Analysis of Solar Panel Outputs In Unique Conditions

Skyla St John

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Advisor Sullivan

Objective & Importance

Background & Motivation

Theoretical Framework

Methodology

Experimental Results

Analysis

Challenges & Limitations

Contributions

Concluding Remarks

Questions & Discussion

Theoretical and experimental approach in analysis of how a solar panel works under varying material overlays in controlled and uncontrolled conditions

The importance of this study pertains greatly to the climate crisis as well as my interest in structural developmental design choices, the further adoption of renewable energy in the aspect of infrastructure will be a profound step in the advancement of solar technology

Solar technology in road infrastructure

Solar Roadways (2006), SolaRoad (2014), Solar Highway (2017), Wattway(2020)

Challenges in large scale implementations (Texas Hail Storm) Smaller scale implementations are more realistic currently

I wanted to explore why there aren't more implementations, and perhaps solutions for making solar infrastructure more feasible

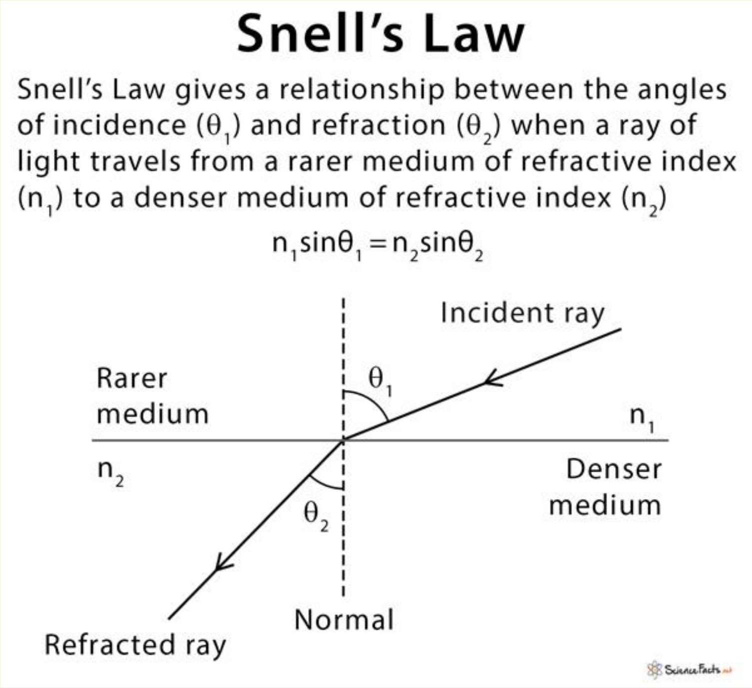
Understanding light-material interactions is critical for optimizing solar efficiency

Photovoltaic Effect: a physical phenomenon which produces a voltage and electrical current upon exposure to light or radiant energy

Snell's Law: When light travels between two media with different refractive indices, its speed changes, causing the light to change direction, mathematically expressed as $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

Material properties such as transparency, refractive index, thickness, and light scattering have all played a role in my analysis

Material Refractive Indices and Angles



Material	Refractive Index (n2)
Acrylic	1.49
Polypropylene	1.49
Polycarbonate	1.586
Tempered Glass	1.5
Clear Sheet Glass	1.5

$\theta 2=\arcsin(n1*\sin(\theta 1)/n2)$

Assumption for measurements
Refractive index of air n1=1.0003

Experimental Setup

Solar panel: 130W flexible panel of dimensions 960 mm by 690 mm by 2.5 mm in metric units

Material Overlays Tested

Turf, foam insulation, acrylic, polypropylene, polycarbonate, tempered glass, and clear sheet glass

Testing Conditions

Controlled: Artificial 5000K light source simulating sunlight at specific angles of 10°, 20°, 30°

Uncontrolled: Natural sunlight around 10°, 20°, 30°, varying environmental conditions

Measurements

Voltage outputs and refractive angles

Uncontrolled

Material	Sun Altitude (degrees)	Voltage Output (volts)
No Overlay	29.79	24.07
No Overlay	20.14	23.18
No Overlay	11.71	22.86

Material	Sun Altitude (degrees)	Voltage Output (volts)
Polycarbonate	29.8	23.91
Polycarbonate	20.38	23.05
Polycarbonate	11.35	22.51

Controlled

Material	Light Altitude (degrees)	Voltage Output (volts)
No Overlay	32.14	12.92
No Overlay	20.7	11.92
No Overlay	11.19	11.27

Material	Light Altitude (degrees)	Voltage Output (volts)
Polycarbonate	32.14	12.24
Polycarbonate	20.7	10.98
Polycarbonate	11.19	10.27

Uncontrolled

Material	Sun Altitude (degrees)	Voltage Output (volts)
Tempered Glass	29.84	20.07
Clear Sheet Glass	29.84	17.69
Polypropylene	29.83	16.47
Acrylic	29.82	14.75
Foam Insulation	29.85	8.74
Turf	29.84	7.12

Controlled

Material	Sun Altitude (degrees)	Voltage Output(volts)
Tempered Glass	32.14	9.43
Clear Sheet Glass	32.14	8.09
Polypropylene	32.14	3.504
Acrylic	32.14	5.64
Foam Insulation	32.14	0.315
Turf	32.14	0.027

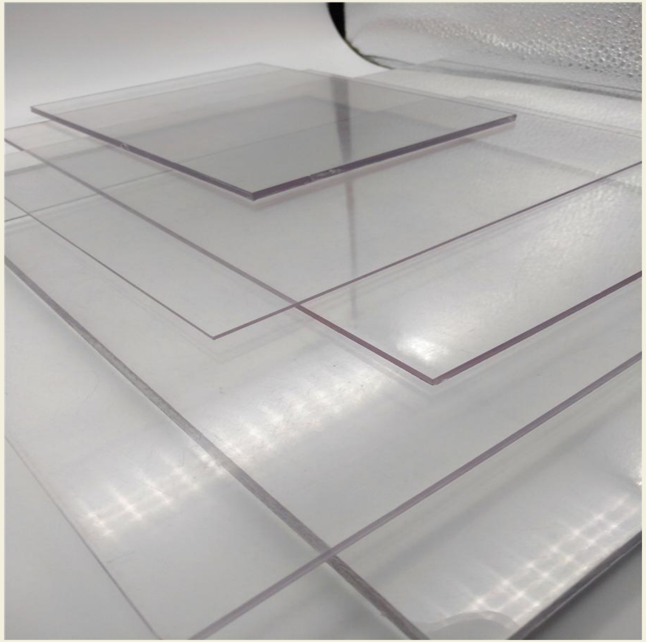
Summary of Findings

Polycarbonate performed best, closely matching results with no overlay on the solar panel

Transparent materials (tempered and clear sheet glass) showed high efficiency

Opaque materials (turf, foam insulation) had minimal output

Controlled Data was consistent with uncontrolled data



Polycarbonate Sheet

Theoretical Predictions

Order of Efficiency Realistic

Polycarbonate, Tempered Glass, Clear Sheet Glass, Polypropylene, Acrylic, Foam Insulation, Turf

Order of Efficiency Prediction

Tempered Glass, Clear Sheet Glass, Polycarbonate, Acrylic, Turf, Polypropylene, Foam Insulation

Unexpected results

Foam Insulation outperforming Turf
Polypropylene outperforming Acrylic

Uncontrolled Challenges

Inconsistent sunlight angles during uncontrolled testing, decreases continually after peak

Weather variability (e.g., cloud cover, wind)

potential material imperfections

While the sun data is accurate, minor deviations (less than a degree) might occur due to atmospheric refraction or local elevation not being accounted for exact

Sun Graph and Daily Specifications

https://www.timeanddate.com/sun/usa/syracuse?month=11&year=2024

Identified polycarbonate as an optimal overlay material due to high transparency and efficiency

Provided foundational data for integrating solar panels into road infrastructure, as well as material selection for these integrations

Gained a preliminary understanding of solar panel performance

Established a first approximation of optimal conditions for materials that could work best under real world conditions such as a solar road tile

Future Research..

Test materials under mechanical stress

Explore new materials with innovative optical properties (e.g coatings, etc)

Design a solar road tile

This project has demonstrated to me the impacts that overlay materials and their optical properties have on the efficiency of solar panels. Through both theoretical analysis and experimental data acquisition, it is evident that optimizing overlay material selection is very important for enhancing solar energy capture particularly when being implemented into future infrastructure technologies. Particularly transparency and refractive properties are critical to pay attention to in maximizing solar energy output.

I am encouraged to further my interdisciplinary research combining material science and infrastructure

Thank You
Questions