

Enhancing irrigation systems with SolarEdge technology

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Abstract

SolarEdge technology is an established advancement in solar energy, optimizing photovoltaic system performance through innovative hardware and software. Its primary objective is to maximize solar energy production and enhance efficiency in intelligent storage systems. The use of power optimizers for individual panels ensures efficient control, eliminating shading issues and system-wide malfunctions. The technology includes a versatile hybrid inverter that operates autonomously or collaborates with alternative sources like batteries or the grid. Remote management ensures seamless operation, while the real-time monitoring platform offers insights into energy production and consumption, facilitating prompt intervention. Compared to traditional approaches, SolarEdge offers higher energy efficiency, rapid issue resolution, advanced management, and potential battery integration. The article underscores SolarEdge's efficacy in addressing energy production and monitoring challenges, particularly shading and monitoring limitations. The technology optimizes individual panel energy generation, enhancing integration with alternative sources for increased output. The article also explores SolarEdge's real-time monitoring and its potential in sustainable irrigation. In conclusion, SolarEdge transforms photovoltaic systems, efficiently addressing challenges and extending to innovative applications, maximizing energy utilization sustainably. The article is structured into sections: Introduction establishes context, Related Work compares existing approaches, The SolarEdge Solution details the technology, SolarEdge's Role in Advancing Sustainable Irrigation explores its application, and Conclusions summarize its impact on photovoltaic systems and sustainable energy.

Keywords: SolarEdge technology, photovoltaic systems, energy optimization.

1. Introduction

Traditional photovoltaic systems have long grappled with obstacles such as shading, panel discrepancies, and restricted monitoring capabilities. These issues not only curtail energy efficiency but also hinder the potential for maximum energy generation [1]. Enter SolarEdge technology, which orchestrates a transformative paradigm shift by confronting these challenges head-on. The cornerstone of SolarEdge's solution lies in the implementation of power optimizers for individual panels. By expertly mitigating the effects of shading, these power optimizers ensure that energy generation remains efficient and unhindered, even in the presence of unfavorable conditions.

Further augmenting the efficiency of energy conversion, SolarEdge leverages hybrid inverters that not only enhance energy conversion processes but also seamlessly integrate with alternative energy sources. This integration not only bolsters energy production but

also offers a versatile framework for optimizing power utilization. As a result, SolarEdge technology not only enhances energy generation but also opens avenues for a diversified energy ecosystem.

In the journey towards efficient and sustainable energy systems, monitoring plays an indispensable role. SolarEdge's sophisticated monitoring platform offers real-time tracking and issue identification, constituting a vital component of operational efficiency. By enabling prompt detection of performance issues, this monitoring platform ensures that the system operates at its optimal capacity, ultimately leading to maximized energy output.

Moreover, SolarEdge's impact transcends the boundaries of energy generation; it extends to revolutionizing irrigation systems. By embracing SolarEdge technology, irrigation processes stand to benefit from improved energy efficiency and operational optimization. This paves the way for sustainable and effective water management, a critical facet in the global pursuit of agricultural and environmental sustainability.

In conclusion, SolarEdge technology emerges as a transformative force in the realm of photovoltaic systems. By strategically tackling shading, monitoring limitations, and even irrigational challenges, it underscores a comprehensive approach to harnessing solar energy's potential. With an unwavering commitment to efficiency and sustainability, SolarEdge presents a compelling narrative that envisions a greener future powered by innovation.

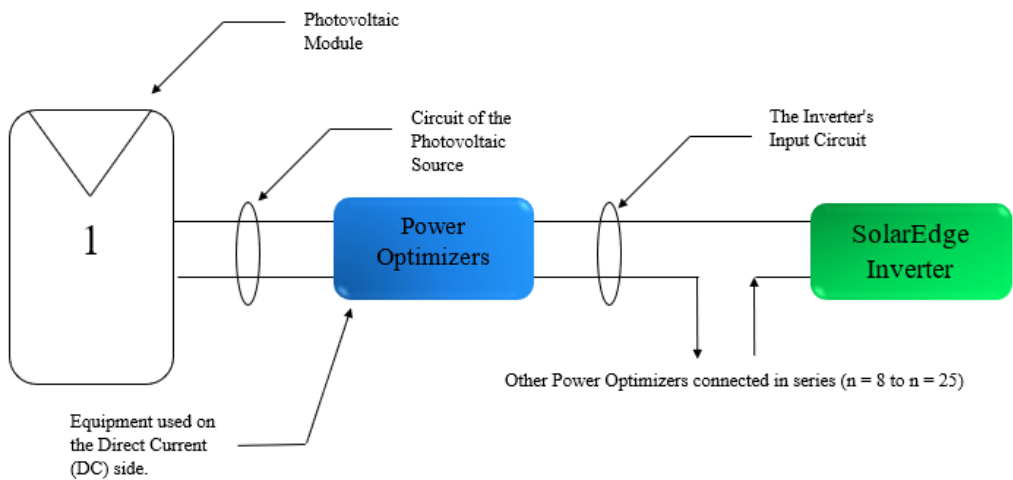


Fig. 1. General architecture of the SolarEdge PV system.

The article also explores SolarEdge's real-time monitoring and its potential in sustainable irrigation. In conclusion, SolarEdge transforms photovoltaic systems, efficiently addressing challenges and extending to innovative applications, maximizing energy utilization sustainably. The article is structured into sections: Introduction establishes context, Related Work compares existing approaches, The SolarEdge Solution details the technology, SolarEdge's Role in Advancing Sustainable Irrigation explores its application, and Conclusions summarize its impact on photovoltaic systems and sustainable energy.

2. Related work

The development of sustainable energy resources is one of humanity's most urgent challenges, as increasing energy demand is in great conflict with the world's limited availability of fossil fuels. Among various kinds of sustainable energy resources, solar energy is considered promising due to its inexhaustible supply, widespread presence, large capacity and environmental friendliness [2].

Solar energy offers a viable solution to address the energy demands crucial for humanity's survival on Earth. Its applications span a range of sectors, including electricity generation through solar panels, thermoelectric generators, and Rankine cycle technology. Furthermore, solar power facilitates water purification, agricultural product drying, refrigeration, and pollution-free irrigation through solar-based pumping systems. Researchers worldwide have extensively explored solar energy's potential in these applications [3].

Advances in Internet of Things (IoT) technology have made it possible to remotely operate, monitor, and control distributed solar energy resources. This IoT-based solar energy system design for smart irrigation is of critical importance to regions around the world facing water and power shortages. Therefore, in this work, such a system is designed. The proposed system uses a single-board system-on-chip controller (“controller”) with built-in WiFi connectivity and connectivity to solar cells to provide the necessary operating power. The irrigation pumps are operated by the controller by issuing the proper actuation command signals after reading field soil moisture, humidity, and temperature sensors. The controller also monitors the groundwater level. This is important to prevent the pump motor from burning out due to the well water level. The proposed system has three modes of operation: local control mode, mobile supervisory control mode, and fuzzy logic-based control mode. A prototype was designed, built and tested to validate the proposed system [4].

Power shortages and high diesel costs are impacting the city's water supply and irrigation pumping needs. Therefore, using solar energy to pump water is an effective substitute for conventional systems that rely on grid power and diesel [5]. Over the past decades, clean and renewable energy has become a priority for the majority of countries from an environmental and economic perspective. One of the best solutions is to harness the abundant and almost free solar energy to power all sectors, especially the irrigation sector. Large amounts of solar radiation occur during the growing season of crops that require frequent irrigation [6].

Mitigating electricity deficits and rising fuel costs is vital for efficient irrigation. Solar energy presents an attractive alternative to traditional electricity and diesel-driven water pumping systems. This approach powers irrigation water pumps alongside sprinklers, with a focus on conserving both electricity and water. Incorporating photovoltaic (PV) technology, which generates electricity from sunlight, drives the motor powering the solar pump [7]. By synergizing the sprinkler system with cost-effective and environmentally friendly PV technology, the consumption of both electricity and water is minimized [8]. A new way to mix AC and DC power via an all-in-one soft-start converter/regulator offers the opportunity to reduce costs, diversify fuel sources and provide continuous off-grid power in remote locations. By installing an electric submersible pump with solar power in

combination with a diesel generator, diesel energy can be replaced with a renewable fuel source. Benefits of adopting renewable fuel sources include reduced greenhouse gas emissions per bale of cotton produced and reduced labor required to monitor and maintain conventional diesel irrigation systems [9]. Emissions calculations show a reduction of 26% or 35 kg CO₂eq per bale of fluff, a reduction of 2,665 tonnes/CO₂eq over the life of the project [10].

The most convenient energy available today is solar energy harnessed by solar cells that convert thermal energy from the sun directly into electrical energy. Sun tracking, converting direct current to alternating current, and using timers to operate agricultural engines are all active research topics. During tracking, the solar panel is always oriented perpendicular to the sun's rays, effectively charging the battery where the light intensity is higher, and the energy in the form of DC is converted to AC through an inverter [11]. The energy required from the battery is used to run the motor. To automate the stepper motor, its shaft is fitted with a silicon solar panel controlled by a microcontroller. Two sensors are connected to the microcontroller, one to record the position of the sun and the other to record the day and night. The first sensor detects the position of the sun attached to the solar panel and the stepper motor is controlled accordingly so that the light beam is always perpendicular to the solar panel. An AT89C51 microcontroller is used for this logic and embedded C program coding is provided in the KEIL Micro Vision Editor. We analyzed the average amount of energy available from the pump, the efficiency that the panel achieves during operation [12].

3. The SolarEdge solution

3.1. The problem

In the pursuit of sustainable and efficient energy production, conventional photovoltaic systems often tackle a range of challenges that hinder optimal performance. Among these challenges, shading effects, panel discrepancies, and deficient monitoring mechanisms emerge as significant hurdles that hinder energy generation's full potential.

Shading, whether from bordering structures or natural obstructions, poses a considerable threat to energy generation. When even a single panel is cast in shadow, the entire system's efficiency can be compromised. Additionally, variations in panel manufacturing can result in output discrepancies, where some panels outperform others. These variations not only undermine the overall system's efficiency but also impede the system's ability to generate energy uniformly.

Furthermore, the limitations of traditional monitoring approaches restrict the timely identification of performance issues. This lack of real-time insights often leads to undetected inefficiencies that accumulate over time, resulting in reduced energy generation. Consequently, the inefficiencies in energy production and monitoring culminate in suboptimal performance, preventing the goals of sustainability and efficiency.

SolarEdge technology emerges as a revolutionary approach, tackling the problems head-on. By integrating power optimizers at the panel level, shading effects are mitigated, and individual panels' performance is optimized. Moreover, the hybrid inverter with advanced

control capabilities maximizes energy conversion and facilitates integration with alternate energy sources.

3.2. The solution

SolarEdge leads in a transformative paradigm that not only addresses the limitations of conventional photovoltaic systems but also reshapes our perception and utilization of solar energy. In response to challenges related to energy production and monitoring in traditional photovoltaic setups, the innovative SolarEdge technology emerges as a revolutionary remedy. This section delves into its essential components and the way it challenges established conventions. The SolarEdge approach entails a revolutionary shift that optimizes energy generation and control through the integration of advanced hardware and software. By implementing power optimizers at the panel level, issues like shading and performance limitations are eliminated, leading to the maximization of energy output. This technology also collaborates seamlessly with alternative sources such as batteries or the grid, ensuring adaptability to diverse energy requirements. The inclusion of a remote management system enables real-time monitoring, facilitating efficient energy utilization. SolarEdge's transformative impact extends beyond mere efficiency, propelling photovoltaic systems into a new era of flexible, data-driven energy management.

3.3. Unveiling SolarEdge technology

SolarEdge's visionary solution rests upon an ingenious integration of advanced components that revolutionize the performance of photovoltaic systems. At the heart of this innovation lies the deployment of power optimizers at the individual panel level. These power optimizers act as sentinel guardians against shading effects, ensuring that even in the presence of partial shading, energy generation remains optimized.

By distributing intelligence to each panel, SolarEdge's power optimizers engage in dynamic power point tracking, adapting to the prevailing conditions to maximize energy production [13]. This granularity of control ensures that energy loss due to shading is minimized, encouraging overall system efficiency. Furthermore, panel discrepancies are neutralized, as each panel's performance is optimized independently, culminating in uniform energy generation across the entire system.

The pinnacle of SolarEdge's innovation is embodied by its hybrid inverter with advanced control capabilities. This component not only enhances energy conversion efficiency but also catalyzes seamless integration with alternate energy sources. By supporting bidirectional energy flow, the hybrid inverter facilitates the injection of surplus energy back into the grid, ensuring that no energy generated goes to waste.

As a testament to SolarEdge's effectiveness, the technology's implementation leads to significant improvements in energy output and operational efficiency. The harmonious synergy between power optimizers and the hybrid inverter transforms photovoltaic systems into dynamic power-generating hubs, capable of adapting to varying conditions and extracting maximum energy from the available resources.

Intriguingly, the impact of SolarEdge technology extends beyond energy generation to sustainable agriculture. By optimizing energy production and ensuring efficient monitoring, SolarEdge opens doors to enhancing irrigation practices. The application of

SolarEdge's principles in irrigation systems potentially revolutionizes water management, a critical aspect of sustainable agriculture.

In the subsequent sections, we delve deeper into the mechanics of SolarEdge technology, exploring its impact on monitoring, irrigation, and the wider landscape of renewable energy. Through its innovative approach, SolarEdge reshapes the landscape of photovoltaic systems, offering an efficient, sustainable, and future-oriented solution to the energy challenges of today.

4. SolarEdge's role in advancing sustainable irrigation

As SolarEdge technology revolutionizes the landscape of photovoltaic systems through enhanced energy production and monitoring, its impact extends beyond electricity generation. This section delves into the transformative role SolarEdge plays in revolutionizing irrigation practices, conducting in a new era of efficient and sustainable water management [14]. SolarEdge technology offers specific benefits in the context of irrigation by providing an innovative solution for sustainable water management. By optimizing photovoltaic system performance and ensuring efficient energy production, SolarEdge technology not only addresses energy challenges but also empowers the effective utilization of solar energy for irrigation purposes. The real-time monitoring platform enables precise tracking of energy production and consumption, allowing for timely adjustments to irrigation schedules based on available energy resources. This integration of SolarEdge technology with sustainable irrigation practices contributes to water conservation and increased agricultural productivity, showcasing its versatile and impactful role in advancing both energy efficiency and water management [15].

4.1. Enhancing energy-efficient irrigation

The conventional landscape of irrigation systems has long been sustained by energy sources that are deeply established in traditional power grids. These sources, often reliant on fossil fuels, not only impose a substantial economic burden but also come with significant environmental consequences. The consumption of these finite resources and the associated emissions have cast a shadow on the sustainability of conventional irrigation practices. Furthermore, the unpredictability of energy costs and supply disruptions exacerbates the challenges faced by agricultural operations, which are already susceptible to various external factors. Amid these challenges, a transformative solution emerges through the integration of SolarEdge technology. This integration marks a pivotal departure from the norm, offering a revolutionary approach to powering irrigation systems. By harnessing the inexhaustible potential of solar energy, SolarEdge technology introduces an entirely new dimension to irrigation practices. This paradigm shift not only addresses the limitations of traditional energy sources but also showcases a forward-looking commitment to sustainable and environmentally friendly energy solutions. Solar energy, abundantly available through sunlight, represents a remarkable departure from conventional energy sources. SolarEdge's adoption of this renewable energy source aligns seamlessly with the global movement towards cleaner and greener energy solutions. By tapping into the sun's vast potential, SolarEdge technology not only mitigates the economic and environmental challenges posed by conventional energy sources but also contributes to a more sustainable energy landscape. This alignment with the broader shift towards renewable energy

underscores SolarEdge's commitment to leading in a future characterized by reduced carbon footprints, minimized resource depletion, and enhanced energy security.

4.2. Optimized operational efficiency

The integration of SolarEdge's innovative power optimizers and advanced control capabilities into irrigation systems indicates a new era of operational efficiency that is unparalleled in its impact. Drawing from their well-established success in photovoltaic systems, SolarEdge's power optimizers play a pivotal role in ensuring that solar energy is harnessed to its fullest potential, even when confronted with challenging conditions such as partial shading. This transformative technology optimizes each individual solar panel's energy production, virtually eliminating energy losses caused by shading. As a result, the operational efficiency of irrigation systems powered by SolarEdge is remarkably enhanced, guaranteeing a consistent and reliable energy supply that transcends the limitations of traditional energy sources.

In the realm of traditional energy-dependent irrigation, interruptions and fluctuations in energy supply are common, often leading to disruptions in agricultural operations and compromised crop yield. The inclusion of SolarEdge's power optimizers effectively addresses these challenges, offering a solution that not only ensures uninterrupted energy supply but also mitigates the risks associated with energy source vulnerabilities. By capitalizing on the fundamental efficiency of solar energy and leveraging advanced control mechanisms, SolarEdge empowers irrigation systems to operate seamlessly, regardless of external factors that would otherwise hinder their performance.

This optimized operational efficiency aligns perfectly with SolarEdge's overarching commitment to sustainability and resource conservation. By seamlessly integrating power optimizers into irrigation, SolarEdge provides an adaptable and intelligent solution that not only elevates the energy output but also enhances the overall operational stability of agricultural systems. Through this integration, SolarEdge not only innovates a new level of efficiency within irrigation practices but also fosters a paradigm shift towards sustainable energy utilization, setting new standards for agricultural productivity and ecological responsibility.

4.3. Real-time monitoring for precision irrigation

SolarEdge's groundbreaking approach revolves around its advanced monitoring platform, which has already proven effective in optimizing energy production. This expertise seamlessly extends to irrigation systems, revolutionizing water resource management. This section explores how SolarEdge's real-time monitoring empowers precise irrigation practices with unparalleled accuracy and efficiency. The platform provides real-time insights into vital parameters like water usage and soil moisture, enabling farmers to tailor irrigation strategies for optimal crop growth. The synergy between energy production and monitoring is a game-changer, directing surplus energy to power irrigation during peak demand, efficiently utilizing water resources without compromising energy efficiency. This harmonious balance between energy and irrigation monitoring fosters responsible water use and productive harvests. By harnessing real-time monitoring, SolarEdge not only tackles inefficient irrigation but also sparks data-driven agriculture, optimizing schedules

and achieving higher yields sustainably. The integration of SolarEdge's monitoring platform into irrigation propels the sector towards a more technologically advanced and sustainable future.

4.4. Paving the way for sustainable agriculture

SolarEdge's technology goes beyond mere efficiency gains in irrigation, making a substantial contribution to sustainable agriculture amidst global challenges. By enhancing energy efficiency and operational aspects, it addresses environmental concerns and aligns with the objectives of responsible resource consumption. The integration of SolarEdge into irrigation conserves water, reduces carbon emissions, and encourages eco-conscious methods. SolarEdge redefines farming by showcasing how innovation can align with sustainability, benefiting crops and the environment. It advances efficient irrigation, fostering a greener agricultural sector and marking a pivotal step towards a sustainable future.

4.5. General approach to irrigation

SolarEdge's approach to irrigation is a general transformation of water management systems that integrates energy production, monitoring, and irrigation. This comprehensive solution optimizes resource utilization by efficiently directing surplus energy to power irrigation during peak demand. Real-time monitoring enhances precision and control in irrigation practices, enabling informed decisions to minimize water wastage while maximizing crop yields. This integrated approach fosters a balanced synergy between energy and agriculture, promoting responsible and eco-friendly farming practices while addressing challenges in both sectors. SolarEdge's innovative approach redefines resource management, ensuring a harmonious and sustainable relationship between energy and agricultural needs.

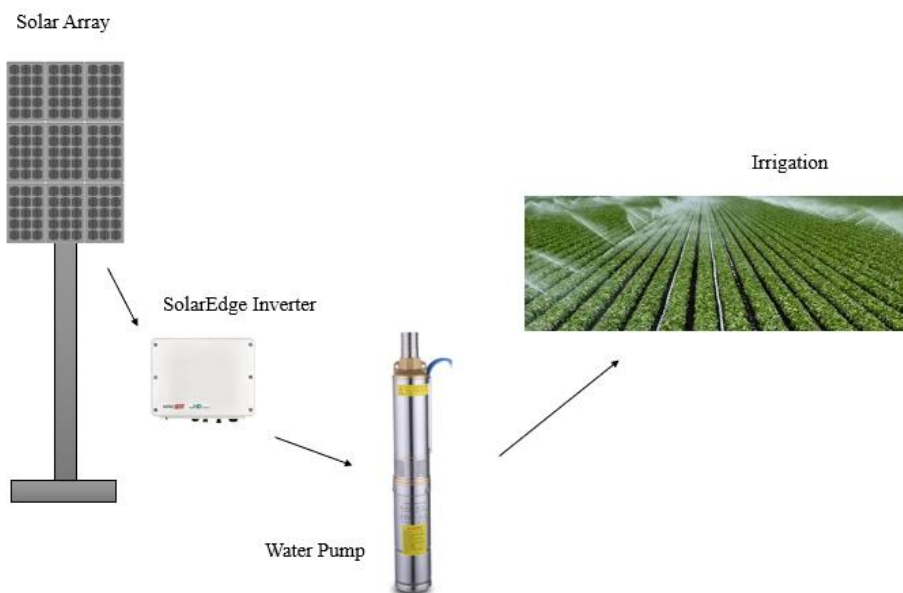


Fig. 2. The conceptual framework detailing the implementation of SolarEdge Technology within irrigation systems.

5. Challenges and limitations

While the integration of SolarEdge technology into irrigation systems presents a promising advancement in sustainable agriculture, it's important to acknowledge and address its potential challenges and limitations.

5.1. Technical and performance challenges:

SolarEdge technology relies on solar energy, which is inherently intermittent. This variability can impact the consistency and reliability of power supply for irrigation, particularly in regions with fluctuating weather conditions.

The integration of advanced solar technology adds complexity to the irrigation systems [16]. This necessitates regular maintenance and technical expertise, which might not be readily available in all agricultural regions, and which might increase the overall costs of operation above the threshold set by local fuel prices in the case of diesel generators and electricity prices in the case of power-grid powered irrigation systems.

5.2. Socio-economic challenges:

Technology Adoption Barriers: Farmers, especially in developing countries, may face barriers in adopting new technologies due to lack of awareness, technical know-how, and reluctance to change from traditional methods [16]. Furthermore, the economic viability of solar powered water irrigation systems, will be hindered by the high cost of adoption; thus, the return on investment period may be too long to justify the initial expense, especially without subsidies or financial incentives. Coupled with the lack of a financing option for smaller farmers, although more economically feasible in the long term, most farmers will choose traditional methods for powering up irrigation systems for vast areas, consisting of diesel powered generators.

The upfront costs of installing SolarEdge systems can be significant. This includes the cost of solar panels, inverters, batteries for storage, and installation labor, potentially making it less accessible for small-scale farmers or those in developing countries.

5.3. Environmental and regulatory challenges:

The manufacturing process of solar panels, including the extraction of raw materials, can have environmental impacts that should be considered in a sustainability assessment. Studies are yet to show whether the current technology of PV cells makes their lifetime carbon footprint lower than that of a diesel generator. However, lower localised pollution will be ensured with the use of a SolarEdge system.

Waste Management: At the end of their life cycle, solar panels and batteries require proper disposal or recycling. This raises concerns about waste management and environmental sustainability.

Regulatory Hurdles: In some regions, there may be regulatory challenges or a lack of supportive policies for the integration of solar technology in agriculture.

5.4. Suggestions for further research and information:

International Renewable Energy Agency (IRENA): IRENA provides comprehensive resources on renewable energy technologies, including solar-powered irrigation systems.

Agricultural Extension Services: Local agricultural extension services can offer practical insights and resources on the implementation of solar technology in farming.

SolarEdge Technologies Publications: Reviewing publications and case studies directly from SolarEdge Technologies can provide detailed technical information and updates on their latest innovations.

Academic Journals: Journals focusing on renewable energy, sustainable agriculture, and environmental studies often publish research on the advancements and challenges of solar technologies in agriculture.

Government Agricultural and Energy Departments: National and regional departments often have resources and data on renewable energy initiatives in agriculture, including potential funding and subsidies.

By addressing these challenges and limitations, stakeholders can work towards more efficient, accessible, and sustainable integration of SolarEdge technology in irrigation systems, paving the way for advancements in agricultural practices.

6. Conclusions

This article introduced the main concepts of how SolarEdge technology brings about a transformative change in the realm of photovoltaic-enhanced irrigation systems. By addressing shading, monitoring limitations, and inefficiencies in energy production, SolarEdge not only maximizes energy generation but also extends its impact to sustainable irrigation practices. The integration of solar energy into irrigation systems marks a significant stride towards a greener future, where technology and innovation converge to create more efficient and eco-friendly solutions. With its versatile approach and commitment to efficiency and sustainability, SolarEdge paves the way for a world powered by the sun, nurturing both energy generation and agriculture.

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