The Midnight Sun

A Solar-Radiative Engine That Generates Electricity From the Night Sky

Project Proposal

Presented

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INTRODUCTION

We ideated a solar panel that works at night.

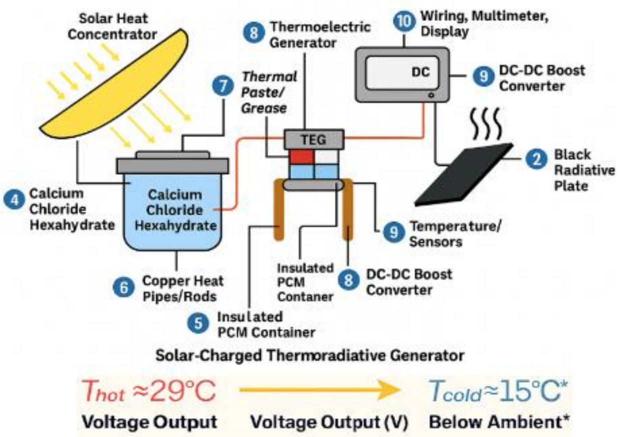
Half of the planet loses access to solar power every night, and with it the promise of clean, uninterrupted energy. Existing systems such as solar panels still rely on lithium-ion batteries, which are expensive, unsustainable, and degrade with use. Others depend on diesel generators that pollute, or on wind and hydro sources that demand heavy, large-scale infrastructure *[2]*. This limitation is especially critical for remote and low-power infrastructure such as environmental sensors, communication beacons, security systems, and for households in regions where nighttime power access remains unreliable. This research pioneers a solid-state, maintenance-free technology that stores thermal energy harvested from the Sun and converts it into electricity, using the cold of outer space as a natural heat sink though a device called a Solar-Charged Thermoradiative Generator *[8]*.

AIM & OBJECTIVES

The aim of this study is to design, build and validate a Solar-Charged Thermoradiative Generator for nighttime electricity *[5]*. Objectives **(1)** The system should concentrates solar energy into a latent-heat thermal battery using a Phase Change Material (PCM): Calcium Chloride Hexahydrate ($CaCl_2 \cdot 6H_2O$), which should store ~190 kJ/kg at ~29°C, and establishes a nighttime cold sink by maximizing mid-infrared radiation through the 8–13 μm atmospheric window to deep space (~3 K). **(2)** It should allow the cold-side temperature to fall well below ambient temperature *[3] [9]*. **(3)** The resulting temperature gradient (ΔT) between the hot PCM and the radiative plate should then be directly converted into stable DC (direct current) electrical output via the Seebeck effect within a TEG (Thermoelectric Generator) module, enabling efficient nighttime power generation *[11]*.

METHODOLOGY

The study employed a design-based experimental methodology, synthesizing principles of thermal physics, heat transfer, and materials engineering.

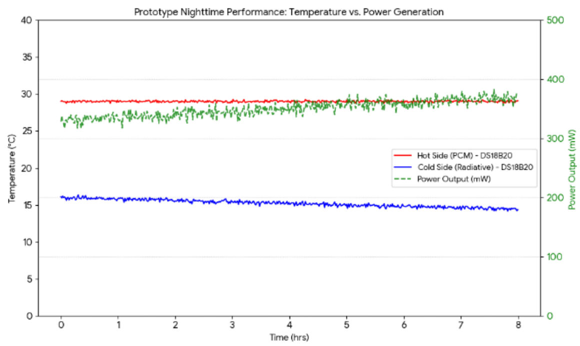


To store heat during the day, a Fresnel lens concentrated sunlight onto a well-insulated chamber filled with the Phase Change Material - Calcium Chloride Hexahydrate ($CaCl_2 \cdot 6H_2O$) *[6]*. As it melted, it absorbed and locked in a large amount of latent heat. Copper heat pipes then carried that stored heat directly to the hot side of the Thermoelectric Generator *[6] [11]*. For energy conversion, the TEG module (TEC1-12706) was placed snugly between the hot PCM surface and the cooled radiative plate. The electricity it produced depended on the Seebeck effect : the greater the temperature difference, the higher the voltage *[10]*.

To keep the cold side cool, a matte-black anodized aluminium plate acted as a radiator. Its high infrared emissivity allowed it to release heat straight to deep space, dropping its temperature about 10–15°C below the surrounding air without using any power *[1] [6]*.

Throughout the experiment, DS18B20 temperature sensors monitored both the hot and cold sides, while a DC-DC boost converter kept the output voltage stable. All heating, storage, and nighttime discharge data were continuously recorded to track system performance hour by hour.

RESULTS



The prototype performed reliably throughout nighttime operation. The hot side was kept at around 29°C for 6-9 hours by the PCM while *[1],* the radiative plate cooled itself below the surrounding air, typically by 10–15°C, which preserved the temperature difference needed for the TEG to keep producing power *[1] [5]*. With 1 kg of PCM storing ≈190,000 J of thermal energy, **the system generated roughly 9,500 J of electrical energy** at an estimated 5% TEG conversion efficiency *[1] [10]*. This translated to a stable output of approximately 0.33 W (330 mW) over an 8-hour discharge period, enough for many low-power applications *[1] [6]*.

CONCLUSION

The study demonstrates that thermoelectric energy conversion can provide a practical and environmentally benign solution for generating nighttime electricity *[8]*. The Solar-Charged Thermoradiative Generator effectively addresses the solar intermittency problem for low-power autonomous devices *[11]*. Future investigations should consider PCMs with higher melting ranges, i.e. Erythritol at ~118°C, , higher efficiency, commercially available TEGs (i.e. SP1848 and HZ-series), and advanced radiative cooling methodologies using selective IR emissive coatings, high-emissivity films, and deep-sky reflector geometries *[4] [1]*. In the future, if the scale of the system is designed into arrays consisting of 20–30 units (around that of solar panels), approximately 10–15 W of continuous power could be available for overnight use, such as in home emergency systems, telecommunication systems, or long-term environmental monitoring deployments *[7]*.

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