

Solar Energy and Resource Utilization—2nd Edition

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The ongoing global energy transition places solar energy at the centre of an increasingly diversified portfolio of low-carbon technologies. Reducing greenhouse gas emissions is not only a scientific imperative but a socio-political priority, shaping investment flows and research agendas. Concentrating solar power, photovoltaic conversion, and solar thermal systems are converging towards higher efficiencies, smarter controls, and deeper integration with energy storage and end-use sectors [1–7]. This Second Edition of the Special Issue “Solar Energy and Resource Utilization” collects eight contributions that, taken together, trace a coherent arc spanning from the materials and component level up to full system integration and application, offering a panoramic view of where solar energy research stands and where it is headed.

The first cluster of contributions addresses solar thermal energy collection and storage, which remains a cornerstone challenge: efficiently harvesting solar heat and retaining it beyond the hours of irradiation. For example, the thermo-hydraulic performance of a solar air heater featuring sequentially placed rectangular obstacles on finned surfaces is investigated using computational fluid dynamics. Studies quantify the interplay between heat transfer enhancement and the inevitable pressure penalty introduced by the obstacles, identifying the optimal obstacle height-to-pitch ratio that maximises the thermo-hydraulic performance factor. The derived correlations for the Nusselt number and friction factor provide practical design tools for engineers seeking to upgrade solar air heaters without resorting to complex or costly modifications. At a different scale, researchers address latent heat storage using sodium acetate trihydrate as a phase change material. The work highlights the growing synergy between advanced additive manufacturing and thermal energy storage engineering, opening a promising route towards compact, high-performance storage units compatible with solar thermal systems.

A second cluster examines photovoltaic energy conversion at both the cell and array levels. Authors probe the mechanisms of light- and elevated-temperature-induced degradation in monocrystalline passivated emitter rear contact silicon solar cells. By directly tracking hydrogen redistribution within the silicon wafer using dynamic secondary ion mass spectrometry and correlating it with carrier lifetime measurements and quantum efficiency spectra, the authors identify hydrogen diffusion as a primary driver. Moving from the cell to the array, scholars have conducted a controlled field experiment in a hot, arid desert environment to disentangle two geometric effects that are often conflated in the literature: the inter-array temperature difference arising from mounting height, and the intra-array edge-to-centre thermal gradient along a single-row configuration. Results have direct implications for racking design and thermal performance modelling in climates where natural convection governs module cooling. In another paper, authors add a further spatial dimension by examining the instantaneous power output of bifacial versus monofacial modules installed on a single-axis tracking platform over five distinct ground surfaces.



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Albedo is shown to be neither constant nor spatially homogeneous. The work challenges the assumption of a fixed albedo coefficient embedded in most simulation tools and calls for spatially resolved albedo characterisation.

A third cluster turns to solar energy utilisation in thermal end-use applications. Researchers propose and experimentally validate an adaptive control strategy for a solar hot water heating system that dynamically selects among three control modes, based on a real-time daily classification of solar irradiance conditions into four categories. The result underscores the value of intelligent control even within relatively simple solar thermal installations, where weather-aware decision logic can significantly outperform fixed-parameter strategies. Other authors broaden the climatic scope by performing an energy and exergy analysis of a single-effect H₂O–LiBr absorption chiller driven by solar thermal collectors, comparing performance under moderate and hot conditions of different geographical areas. Optimal operating temperatures substantially differ between the two climates, a finding of practical importance as solar cooling technologies expand simultaneously towards regions with the highest cooling demand and the highest solar resource.

Completing the picture, researchers address the integration of solar photovoltaics with electric vehicle charging infrastructure, a nexus that is rapidly gaining prominence as both technologies scale. Using a population-based metaheuristic that outperforms both genetic algorithms and particle swarm optimisation, the study simultaneously optimises the siting of residential, commercial, and industrial fast-charging stations and the sizing of rooftop photovoltaic systems.

Taken as a whole, the eight papers collected in this Special Issue illustrate the breadth and vitality of contemporary solar energy research. The contributions span length scales from the nanometre-level hydrogen profile in a silicon wafer to the system-level optimisation of a multi-node distribution grid; they investigate methods from computational fluid dynamics and numerical thermal analysis to field experiments and metaheuristic optimisation; and they address applications from building heating and cooling to electric mobility. Several cross-cutting themes emerge and deserve further investigation. The role of material innovation (whether in phase change materials, silicon passivation layers, or solar collector geometries) continues to be pivotal. Intelligent, weather-aware control is proving its worth across both photovoltaic and solar thermal systems. Spatial heterogeneity, whether of albedo, temperature, or irradiance, cannot be neglected at the system level. And the coupling of solar energy with storage and with demand-side technologies such as electric vehicles is reshaping the boundaries of what solar research must encompass. We trust that Readers will find in these contributions both rigorous engineering insights and inspiration for future lines of investigation.

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