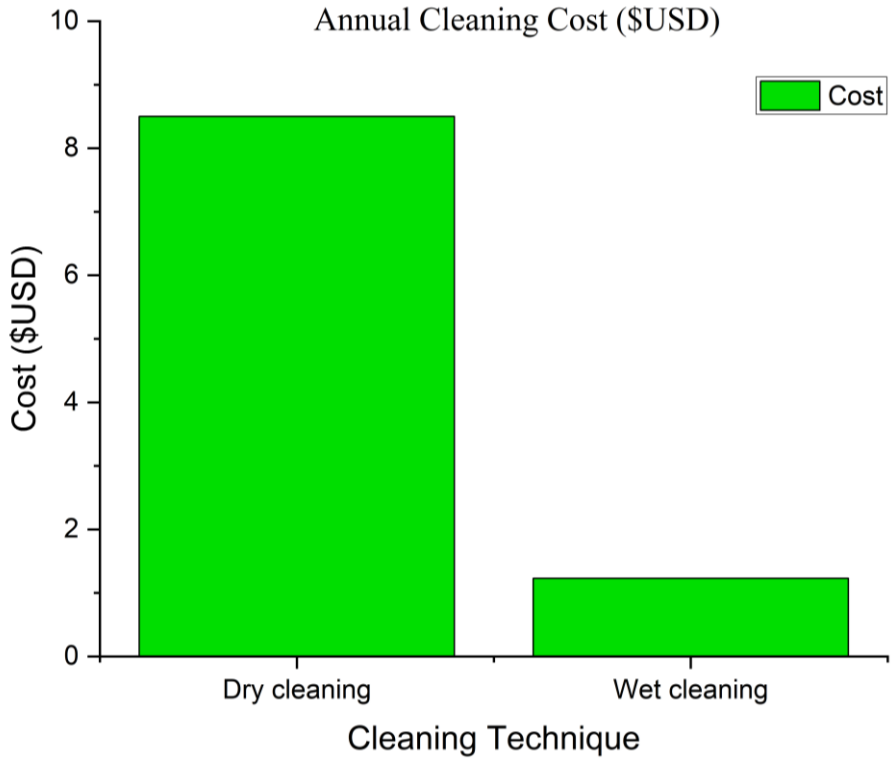

Fig. 12 Comparison of the cost for the use of wet and dry cleaning prototypes.

CONCLUSIONS

This study analyzed the negative impacts of soiling on photovoltaic modules and the cleaning techniques used to mitigate it. Two main methods were identified: dry cleaning and wet cleaning, which can be natural, manual, or automatic.

The experimental comparison showed that wet cleaning is more effective at maintaining module performance due to water's ability to remove dust particles. However, dry cleaning is faster but consumes more energy, making it more expensive, though it remains an excellent option in arid regions where water is scarce.

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