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Life span of Solar panels Review

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Abstract: **In today's world, as electricity consumption is increasing, people are more dependent on electricity. Solar Photovoltaic system is one method to generate electricity. The conversion efficiency of solar photovoltaic panel depends on atmospheric condition and reflection. The operating temperature of photovoltaic module plays an important role in performance of PV system as efficiency of PV system decreases when temperature module increases. The operating photovoltaic cells at high temperature degrades the material of it in long time.**

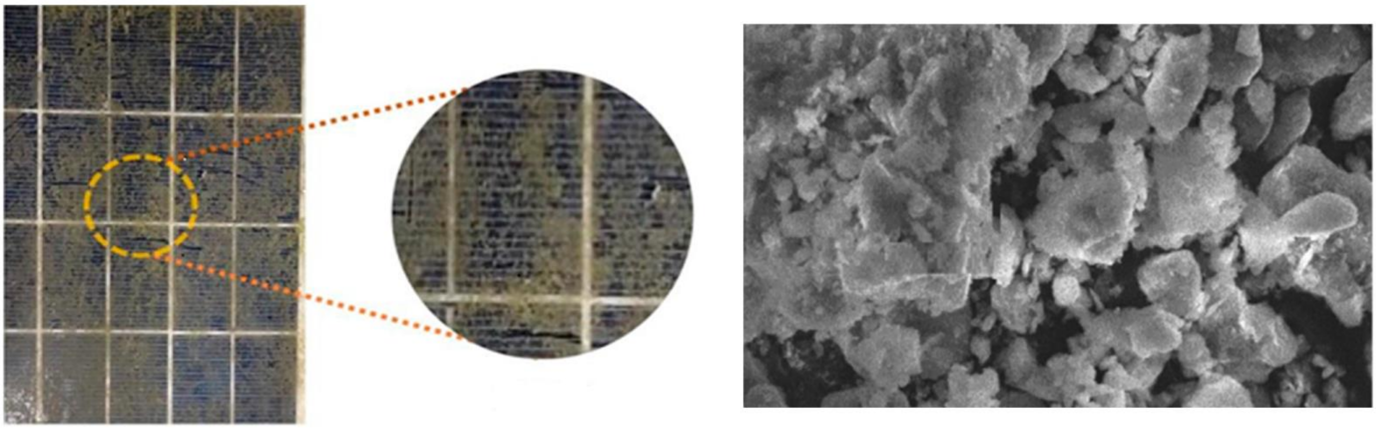
I. Introduction

Utilizing solar PV to generate energy is not a simple operation due to degradation, which can result in a reduction in solar PV performance and efficiency. According to recent studies, the rate of degradation varies between 0.6% and 0.7% per year. Photovoltaic (PV) degradation can be both linear and non-linear depending on the underlying mechanisms causing the degradation. Linear degradation occurs when the rate of degradation is constant over time, resulting in a gradual decrease in the performance of the PV module. Non-linear degradation occurs when the rate of degradation varies over time, resulting in an accelerated or decelerated decrease in performance. There are several factors that can contribute to the linear degradation of PV modules. One of the most significant factors is exposure to sunlight, which can cause the gradual breakdown of the materials used in the PV module. This breakdown can result in a 2.8% reduction in the performance ratio of the PV module, leading to a gradual decrease in performance over time. In general, solar PV has a 25-year expected lifespan. Solar PV modules will not survive for this long in the majority of cases. Aging is the term that is used to describe the degradation of a PV module before its expected lifespan. The factors that underlie the reduction in the lifetime of a PV module can be defined as aging factors. The roots of this degeneration are aging-related issues. Researchers and scientists from all around the world have discovered that one of the major causes of reduced life expectancy is aging. Aging factors are among those that significantly affect both performance and efficiency. Each aging factor has its own individual impact, but when combined, they significantly affect the lifespan of PV modules.

Major Aging Factors of Solar PV

1. Dust

Generally, dust is defined as small, solid particles with diameters of less than 500 mm. The particles are made up of dust in the air that originates from many environmental causes. The solar PV's output power decreases as a result of these airborne particles building up on its surface and causing shedding on the PV panel. However, the shape, size, and accumulation structure of dust may affect the shedding and its effect on both the lifetime and the efficiency of the PV module. The accumulation of dust particles on solar panels is shown in fig along with a microscopic image of these tiny particles. The significant influence that dust has on PV performance makes it one of the most critical issues confronting scientists and academics today.



(a) (b)

Six photovoltaic modules were exposed to the elements for 6 months in a study by Adinoyi about the effect of dust accumulation on the solar photovoltaic module's output power. The findings show that the output power of solar PV decreased by 50% with the accumulation of dust on a panel left uncleaned for 6 months. With time, this output decline became more pronounced, which caused the panel to permanently age. An experimental examination of the effects of dust deposition on solar PV was conducted by Aslan Gholami et al.. The experiment was conducted for 70 days without any precipitation, and the rate of dust buildup was 6.0986 (g/m^2). The results indicate a 21.47% reduction in output power. Dust can form on the surface of photovoltaic (PV) panels through various mechanisms, which depend on the location and environment in which the panels are installed. Natural processes such as wind erosion, volcanic eruptions, and forest fires can generate dust particles that can travel long distances and settle on the surfaces of PV panels. Human activities such as construction, mining, and transportation can generate large amounts of dust that can be carried by the wind and deposited on PV panels. Agricultural activities such as plowing, harvesting, and livestock grazing can also generate dust that can settle on the surfaces of PV panels. A sawtooth wave shape of dust accumulation is typically seen. Another investigation was performed by Ahmed Amine Hachicha et al. in the UAE climate, where it has been amply demonstrated that the tilt angle has a direct impact on the buildup of dust on the surface of the solar panel and that the dust density has a linear relationship with solar PV deterioration. A solar panel's effectiveness decreases over time when it is dirty, and this process gradually and permanently ages the panel. Another investigation was performed by Juaidi et al. in Palestine, where a grid-connected PV plant was exposed for 7 months to determine the impact of dust on the efficiency of the entire PV plant, and the results indicate that the average rate of power reduction was 2.93% per month, which clearly shows that dust significantly influenced the power reduction in a large-scale PV system as well. Kazem et al. evaluated the effect of aging on a grid-connected photovoltaic system by investigating a 1.4 KW PV plant exposed for 7 years; the results indicate that the efficiency of the PV modules decreased by 5.88%, and it is also notable that the degradation rate was severe during the summer months because of the dust density. The rate of PV degradation has a linear relationship with dust density. Frost formation on solar panels can have a significant impact on the general performance of the panels. When frost forms on the surface of a solar panel, it creates a layer that reduces the amount of sunlight that can be absorbed by the panel. This, in turn, reduces the output power of the panel. The reduction in output power can be as high as 25% in a month, depending on the thickness of the frost layer.

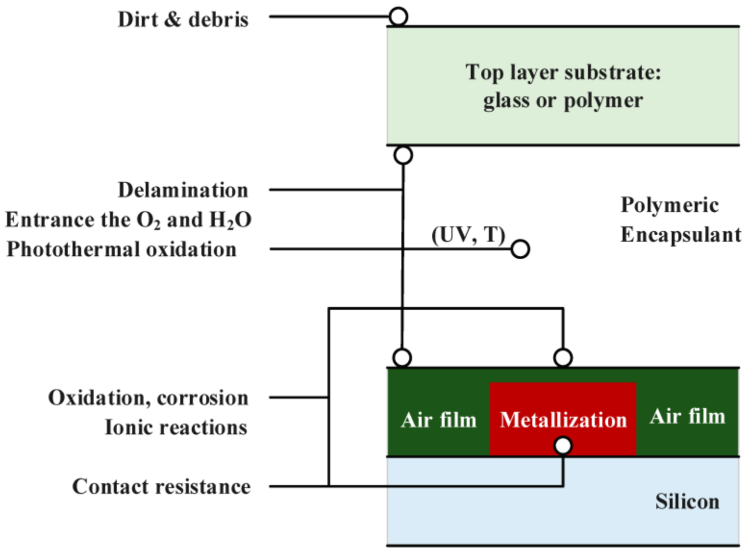
2. Temperature and Humidity

Kinetic energy is transferred from one thing to another through heat. Here, the heat comes from the sun, which is transferred to the PV panels and raises the temperature. Temperature is a measure used to describe how warm or cold something is. The environment's high temperature creates moisture or humidity, which is one of the main elements affecting how well the PV panels perform. With the installation time, this impact grows.

Vásquez et al. experimented with the processing of global climate data and the mapping of the mechanisms and rates of PV module degradation. The Köppen-Geiger-Photovoltaic (KGPV) climatic classification and the anticipated deterioration rates, according to Vásquez, have a direct association. The average rate of deterioration in Europe's hot temperate zones is around 0.5%. However, depending on the year, this figure might change. Additionally, this shows that climate change may influence the long-term effectiveness of PV systems. Another study was conducted by Dhimish et al. on the photovoltaic degradation rate affected by different weather conditions based on PV systems using the YOY (year-on-year) technique for more than 10 years (2008 to 2017) for six distinct photovoltaic (PV) sites in the UK, which is mostly influenced by cold weather conditions, and Australia, which is primarily affected by cold weather conditions. It was discovered that the UK sites' deterioration rates ranged from −1.05% to −1.16 %/year. However, because the temperature is lower than in Australia, a greater deterioration of between −1.35% and −1.46%/year was seen for the PV sites deployed there. Research on the effects of humidity on photovoltaic cell performance was presented by Hamdi et al.. Water has an impact on photovoltaic units when it comes into contact with the cellular elements of the cell, causing its efficiency to decrease and lowering its electrical productivity. The efficiency of solar cells was significantly reduced when they worked in challenging conditions, such as high temperatures and relative humidity of more than 70%. The effects of various environmental and operational parameters on PV performance were reviewed by Hasan et al.. According to their study, the PV module performance degrades with increasing module temperature. Without a cooling facility, the efficiency decreases by around 0.03% to 0.05% for every 1°C increase in temperature. They advise selecting materials carefully so that they can tolerate a humid environment since the corrosion of the PV panel is caused by moisture ingress in humid settings. Tripathi et al. evaluated the performance of solar PV panels in a humid environment. The findings of the experiment show that a rise in the humidity of 50.15% caused a reduction in solar radiation of 24.05% on the panel surface. Additionally, this investigation demonstrated that a rise of 50.15% in relative humidity caused a loss of 36.22% in the panel's output power. However, when the humidity increased from 65.40% to 98.20%, the temperature of the PV panel was lowered by 11.40%, indicating an increase in output power.

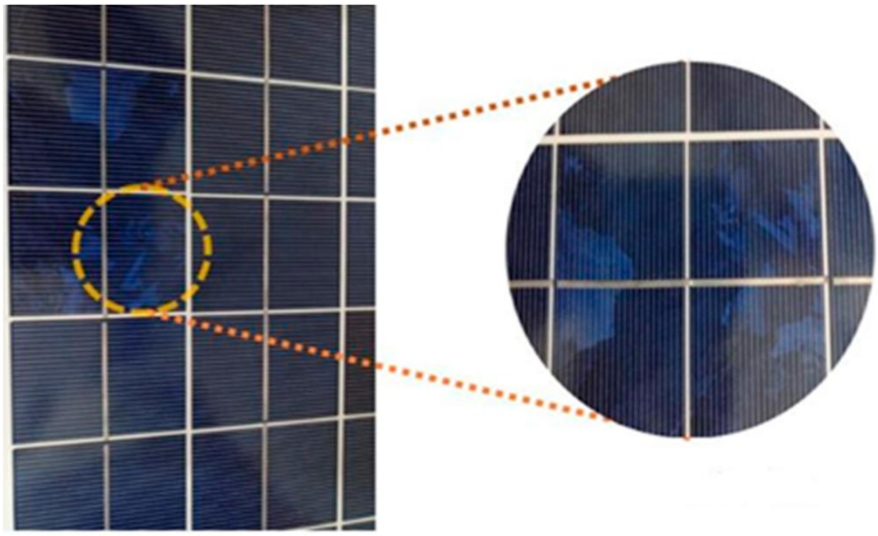
3. Delamination

The phenomenon of delamination is the separation of laminated solar panel parts from one another. Due to delamination, the production output for the panels will considerably decrease. EVA (ethylene and vinyl acetate), glass, the back sheet, and other raw materials used to make solar photovoltaic modules can become contaminated and consequently delaminate. In addition, the delamination of panels is caused by the environment's high temperature. Other than that, a lot of evidence suggests that delamination is a sign of the solar panel manufacturer's shoddy manufacturing process. The delamination of solar panels causes degradation, which is usually seen after a long period of exposure and soars with time. **Fig** presents the degradation process through delamination.



PV degradation process through delamination

A review was presented by Oliveira et al. in which they discuss ethylene-vinyl acetate copolymer (EVA) deterioration in crystalline silicon photovoltaic modules, including its origins and consequences. The generation of acetic acid and other hazardous gases is caused by the photodegradation of EVA by UV light, which also raises temperatures. These gases may result in bubble formation or delamination, which will lower the performance of the PV module. **Fig** depicts the delamination-based deterioration process. Fonseca et al. performed a degradation analysis of a photovoltaic generator made up of 48 solar panels after it had been operating for 15 years in southern Brazil. The results show that EVA darkening affected 100% of the module cells and produced a milky pattern. Twenty-four of its seventy-two cells were not functioning correctly because of a faulty internal electrical junction. The average installation power had decreased by 9.50%, or 0.7% annually, according to the electrical characterization of the I-V curve data gathered before and after the 15 years of operation for each of the 48 modules. The current decrease (9.19% and 9.12% for IMP and ISC, respectively) was mostly to blame for this power loss. In their experiment on the electrochemical processes of leakage-current-enhanced delamination and corrosion in Si photovoltaic modules, Li et al. demonstrated delamination on the metallization of an Arco Solar module after 27 years of field exposure. The electrochemical reaction on cell metallization results in corrosion and delamination, which are influenced by leakage current, which can be produced by temperature, humidity, and contaminants. The ionic composition of the leakage current can trigger electrochemical reduction processes that result in hydrogen and hydroxide ions when the cell bias is negative. On the metal surface, hydrogen gas can build up, which encourages delamination and reduces the output power. **Fig** shows a realistic representation of PV delamination.



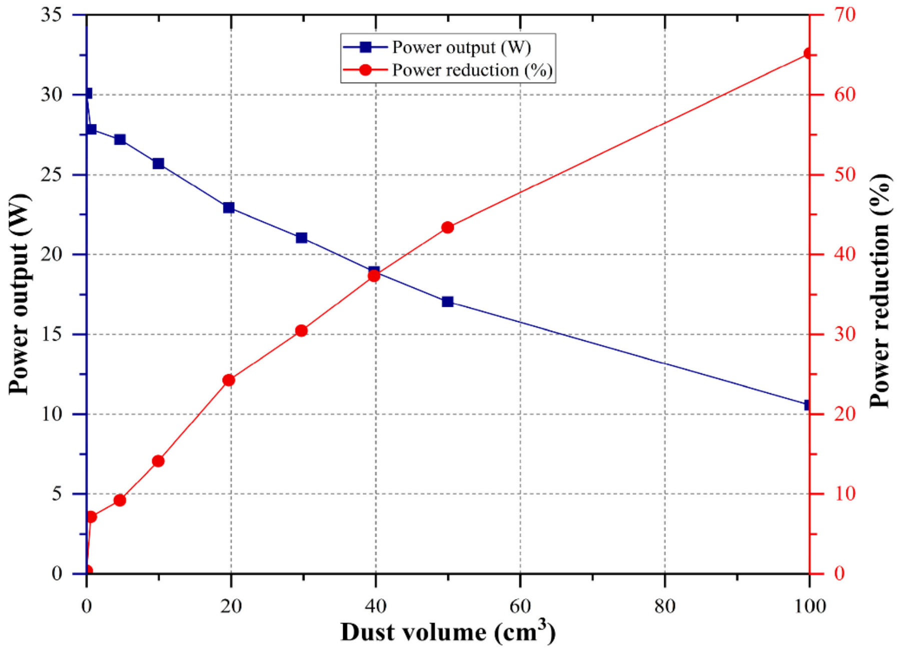
Delamination in solar panels

In the western Himalayan area of India, Chandel et al. performed a degradation study of 28-year field-exposed mono-c-Si photovoltaic modules of a direct coupled solar water-pumping system. PV modules visually displayed considerable cell delamination. Additionally, it was discovered that the PV deterioration rate had increased by 1.4% yearly, which is equal to India's 1.45% degradation rate for monocrystalline modules. Sequential and combined acceleration tests of crystalline Si photovoltaic modules were performed by Masuda et al.. Several variables contribute to degradation when exposed to the elements outside, such as high temperatures, high levels of humidity, thermal cycling, UV rays, current flow, high voltage, salt spray, and mechanical stress. The results, however, indicated that Pmax only slightly degraded throughout the TC (thermal cycling) test, which also included the HF (Humidity Freeze) test, a delamination phenomenon frequently seen in PV modules exposed to the outdoors for an extended period.

Impact of Aging Factors on Lifespan

Generally, the life expectancy of solar panels is 20–30 years, and this period can be decreased by the influence of some aging factors. Aging factors influence the solar panel in such a way that it starts to slowly lose its power generation capability. The continuation of this process for a long period triggers the reduction in power generation and, after a time, the solar panel is fully degraded before its expected lifespan.

The performance of solar PV is significantly impacted by dust. The efficiency and output power of solar PV are reduced by the uniform deposition of dust on the surface. The type of dust and the length of time over which it builds depend on the solar PV system's lifetime; dust comes in many different forms, including biological dust, industrial dust, agricultural dust, and airborne dust. Although the output power and efficiency of the solar panel are reduced by airborne dust accumulation, this can be improved by cleaning the PV module. However, if the panel is left dirty for an extended time, such as a year or more, this can affect the light transmission into solar cells because dust particles cause partial shedding, which causes the solar panel to mismatch and develop hotspots, which causes the PV module to age. Bird droppings and other biological dust have a higher impact than airborne dust. Its increased size can result in a 31% reduction in transmittance, which leads to partial shedding and causes the panel to mismatch and develop hotspots. For 15 g of dust deposition, agricultural dust such as mud, rice husk, compost, etc., can result in a maximum power loss of 51.82%. On the other hand, industrial dust such as gypsum and coal can decrease a panel's efficiency by 64% and 42%, respectively. Therefore, it is evident that this will decrease the PV panel's transmittance and result in partial shadowing, both of which will shorten the panel's lifespan. The graph in **Fig** was created after an in-depth study, which shows the PV power loss caused by dust accumulation.



Reduction in PV output power due to the accumulation of dust panels.

Temperature and humidity have a variety of consequences on PV cells that can lead to cell failure and early panel deterioration. The bypass diode problems with PV panels are more prevalent in hot climates such as Australia than they are in cold climates. However, compared to hot tropical climate zones, PV panels installed in cold climate zones, such as the UK, exhibit more hotspots. Rapid changes in the surrounding temperature can also lead to PV panel glass breakage. Due to thermomechanical stress, cracks in the solar cell can be seen. Solar cells with cracks in them can still produce a current, but the voltage will be lower and the output power will be reduced. With time, the percentage of cracks increases, increasing the number of damaged cells. As a result, the PV panel deteriorates earlier than expected. Due to decreased light reflectance and transmittance caused by discoloration and delamination (D&D), which can cause both short-term and long-term deterioration, cell damage, and a reduction in maximum power, the PV panel degrades earlier than predicted.

Future Directions for Mitigating the Impacts of Aging Factors on PV Modules

- This study found that dust is one of the main components that accumulate on the PV module's surface and causes shedding, decreases photon absorption, and increases PV module degradation in a variety of ways, including output power reduction and efficiency degradation, which decrease the PV module's lifespan and efficiency as well. Therefore, more research is needed to understand how the form, size, and accumulation direction of dust particles impact the rate of deterioration and lifespan of PV modules.

- A PV module's stability and structural integrity may be impacted by delamination, which happens when its layers split or detach from one another. By lowering the amount of light that reaches the solar cells and by raising the resistance in the module's electrical circuit, delamination can also result in a decrease in the performance of the module. This may cause the module's efficiency and power output to decline, which will lower its overall performance. To reduce the effect of delamination on the deterioration and longevity of PV modules, extensive investigation is required. It is also crucial to employ high-quality, long-lasting materials and construction methods, as well as to properly maintain and monitor the condition of the PV modules. Additionally, regular inspections and preventative maintenance can also help identify and address any delamination-related symptoms before they cause serious harm.

- The materials used in the manufacturing of the module, such as the encapsulant material, solar cells, and metal frame, can experience thermal stress at high temperatures. This may result in physical damage, such as warping, cracking, and other issues. High temperatures can also slow down the deterioration of the module's materials and lower the danger of electrical failure. To reduce the effect of temperature and humidity on the deterioration and lifespan of PV modules, extensive research is required. It is also crucial to properly design and install the modules with the right ventilation and temperature control, as well as to regularly monitor and maintain the modules. The danger of degradation due to temperature and other environmental factors can also be decreased by using high-quality, long-lasting materials and building methods.

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Conclusions

Solar energy will be a future alternative energy source that the world realizes due to the global energy crisis and rise in carbon emissions over the past few decades. However, there are several key aspects that need to be taken into account for solar PV degradation. Due to the influence on longevity, material deterioration, and efficiency decrease, several aging elements, including dust, delamination, temperature, humidity, were examined in this research. Firstly, the causes of degradation and the degradation rate were analyzed for different types of solar cells in different countries. Secondly, aging factors were introduced, followed by in-depth investigations regarding each of the aging factors. This analysis provides an overview of the current situation, the impact on performance, and the characteristics of the PV aging variables. Thirdly, a comprehensive assessment was conducted on the effects of aging variables on PV modules, including lifetime decrease, material degradation, and efficiency degradation. This investigation showed that each factor affecting aging has a distinct and varied effect on PV modules. According to reports, dust can decrease solar panels' effectiveness as it accumulates over time; nonetheless, dust's effect on the lifespan is less severe than that of other aging factors. Cracks and hotspots, on the other hand, have a significant influence on lifetime and efficiency deterioration; however, the rate of degradation is based on the proportion of afflicted PV cells. The solar PV's lifetime expectancy, material deterioration, and efficiency reduction are all impacted by delamination; nonetheless, delamination caused by temperature and humidity are more severe. The effects of all aging variables were also demonstrated to linearly increase over time.

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Conflicts of Interest

The authors declare no conflict of interest.

References

1. Ansari, S.; Ayob, A.; Hossain Lipu, M.S.; Md Saad, M.H.; Hussain, A. A review of monitoring technologies for solar pv systems using data processing modules and transmission protocols: Progress, challenges and prospects. *Sustainability* **2021**, *13*, 8120. [**Google Scholar**] [**CrossRef**]
2. Malvoni, M.; Kumar, N.M.; Chopra, S.S.; Hatziargyriou, N. Performance and degradation assessment of large-scale grid-connected solar photovoltaic power plant in tropical semi-arid environment of India. *Sol. Energy* **2020**, *203*, 101–113. [**Google Scholar**] [**CrossRef**]
3. Annigoni, E.; Virtuani, A.; Caccivio, M.; Friesen, G.; Chianese, D.; Ballif, C. 35 years of photovoltaics: Analysis of the TISO-10-kW solar plant, lessons learnt in safety and performance—Part 2. *Prog. Photovoltaics Res. Appl.* **2019**, *27*, 760–778. [**Google Scholar**] [**CrossRef**]
4. da Fonseca, J.E.F.; de Oliveira, F.S.; Massen Prieb, C.W.; Krenzinger, A. Degradation analysis of a photovoltaic generator after operating for 15 years in southern Brazil. *Sol. Energy* **2020**, *196*, 196–206. [**Google Scholar**] [**CrossRef**]
5. Micheli, L.; Theristis, M.; Talavera, D.L.; Almonacid, F.; Stein, J.S.; Fernández, E.F. Photovoltaic cleaning frequency optimization under different degradation rate patterns. *Renew. Energy* **2020**, *166*, 136–146. [**Google Scholar**] [**CrossRef**]
6. Abenante, L.; De Lia, F.; Schioppo, R.; Castello, S. Non-linear continuous analytical model for performance degradation of photovoltaic module arrays as a function of exposure time. *Appl. Energy* **2020**, *275*, 115363. [**Google Scholar**] [**CrossRef**]
7. Theristis, M.; Livera, A.; Micheli, L.; Ascencio-Vasquez, J.; Makrides, G.; Georghiou, G.E.; Stein, J.S. Comparative Analysis of Change-Point Techniques for Nonlinear Photovoltaic Performance Degradation Rate Estimations. *IEEE J. Photovolt.* **2021**, *11*, 1511–1518. [**Google Scholar**] [**CrossRef**]
8. Baldus-Jeursen, C.; Côté, A.; Deer, T.; Poissant, Y. Analysis of photovoltaic module performance and life cycle degradation for a 23 year-old array in Quebec, Canada. *Renew. Energy* **2021**, *174*, 547–556. [**Google Scholar**] [**CrossRef**]

9. Mahmud, S.; WazedurRahman; Lipu, H.; Al Mamun, A.; Annur, T.; Islam, M.; Rahman, M.; Islam, A. Solar Highway in Bangladesh Using Bifacial PV. In Proceedings of the 2018 IEEE International Conference on System, Computation, Automation and Networking (Icscan), Pondicherry, India, 6–7 July 2018. [Google Scholar]
10. *Renewables in Russia from Opportunity to Reality*; International Energy Agency (IEA): Paris, France, 2019.
11. Chien, F.S.; Hsu, C.C.; Andlib, Z.; Shah, M.I.; Ajaz, T.; Genie, M.G. The role of solar energy and eco-innovation in reducing environmental degradation in China: Evidence from QARDL approach. *Integr. Environ. Assess. Manag.* **2022**, *18*, 555–571. [Google Scholar] [CrossRef]
12. Afful-Dadzie, A.; Mensah, S.K.; Afful-Dadzie, E. Ghana renewable energy master plan: The benefits of private sector participation. *Sci. Afr.* **2022**, *17*, e01353. [Google Scholar] [CrossRef]
13. Quansah, D.A.; Adaramola, M.S. Ageing and degradation in solar photovoltaic modules installed in northern Ghana. *Sol. Energy* **2018**, *173*, 834–847. [Google Scholar] [CrossRef]