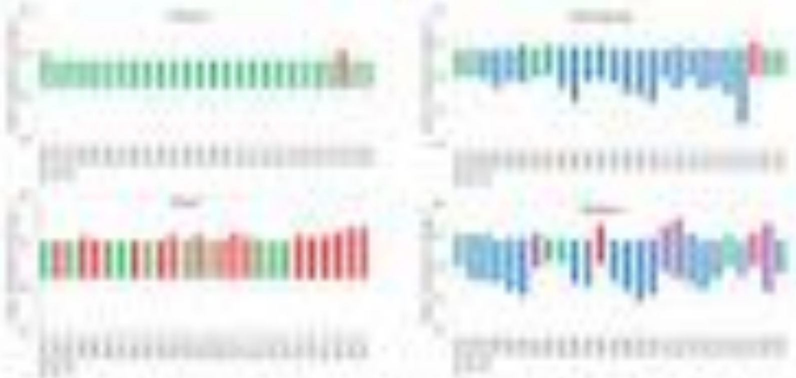
Typical and extreme weather data for simulating the performance of buildings entirely conditioned with ambient energy

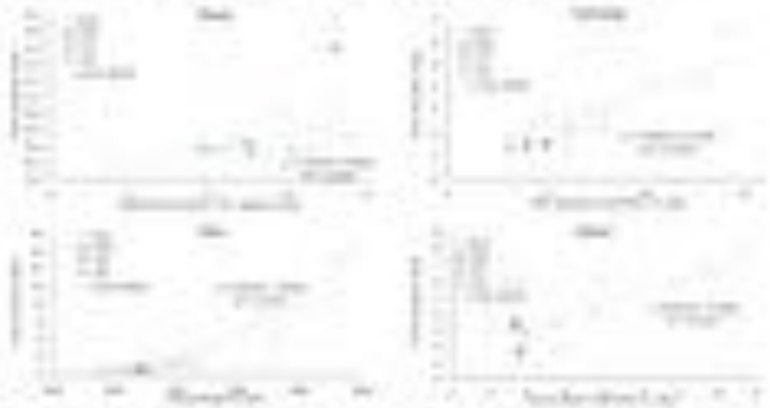
M. Keith Sharp

INTRODUCTION

METHODS

RESULTS





DISCUSSION

REFERENCES

Typical and extreme weather data for simulating the performance of buildings entirely conditioned with ambient energy

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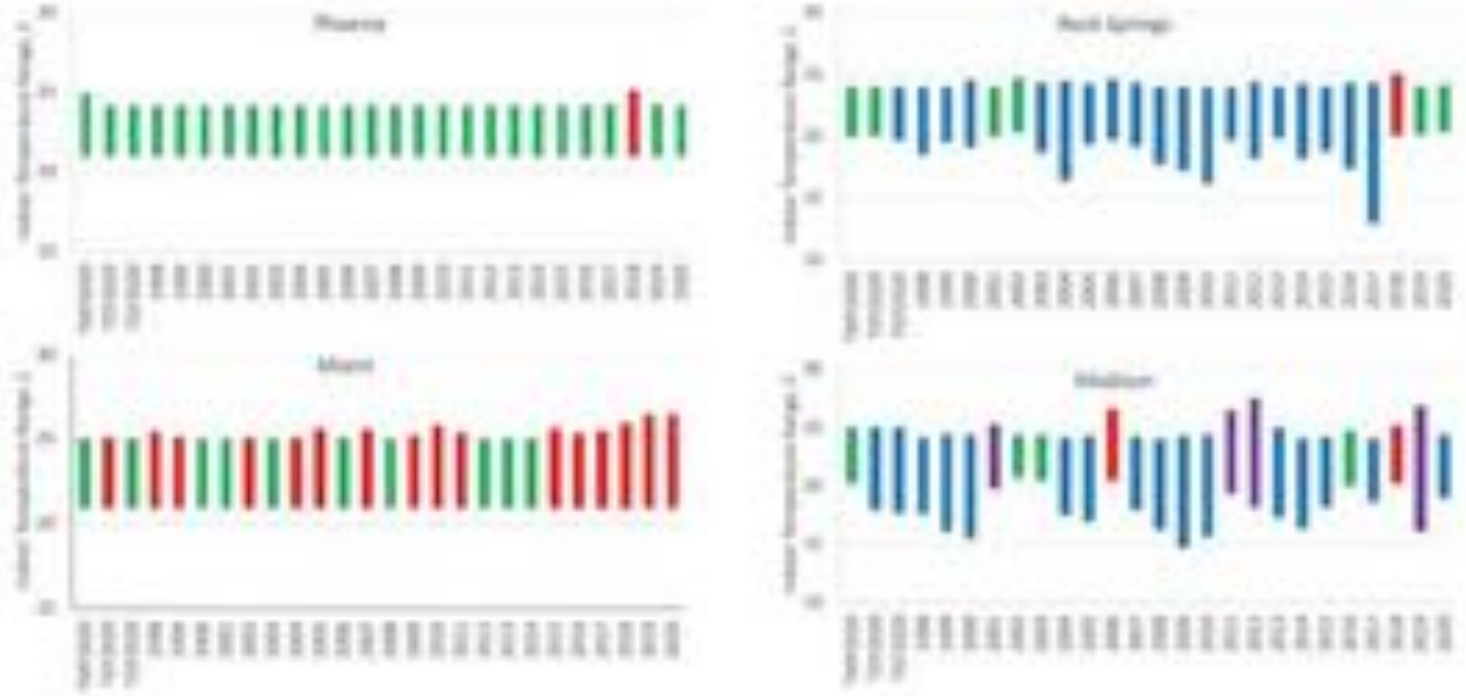
Summary

Typical meteorological year (TMY) weather data does not produce mean or median results for buildings that are conditioned entirely with ambient energy.



Results

- For a house designed to be comfortable for TMY in Phoenix, it is also comfortable for all years from 1998-2020 except 2018.
- Miami: overheats for 14 of 23 years.
- Rock Springs: overheats for 2018 and undercools for 18 years.
- Madison: overheats for 6 years and undercools for 18 years.

Conclusions/Implications

- Instead of TMY, multi-year simulations should be performed.
- TMY may contribute to perceived low performance in early passive solar homes.

First year performance of the Pagosa Springs Ambient House

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INTRODUCTION

The Pagosa Springs Ambient House is heated almost entirely by passive solar and cooled by nighttime ventilation, and has no auxiliary heating or cooling other than a fireplace. Ventilation is provided by an ERV. The Pagosa Springs climate is sunny and cold, with 8323 degree F days of heating and 50 degree F days of cooling for TMY3 weather data.

METHODS

The 3700 ft^2 house has R73 walls, R123 ceiling and R48 floors. Windows are R7. Thermal mass is provided by concrete floors in the basement and on the main floor, and by concrete walls around the basement, giving thermal capacitance per unit floor area of 325 kJ/K m^2 (compared to conventional construction of 125 - 452 kJ/K m^2. The windows for solar gain are 6% of the floor area, including a Trombe wall. The internal heat gains per unit floor area average 2.06 W/m^2. The peak heating load is 8.7 W/m^2 (compared to the PassivHaus limit of 10 W/m^2).

These dimensional building parameters give the following dimensionless parameters:

1. **Solar Load Ratio** $SLR = SA_c/UA\Delta T_o = 0.808$ for January, where S is absorbed insolation, A_c is the solar aperture area, UA is the overall building loss coefficient and ΔT_o is the largest difference between indoor and outdoor temperature.
2. **Internal heat Load Ratio** $ILR = G/UA\Delta T_o = 0.345$ for January, where G is the internal heat gain.
3. **Thermal time constant** $T = mc_p\Delta T_i/UA\Delta T_o = 1.75$, where mc_p is the thermal capacitance and ΔT_i is the design indoor comfort temperature range of 25 – 20 = 5ºC.

RESULTS

The house was unoccupied during the Christmas through New Year holidays of 2021-2022, and the indoor temperature dropped to 54ºF (Fig. 1 upper left). When the house was occupied, the indoor temperature during 2022 varied from 64 to 79ºF compared to the design range of 65 – 75ºF. The lowest temperature was in December (Fig. 1 lower right), which was unusually cloudy compared to TMY. The fireplace was used eight time during December, for a total of about 24 hours, and was not fired the rest of the year. The highest temperature occurred during an unseasonably warm period in October (Fig. 1 lower left), when solar gains through south-facing windows were also increased due to the lower solar altitude. The windows that were opened made a significant difference in nighttime ventilation cooling (Fig. 1 upper right).

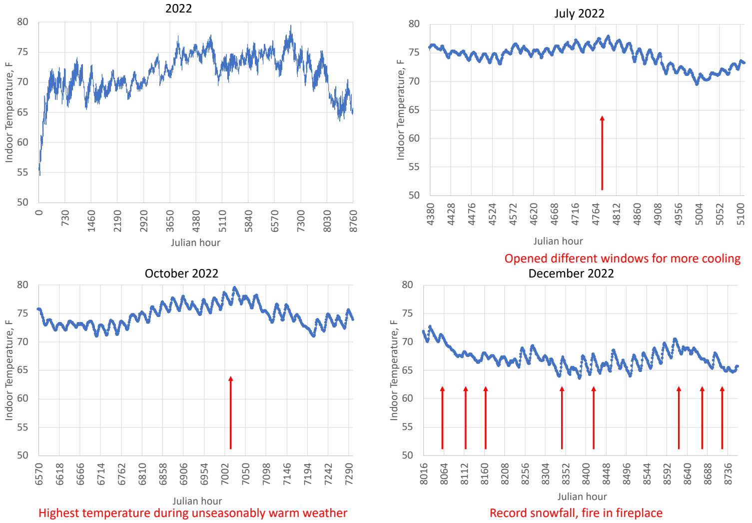

Figure 1. Indoor temperatures for 2022.

DISCUSSION

In 2022, the house got one degree F cooler, and required several wood fires, compared to TMY3 design conditions. This was largely due to the cloudy December 2022. The house also got four degrees warmer, again due to unusual weather. These results are consistent with a new study that shows that TMY data is not reliable for designing ambient-conditioned buildings (see my other poster at this conference).

Potential additions that may improve future performance include:

1. Geothermal preheating of air for the ERV.
2. Shade for the Trombe wall.
3. Insulate attached garage.

First year performance of the Pagosa Springs Ambient House

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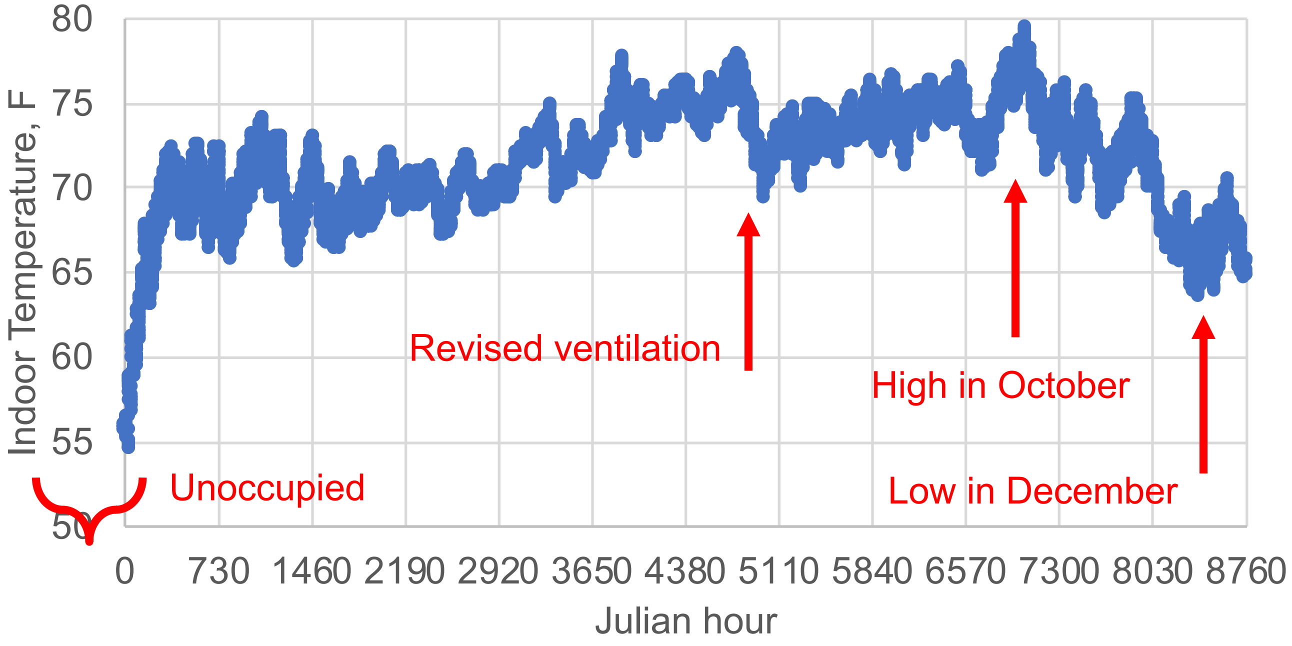
Summary

The Pagosa Springs Ambient House, when occupied, had an indoor temperature range of 64 – 79^oF during 2022, close to its design range of 65 – 75^oF for TMY3 weather.



Results

- When unoccupied during a 12-day storm, 54^0F.
- High of 79^oF in October during unusually hot period.
- Low of 64^oF in December during unusually cloudy period. Wood fires for ~24 hours.
- Nighttime ventilation window opening strategy matters.

Conclusions/Implications

- Unseasonable weather impacts performance of an entirely ambient-conditioned building.
- ➢ See my other poster evaluating TMY weather data.


Designing Buildings of the Future
Solar Decathlon

Over 700 Student Teams Designing Buildings of the Future

Jes Brossman, jes.brossman@nrel.gov, NREL

Summary

The U.S. Department of Energy (DOE) Solar Decathlon® Design Challenge focuses to support educational programs in training the next generation of building design professionals. Solar Decathlon's 10 Contests aim to transform the building industry by challenging student teams to think beyond a zero energy ready building and address complex real-world issues. **Come learn how college students are designing buildings of the future.**


On-site photovoltaics (PV) and community solar for residential home


On-site PV and solar water heating on floating cabins at a girl scout camp


Bifacial PV in multifamily building

Results

- ✓ Inspired over 5,000 students
- ✓ Involved 218 collegiate institutions from 32 countries and 47 states
- ✓ Over 300% growth in participation since program inception
- ✓ A network of more than 1,000 industry partners
- ✓ Provided student effective building science curriculum enhancement
- ✓ 25% of Design Challenge projects focused on retrofit or renovation of existing buildings

AMERICAN SOLAR ENERGY SOCIETY

Evaluation of Six Greenhouse Covering Materials for Energy Performance

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Supported by USDA Natural Resources Conservation Service NR203A750008G006

Summary

Investigation of Six Greenhouse Coverings: This study explores various greenhouse coverings, including diverse glass types, polyethylene (PE), and polycarbonate (PC) layers, with a focus on their optical and thermal properties. Spectrum data collection and optical data simulation were performed using LBNL software OPTICS and WINDOWS.

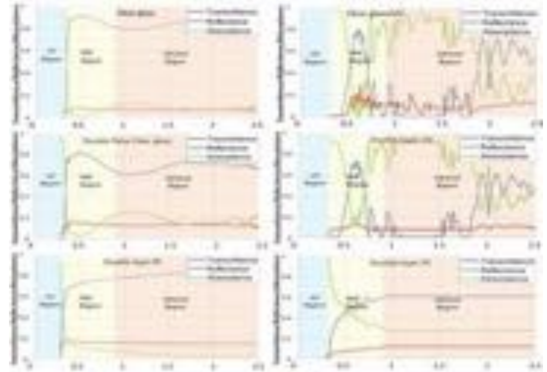
Energy Efficiency Assessment: The study utilized SHGC and U-factor to evaluate the energy efficiency of the greenhouse cover materials. A Sketchup established model was employed to assess the performance, and EnergyPlus software was utilized for model simulation. The research was conducted in State College, PA, which falls under the 5B climate zone.

Comparative Analysis: Annual energy consumption, specifically total energy usage, heating through natural gas, and interior lighting, was compared and analyzed in the context of the different greenhouse coverings.

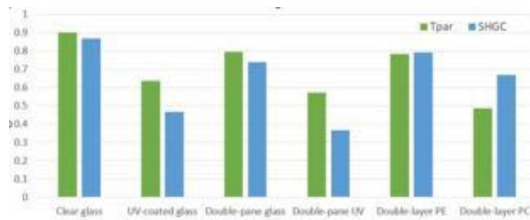
Notably, double-pane structures exhibited similar U-factors but displayed significant differences in PAR transmittance and SHGC.

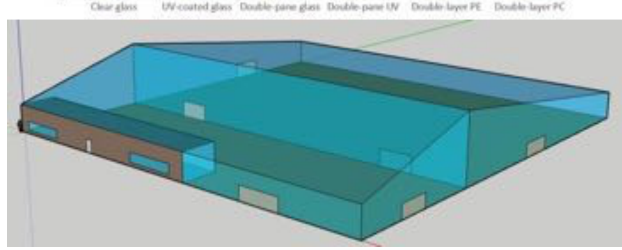
All transparency surfaces with raised roofing.

Specific features and controls were added, such as daylight control maintaining setpoint lux and DGI levels, a lighting system operating for 14 hours daily, and adjusted HVAC settings.

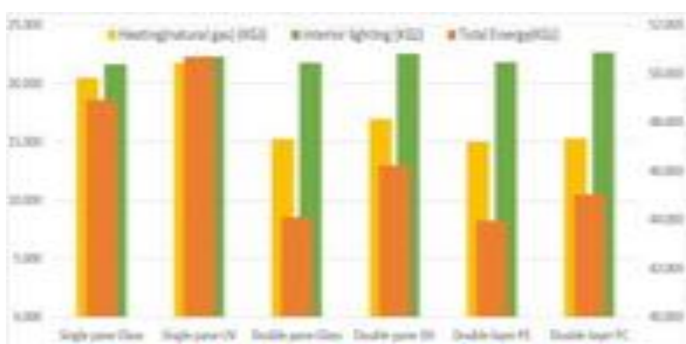


OPTICS WINDOWS





Sketchup Energy plus



Results

UV-coated materials show high PSG values, indicating superior photosynthetically active radiation transmission with reduced solar heat gain. Double-layer PC exhibits a lower PSG value, reducing light transmission and increasing heat gain. PAR transmittance varies among materials, with clear glass having the highest value and UV-coated clear glass reducing SHGC by 46.2%.

Double-layer PE and PC show remarkable energy savings of 10.1% and 7.9% compared to single-pane glass. Double-layer PE and PC also demonstrate substantial reductions in heating energy consumption by approximately 26.9% and 25.2%, respectively.

PAR transmittance on interior lighting is relatively minimal, with double-layer PC resulting in a slight 4.61% increase in interior lighting usage due to reduced PAR transmittance compared to clear glass.

Conclusions

In total and heating energy consumption, with double-layer PE and PC materials showing high energy efficiency. The U-factor played a critical role in energy consumption, while the interplay between U-factor, SHGC, and PAR transmission was important to consider. Moreover, the study found that PAR transmittance had a relatively minor impact on interior lighting.

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PennState College of Engineering · ARCHITECTURAL ENGINEERING · ARCHILAM BDA · AMERICAN SOLAR ENERGY SOCIETY

Energy Performance Greenhouse Covering Materials

Simulation based on real spectrum and optical data

Full transparency glazing and consideration of interior lighting

Various covering material including
Clear glass, PE, PC, and UV coating

All at poster presentation for
Evaluation of Six Greenhouse Covering Materials
for Energy Performance

Quantifying Solar Light-Induced Thermal Comfort Effects of Architectural Windows

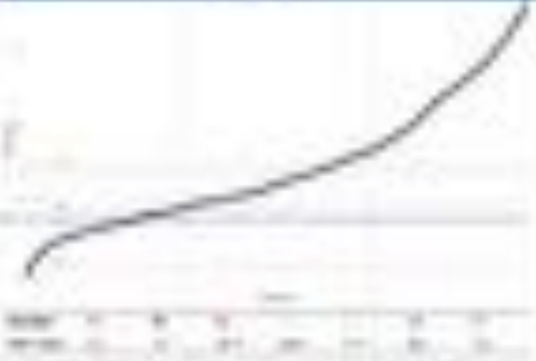
The Pennsylvania State University

Problem Statement

Introduction

Methods

Results



Conclusion

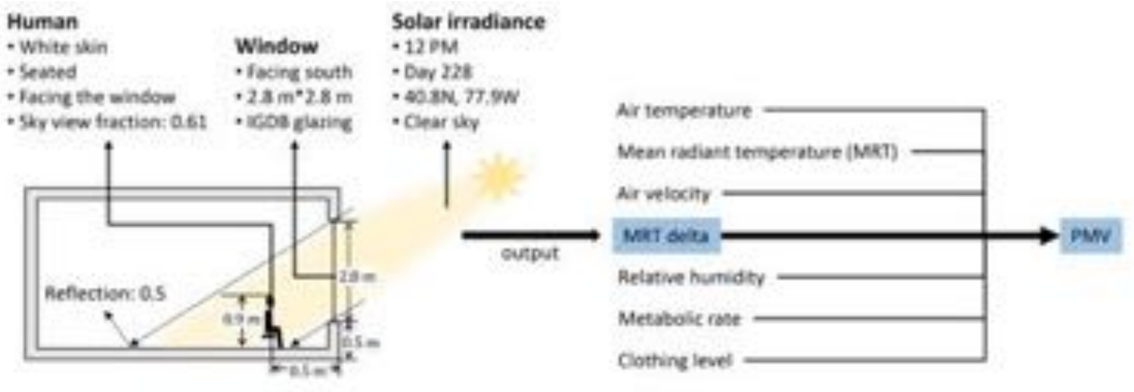
ASES SOLAR 2023

Quantifying Solar Light-Induced Thermal Comfort Effects of Architectural Windows

Nan Wang, nfw5139@psu.edu, The Pennsylvania State University

Summary

Quantifying the solar light-induced thermal comfort effects of architectural windows can be helpful in selecting appropriate windows for buildings, ultimately improving the thermal comfort of humans and energy savings.



Results

- MRT delta values range from 0.0014 to 36.15, which corresponds to a difference of approximately 6.5 difference in PMV values.
- The preferred MRT delta values differ across various indoor environmental conditions.

Conclusions/Implications

- Window has a substantial influence on solar light-induced thermal comfort effect.
- Different windows would require different indoor environment conditions to maintain thermal comfort, thereby offering the potential for energy savings.

AMERICAN SOLAR ENERGY SOCIETY

Development of a novel approach for spectral characterization of individual daylighting exposure through windows

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Penn State University

National Institute on Aging

Supported by "The Effect of Smart Ambient Bright Light for Nursing Home Residents with Alzheimer's Disease and Related Dementias", National Institute of Health (NIH)/National Institute of Aging (NIA)

Introduction

This study focuses on understanding the impact of light exposure on the circadian rhythms of nursing home residents with dementia. Inadequate light exposure can disrupt sleep patterns and circadian rhythms, leading to negative effects on overall well-being. The study aims to explore this relationship and its implications.

Methods

Two types of sensors were utilized: a light spectrometer called CL-500A (fig. 1) and button-sized sensors. Data was collected manually and recorded in a spreadsheet. Correlations between light metrics such as circadian stimulus (CS), correlated color temperature (CCT), lux values, and circadian light (Cla) were analyzed. Other variables, including electric light, window blind slat angle, viewing angle, and distance from the window, were also considered (fig. 2).

Exploratory Analysis

Scatterplots were created to visualize the relationship between CS and CCT, lux, and Cla. Strong positive correlations were observed between CCT and CS, as well as between CCT and Cla (fig. 3).

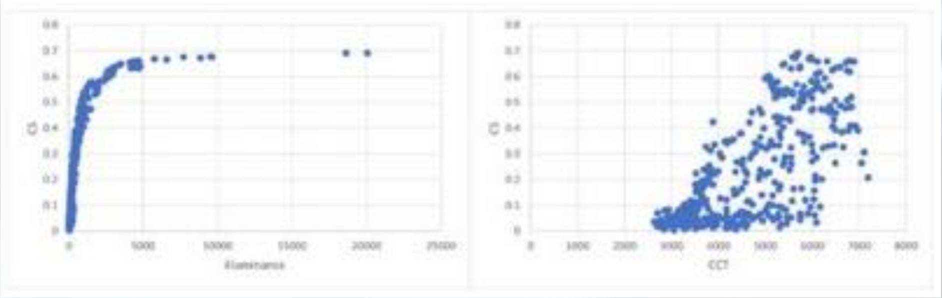

Figure 3. Lux amount vs. CS (left) and CCT vs. CS levels (right)

Figure 1. CL-500A Illuminance Spectrophotometer KONICA MINOLTA

Figure 2. Preparing to set up the measurements inside the nursing home resident's individual room

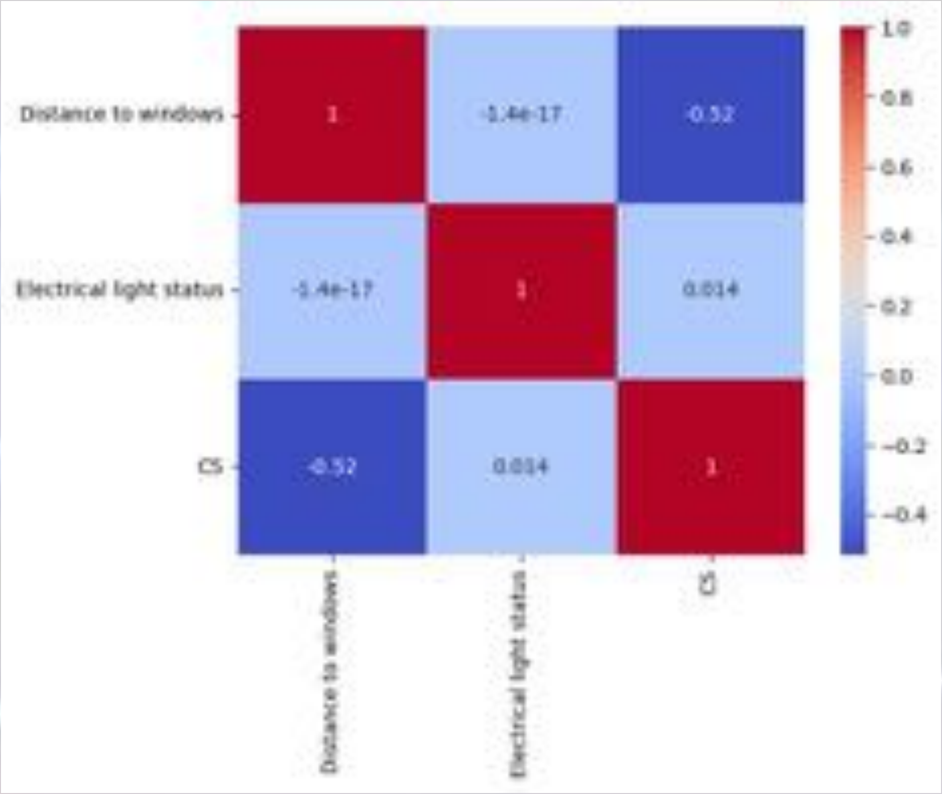

Figure 4. Diagram of project heatmap, denoting the strongest correlations resulting in circadian stimulus variations

Descriptive statistics were computed, revealing mean CS and Cla values of 0.369 and 0.178, respectively, with corresponding standard deviations.

Data Analysis

A multiple linear regression model was applied to predict CS and Cla based on CCT and lux values. Results indicated that CCT significantly predicted both CS and Cla, while lux values did not have a significant impact (fig. 4).

Model Selection and Application

Machine learning algorithms were employed to analyze the dataset collected from nursing homes. The impact of various factors, such as electric light, window blind slat angle, viewing angle, and distance from the window, on CS levels was investigated. Distance from the window was found to have the most significant impact, suggesting the importance of natural light exposure for better circadian health.

Conclusion and Future Research

The study highlights the significance of lighting conditions in nursing homes, particularly for residents with dementia. Optimizing lighting conditions can improve circadian rhythms and overall well-being. Recommendations include positioning patients closer to windows, using angled blind slats, and reducing the reliance on electric light. Future research could explore additional factors and include a larger sample size for broader generalizability.

AMERICAN SOLAR ENERGY SOCIETY

Development of a novel approach for spectral characterization of individual daylighting exposure through windows

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Supported by "The Effect of Smart Ambient Bright Light for Nursing Home Residents with Alzheimer's Disease and Related Dementias", National Institute of Health (NIH)/National Institute of Aging (NIA)

Summary

Daylighting is a significant source of interior electrical lighting energy savings and has a significant impact on the well-being and health of building occupants. In recent years, the proliferation of sustainable films, coatings, and attachment systems has complicated the spectral characteristics of architectural windows and glazing systems. Compounded with the color characteristics of domestic materials, surfaces, and furniture, it is difficult to comprehend the spectral details of incident daylight for each individual. Using sensors and machine learning algorithms, we develop a methodological framework for estimating individual exposure to the daylight spectrum. In this framework, various window and glazing systems are also considered.

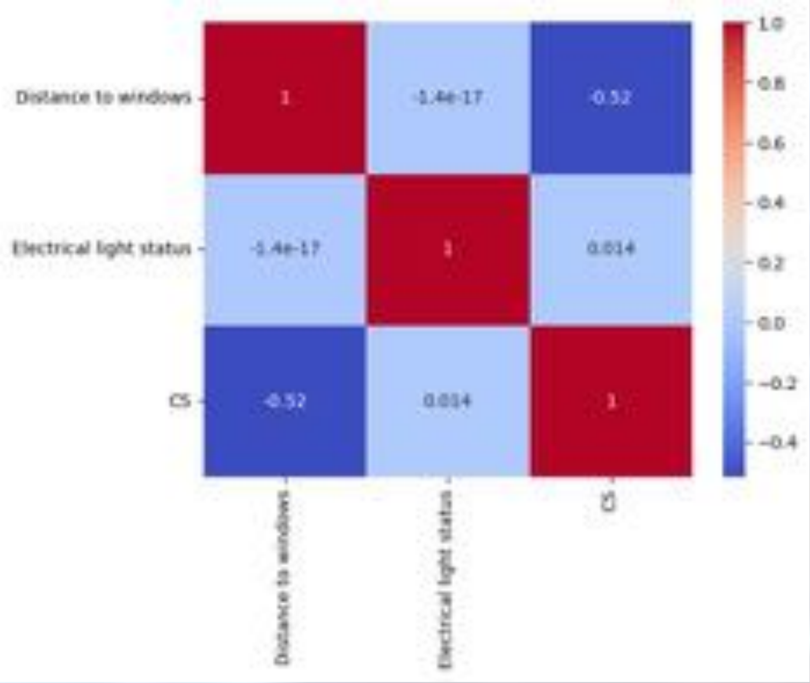


Figure 1. Diagram of project heatmap, denoting the strongest correlations resulting in circadian stimulus variations

Results

- The study findings suggest that lighting conditions have a significant impact on the circadian rhythm of nursing home residents. The project analyzed data collected from two types of sensors, a light spectrometer, and a button-sized sensor that tracked circadian light data worn by patients. Machine learning algorithms were applied to perform time-series analysis to determine the optimal circadian situations for human subjects, primarily dementia patients. The time-series analysis determined the optimum times for circadian situations for dementia patients, with recommendations such a positioning patients closer to the window with angled blind slats and reducing the use of electric light during these times.
- The initial exploratory analysis revealed a positive correlation between the CCT and lux values and the CS and a negative correlation between the distance from the window and the blind slat angle with the CS.
- Furthermore, the distance from the window had the most significant impact on the CS condition. These findings emphasize the importance of nursing homes providing access to natural light and promoting better circadian health among their residents (fig. 1).

Conclusions/Implications

- This study's results have important implications for nursing home facility staff, as they can use this information to adjust patients' activities schedules to take advantage of the best light conditions, particularly for dementia patients.
- Future research could expand on this study by investigating other factors that affect the CS of dementia patients and include a larger sample size to increase the generalizability of the findings.

What Consolidation Means for the Solar Industry

Embracing Market Consolidation and the Benefits of Mergers

What is Driving Consolidation in the Solar Market?

Advantages of Mergers in the Solar Industry

What Does This Mean for the Future?

Summary

What Consolidation Means for the Solar Industry

Eric Peterman, Solar.Info@nelnet.net, Nelnet Renewable Energy

Summary

The solar industry's 20% annual growth over the past several years has led to inevitable consolidation and mergers. This activity has paved the wave for a more robust, efficient, and sustainable solar industry, leading to a greener and more sustainable energy landscape.

Results

- Pooled expertise, technology and resources amplify innovation that propels the industry forward.
- Greater economies of scale and optimized efficiency increase affordability and access and enhance products and experiences.
- A more stable market creates a stronger voice for shaping policy.

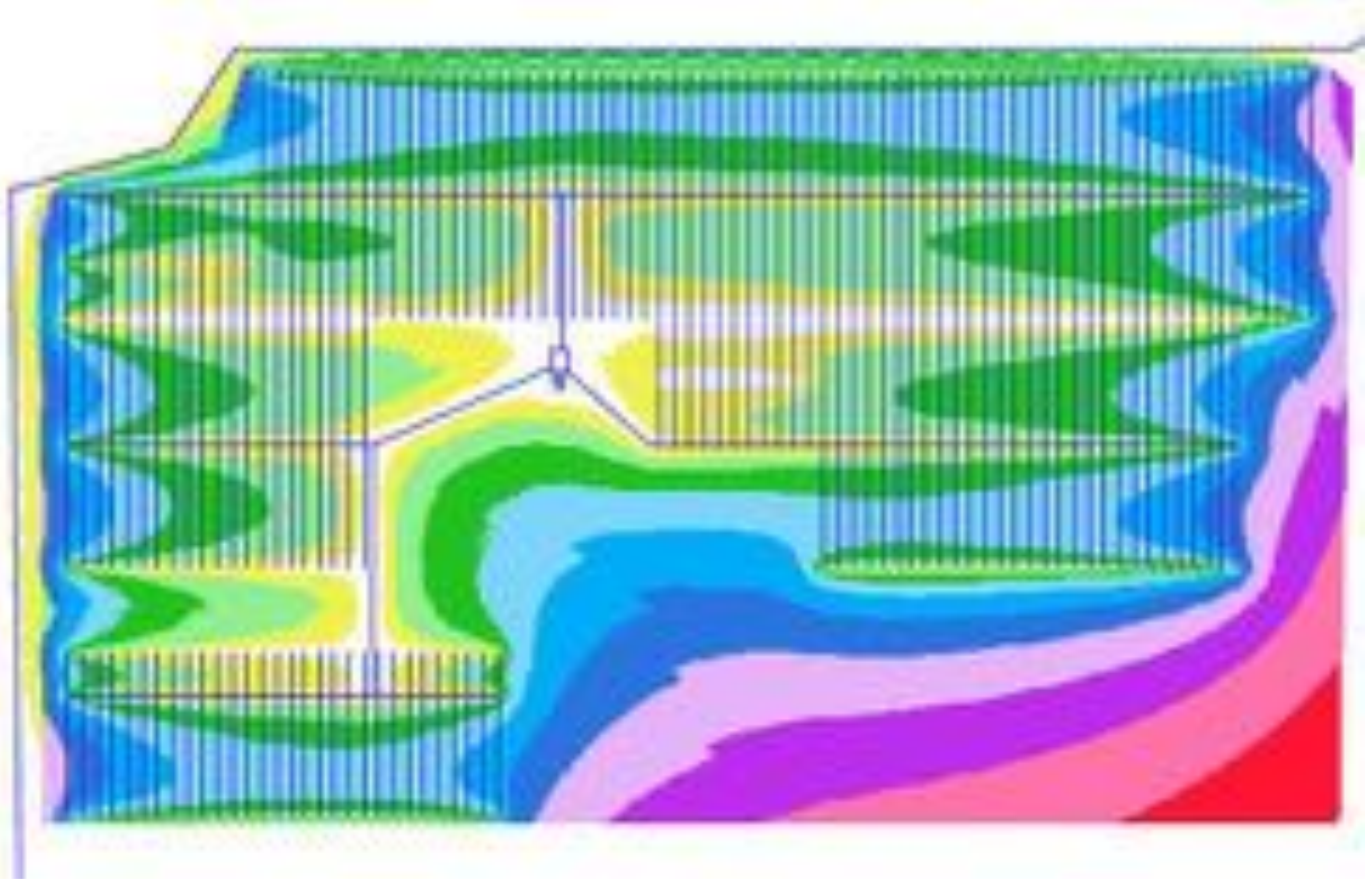
Conclusions/Implications

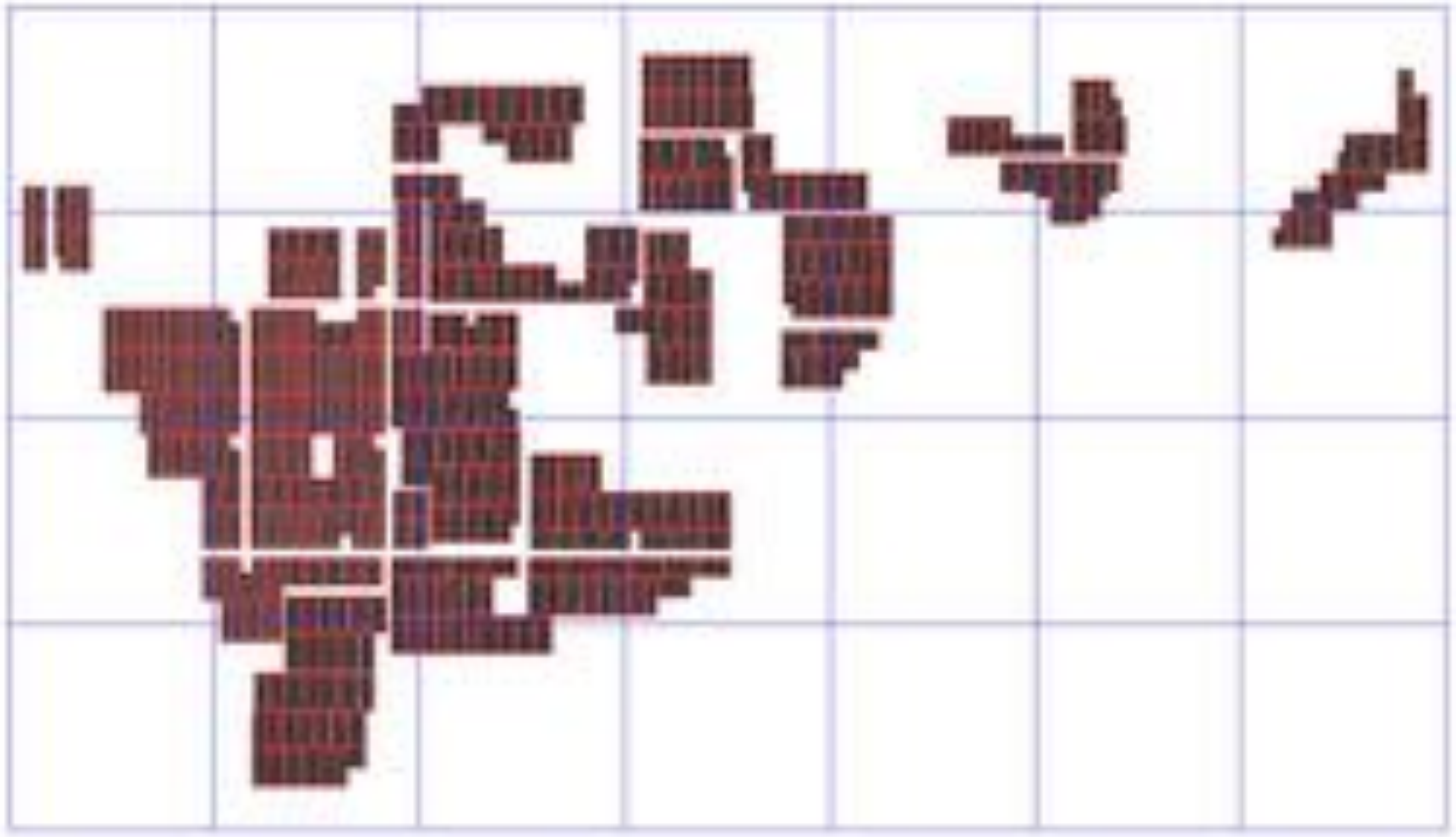
- Accelerated advancements in solar technologies.
- Increased solar adoption rates.
- A more stable solar market.
- Solar pricing more competitive with traditional power sources.
- Tremendous job creation and growth.

nelnet Renewable Energy

OPTIMIZING PV SAFETY GROUNDING

PV facilities typically have odd shapes and large layouts making the challenges for creating safe grounding solutions more apparent than in substations and other renewables technologies.





Obtaining quality soil resistivity data is influential in the analysis.

Following IEEE 2778 is recommended for collecting soil resistivity data.

OPTIMIZING PV SAFETY GROUNDING

Inverter Grounding

- Standard ground ring with ground rods

Trench Ground Wires

- DC connections to trackers
- AC ground wire works with concentric neutrals

Safety Assumptions

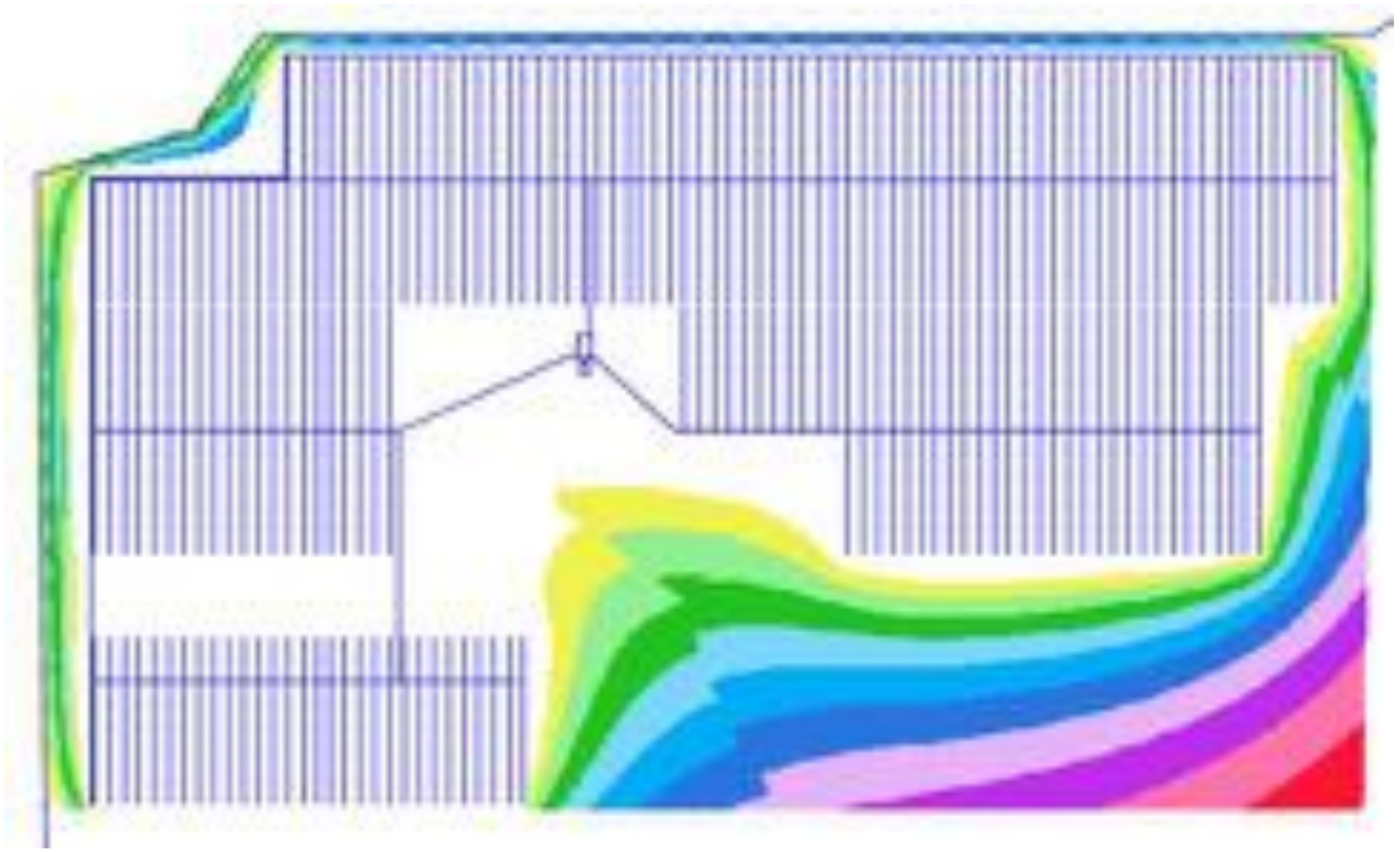
- Clearing time
- IEEE 80

PV Tracker Grounding

- Bonding piles & torque tube
- Each pile acts as a ground rod

Fence Grounding

- Distance from modules to the fence
- Ground rods & isolation panels



Since the grounding network is inter-connected, decisions made in all stages of the project design affect the resulting grounding network's performance and risk management for electrical hazards.

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A Comparison of Advection-Based and Machine Learning PV Forecasts for Puerto Rico Forecasting

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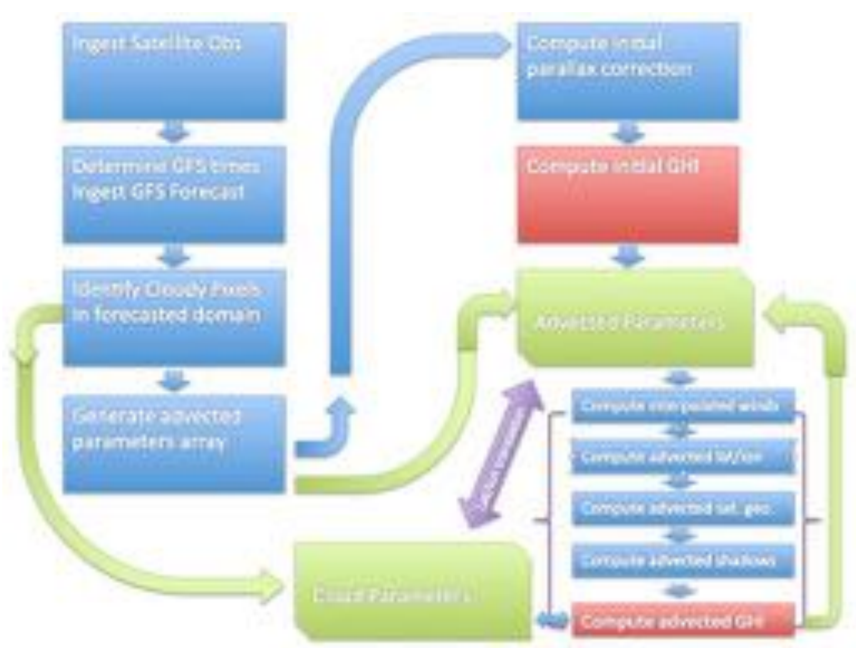
Power infrastructure for Puerto Rico fragile after tropical storm/hurricane

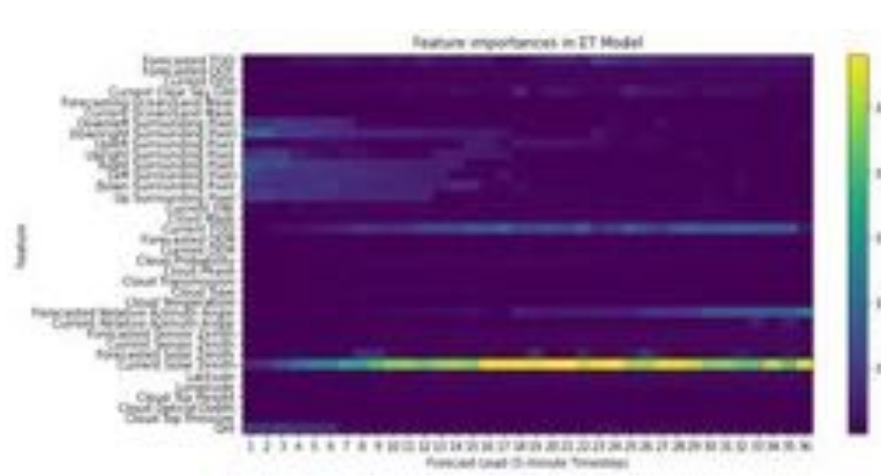
Considerable outages after Hurricane Maria, impact on disaster response, healthcare sector, and emergency communications

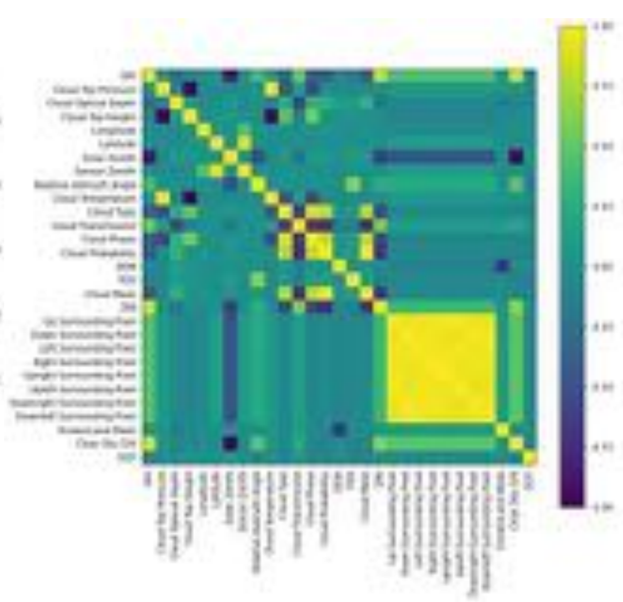
Idea: distributed solar to generate power, replacing central power grid and power line with more resilient dispersed photovoltaic (PV) generation

Solar needs: nearcasts of cloud shadow to prevent damage or outages in power due to cloudiness

Goal: 1-3 hour high turnaround solar forecast for Puerto Rico



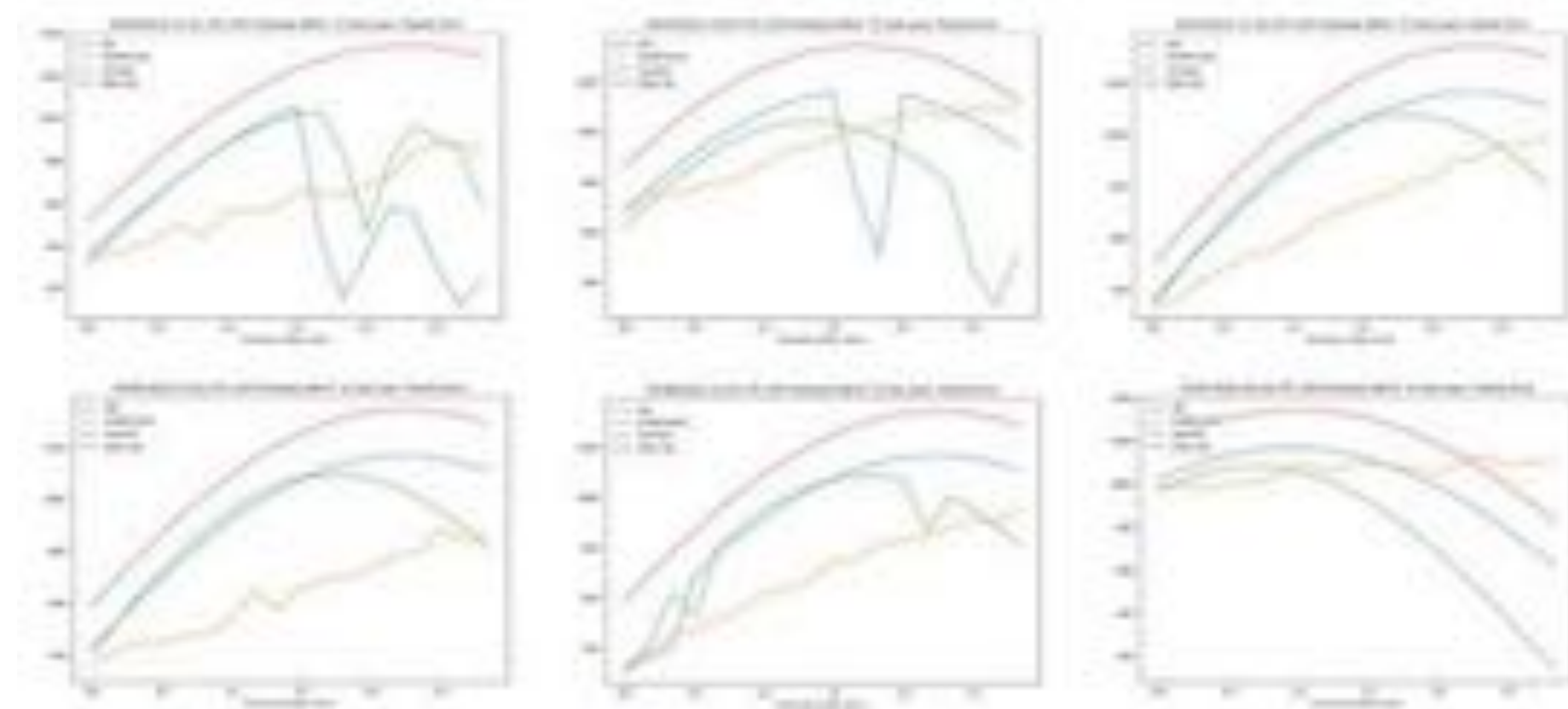




Satellite advection forecast – CIRACast – uses satellite observations in concert with NWP winds to 'push' cloud groups forward in time. Benefits – fast, accurate current cloud locations, ability for advanced radiative transfer models for GHI calculations. Limitations: advection for stationary and sheared clouds – cloud motion outside of wind-driven model.

Machine learning – 'extremely random trees' model. Similar to random forest. Was developed as an extension to random forest. Randomly selects the best feature for splitting the node and uses the whole training.

Approach – perform random trees forecast using GHI information from satellite forecast, compare to computed GHI foreacast from CIRACast.



- The extra trees model works best for up to 1-hour forecasts. By the three-hour mark, clouds are being overpredicted over the west part of the island regardless of where the clouds are actually supposed to be.
- CIRACast does a much better job at catching solar ramps, while the ET model just assumes that GHI increases linearly over time, even when the forecasts start later in the morning.
- The ET Model could work better at predicting the warmer months (April to October) than the "colder" months (December to March).
- Limitations: five days of training data not enough.
- Future work: Climatology, better validation, optimization techniques.

LOYOLA UNIVERSITY CHICAGO

“Investigating Property Value Impacts Near Midwestern Utility-Scale Solar Projects Using Difference-in-Difference Methods”

Sampson Hao, MS & Gilbert Michaud, PhD
For more info, contact: sampsonhao@pgrenewables.com

Introduction:

Utility-scale solar project proposals have been accelerating exponentially in the U.S. as the energy transition from fossil fuels to renewables unfolds. While the emissions and economic related benefits of deploying such projects are well documented, relatively less is known about their impact on nearby **property values**. This research investigates the location of utility-scale solar facilities in the **Midwest**, the average 3-bedroom housing value in the surrounding area, and whether the presence of a utility-scale solar project affects nearby property values in any manner.

Research Objective:

To determine the **association** and **magnitude** of impact between utility-scale solar projects and nearby property values.

Data and Methods:

This study included **70** utility-scale solar facilities (≥5MW-DC installed capacity) that became operational in the Midwest from **2009–2022** using data from the Lawrence Berkley National Laboratory. Alongside housing value data from Zillow, additional data was incorporated, including rurality, county, and state. Both normal housing value and standardized housing value (Case Schiller Index adjusted value) were tested. Three difference-in-difference (DID) models were conducted to determine the results.

Utility-Scale Solar Installs Across the Midwest

Variable Definitions

Variable	Definition
P_{xt}	Housing pricing at zip code x at time t
$Treated_{xt}$	Binary variable, 1 for the treatment group, 0 for the control group
$Post_{xt}$	Binary variable, 1 for after operation, 0 for before operation
$Rurality_{xt}$	Binary variable, 1 for non-metro zip codes, 0 for metro zip codes
$Size_{xt}$	Binary variable, 1 for projects with an installed capacity between 5–20 MW, 0 for projects with an installed capacity larger than 20 MW
$Year_{xt}$	Categorical variable, each year is in its own category
δ_{st}	State fixed effect
δ_{ct}	County fixed effect
δ_{xt}	Zip code fixed effect
C	Constant
E	Standard Error

DID Model Example (State Model)

$$P_{xt} = \beta^1 * Treated_{xt} + \beta^2 * (Treated_{xt} * Post_{xt}) + \beta_3 * Rurality_{xt} + \beta_4 * Size_{xt} + \beta_5 * Year_{xt} + \delta_{st} + C + E$$

Results:

DID Property Value Impact CS Adjusted AHV Analysis

Variables/Models	Model 1: State	Model 2: County	Model 3: Zip Code
Treated VS Controlled (β_1)	-1,458	-3,338***	Unidentified
Property Value Impact (β_2)	-662	2,640**	700***
Rurality (β_3)	-25,563***	-22,166***	Unidentified
Project Between 5–20 MW Installed Capacity (β_4)	13,620***	50,206***	23,200***
Constant (C)	177,335***	158,793***	143,235***
Numbers of Observations (n)	5,778	5,778	5,778
Standard Error (E)	12,472	2,670	2,443
R^2	0.5642	0.8209	0.9897
Adjusted R^2	0.5629	0.8197	0.9895
* p < 0.10; ** p < 0.05; *** p < 0.01			

DID Property Value Impact Normal AHV Analysis

Variables/Models	Model 1: State	Model 2: County	Model 3: Zip Code
Treated VS Controlled (β_1)	-2,921***	-2,976***	Unidentified
Property Value Impact (β_2)	2,004**	1,310**	3,199***
Rurality (β_3)	-21,910***	-10,425***	Unidentified
Project Between 5–20 MW Installed Capacity (β_4)	19,492***	779	8,357***
Constant (C)	94,369***	185,827***	143,235***
Numbers of Observation (n)	20,815	20,815	20,815
Standard Error (E)	9,985	21,281	18,388
R^2	0.5880	0.8158	0.9483
Adjusted R^2	0.5875	0.8151	0.9479
* p < 0.10; ** p < 0.05; *** p < 0.01			

Conclusions:

-Utility-scale solar projects can increase nearby property values by **0.5–2.0%**
-Smaller projects have more of a positive impact on nearby property values than projects that are ≥20 MW

Acknowledgments: Special thanks to the School of Environmental Sustainability at Loyola University Chicago and the graduate thesis committee: Dr. Gilbert Michaud, Dr. Lopa Chakraborti, Dr. Richard (Max) Melstrom, and Dr. Bo Zhang.

Solar:
Just Cook With It Already!

No Excuses!
Top Ten Learnings from Inventors, Makers, Promoters, Tinkerers

10. **Create partnerships, even if your partner has to be a hearse**

9. **Get regulators to recognize–legislators incentivize solar thermal for food processing and cooking– and disincentivize fossil fuels.**

8. **The 30,000 foot view is not enough. Try the 5'9" view as well.**

7. **PV fans: Don't dis' solar thermal – cookers.**

6. **Thermal Solar Cooker Fans: Get used to PV-to-electric cookers.**

5. **Love it or hate it– use social media to get the word out.**

4. **Phase out plastics in solar cooker design.**

3. **Yes. You can solar cook in winter. With low sun. Even after sunset.**

2. **Go hybrid! Thermal under sunlight, plug in the rest of the day.**

1. **It's not just for camping any more. Start cooking with pure sunlight. Today**

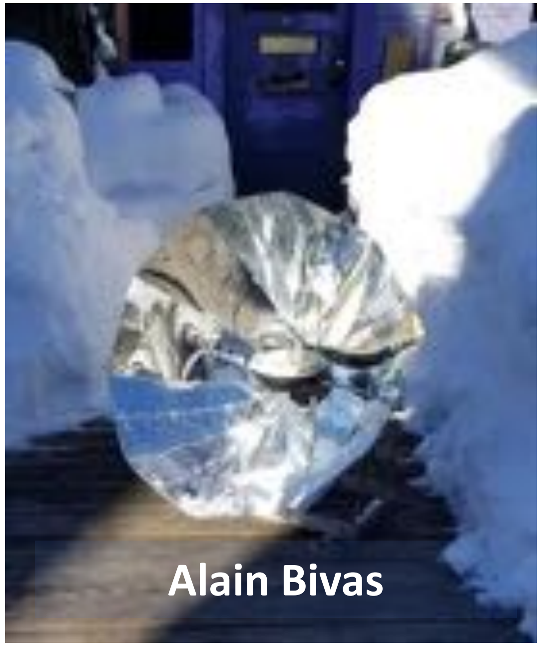
Help halt climate change. Become energy independent. Cook with sunlight.

Solar: Just Cook With the Sun Already!

Luther Krueger Museum@BigBlueSun.net

Over 100 solar cooks interviewed say:

* No Excuses! It's as easy as using any kitchen appliance.
* It is the cleanest way to cook - period. Zero emissions.
  Up to 76 gigatons CO^2 reduction through clean cooking.
  Can be done *anywhere there is* sunlight.
* Not just for preventing deforestation any more!
* You can cook any day of the year, anywhere in the world.
* It's FREE or next to it.
* "It's just freakin' awesome!"



Solar Cookers International WIKI

Performance Evaluation of a Floating Photovoltaic System in Saudi Arabia

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Summary

This study reports the potential of Floating Photovoltaic (FPV) systems in the Saudi Arabian environment. As the temperature of PV module increases, its efficiency drops depending on its rated temperature coefficient. The solar panel back surface is mostly affected by the temperature due to heat encapsulation. The temperature difference between the ground mounted and the FPV systems reached a maximum of 16.15 ºC during May. Even a moderate reduction in PV module temperature can play an important role in large scale solar power plants over a long period of time. This demonstration set up includes the design of an FPV system of 171.9 kWp capacity installed on the water surface a lake around the centre of KFUPM campus.

Keywords

Floating Photovoltaic (FPV) Plant, PV efficiency, Back Surface Temperature, Energy Output

Introduction

To reach the CO_2 emission target set by the VISION 2030 of the Kingdom of Saudi Arabia, the share of renewables in its energy mix has to be increased significantly. Towards the set goal, the proposed system will be an excellent option for power generation at places having bounded water bodies. In the proposed modern "LINE" cities in the RED SEA areas; such systems will be extremely useful to generate power efficiently and at the same time conserve water by minimizing the surface water evaporation losses. As of 2014, there were 482 dams in the country with total capacities of 2.08 Billion cubic meters of water. Some of these dams are located in Al-Baha (22), Asir (16), Jazan (2), Madina (5), Mecca (11), Najran (1), Riyadh (6) and many others. Such dams and water reservoirs can be utilized to deploy the floating PV systems and can generate power for the local communities. As an example, Baysh dam is a gravity dam on Wadi Baysh about 35 km northeast of Baysh in Gizan, as shown in Figure 1. Its catchment area is 4,843 km^2 and volume capacity is 675,000 m^3.

Fig. 1. The Baysh dam near Gizan

Fig. 2. A 10 KW FPV plant [7]

FPV is relatively a new concept, with few commercial deployments. However, proof of concept type of implementations is available around the world. To conserve the valuable land & water, installing Solar PV system on water bodies like oceans, lakes, lagoons, reservoirs, irrigation ponds, waste water treatment plants, wineries, fish farms, dams, and canals can be an attractive option [1]. Floating type solar photovoltaic panels have numerous advantages compared to ground based solar PV plants, including fewer obstacles to block sunlight, convenient, energy efficiency, and higher power generation efficiency owing to its lower temperature underneath the panels. Photovoltaic technology is the most common, effective, sustainable, and eco-friendly for direct power generation in the field of renewable energy and does not involve any moving part [2–6]. Some of the existing proof of concept implementations of FPV plants in different regions of the globe are listed in Table 1. Two of such proof of concept FPV plant are shown in Figures 2 and 3 [7-8]. Generally, FPV systems are are similar to the regular ground or roof mounted PV ones, with the exception that the panels and the inverters are mounted on a floating structure, called floats. The DC current generated by PV modules is directed towards combiner boxes and converted to AC current by inverters. Generally, in small plants which are very close to shore, inverters can be placed on land. Some extra arrangements are necessary for floating PV compared to regular PV systems.

Fig. 3. A proof of concept implementation of a 500 KW FPV plant at Wayanad in Kerala [8]

Table 1. List of some of the existing FPV plants around the globe

S. No	Capacity (kW)	Location
1	175	Napa valley's Far Niente Wineries, California, USA
2	2,300	Hyogo prefecture, western Japan
3	4,000	Jamestown, South Australia
4	30	Gundlach bunshu wineries, California, USA
5	500	Bubano, Italy
6	300	Agost, Spain
7	14	Piolenc, France
8	20	Cheongju, South Korea
9	5	Bishan Park, Singapore
10	0.5	Sadbury, Canada
11	200	Sheeplands farm, Barkshire, UK
12	50,000	West Kallada, Kerala India

System Description (Figure 4)

- **Pontoon/floats**
- **Mooring and anchoring system**
- **Waterproof cables and connectors**
- **Lightning Protection System**
- **PV Panels**
- **Combiner box**
- **Central inverter and Transformer**

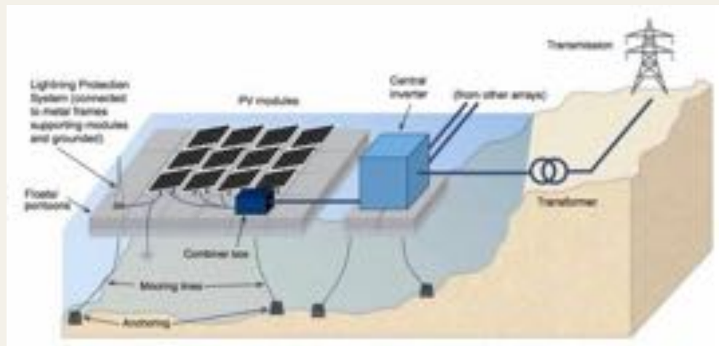
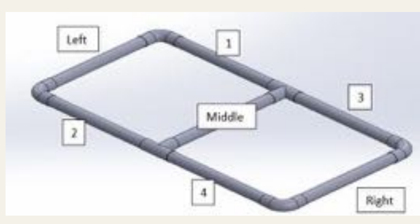
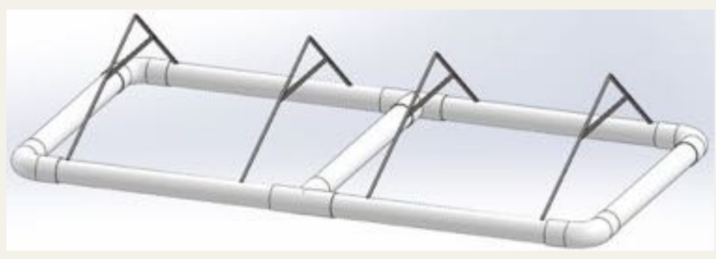


Fig. 4. Schematics of an FPV power plant [8].

Fig. 5. Experimental set up of the FPV assembled in-house





Results and Discussion

After monitoring the FPV system, it was observed that the highest temperature was recorded on the back side of the panel, as shown in the graph below (Figure 6).

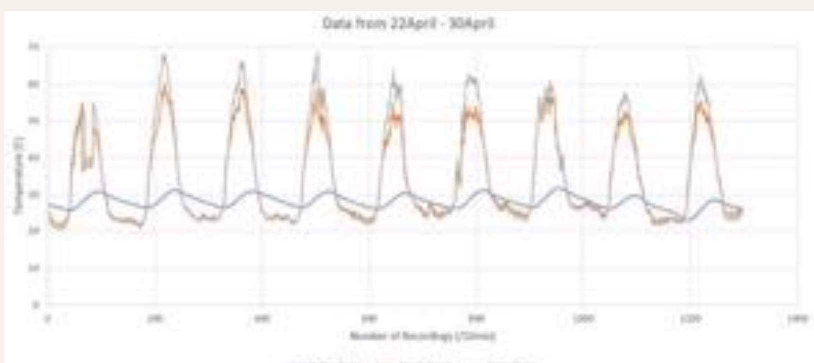


Fig. 6. Temperature data of the floating PV system.

To compare with ground based PV panel temperature, another panel was installed on ground in the vicinity of the floating PV system. The sensor was installed on the back surface of the ground mounted panel. Figure 7 compares the temperature of the two sensors, ground and FPV mounted.

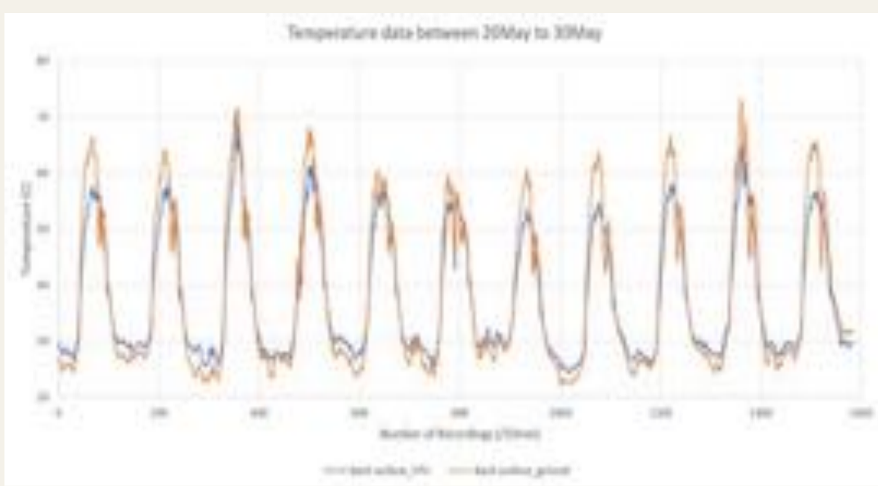


Fig. 7. Temperature difference between FPV and ground mounted system.

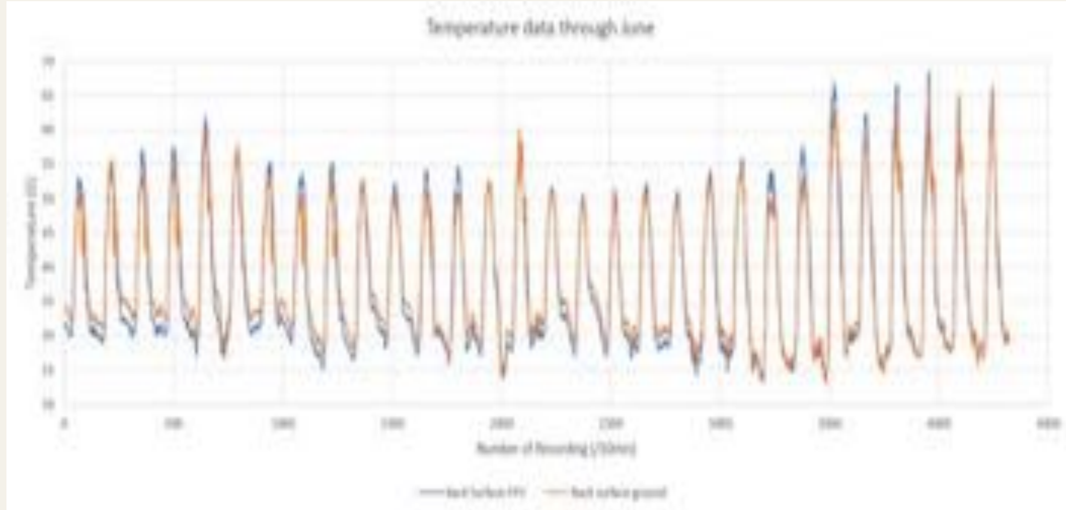


Fig. 8. Temperature data through June.

Fig. 9. Sun light reflection on the back surface of the solar panel.

Cell type	**Mono crystalline silicon 156mm X 156mm (36 cells)**
Max power	150 W
Max power voltage V_{mp}	18.62 V
Max power current I_{mp}	8.06 Amp
Open circuit voltage V_{OC}	22.33 V
Short circuit current I_{sc}	8.53 Amp
Cell efficiency	17.96
Temperature coefficient	-0.30% / C
Dimensions	(1480 X 670 X 40) mm
Weight	13 Kg

Table 2. Technical specifications of the PV panel

Conclusions

In the present scope of the work, a total capacity of 300 W floating photovoltaic system is designed, sized, assembled, and monitored in the months of July and August.

The performance of both the systems FPV and ground bases is monitored by sensors installed on the back and front surfaces of the PV panels.

Relatively lower temperatures are observed on the back surface of the panels of the FPV system compared to that installed on the ground surface.

The temperature difference is found to be small between the two systems which could be accounted for a shallow depth of the water (only 70 cm).

Such systems are expected to be more effective where the water depths are more than 2 m.

The present system, though exhibited small temperature difference, might increase the power output from the FPV system.

It is recommended to test such a system in water bodies with deeper water.

For the experimental setup, different tilt angles should be tried to find the optimum tilt that would provide the best performance for FPV systems. Beside that, there should be a continuous monitoring for at least a year to observe the annual trend and the advantage of FPV over ground mounted system in the Saudi Arabian region.

Acknowledgements

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Experimental study of a small Beam-Down and Direct-Down solar system for water preheating/desalination applications

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NM STATE UNIVERSITY BE BOLD. Shape the Future. College of Engineering

Surface-environmental Interaction REsearch Laboratory

Objective

The objective of this study is to assess the feasibility of multiple direct solar configurations for small-scale water preheating and desalination through experimental analysis and complementing the results with a theoretical model.

Materials

Fig. 1 depicts the experimental setup used in the study, consisting of 11 heliostats arranged around a testing basin, a water level controller, and a central mirror for Beam-Down Concentration (BDC) testing.

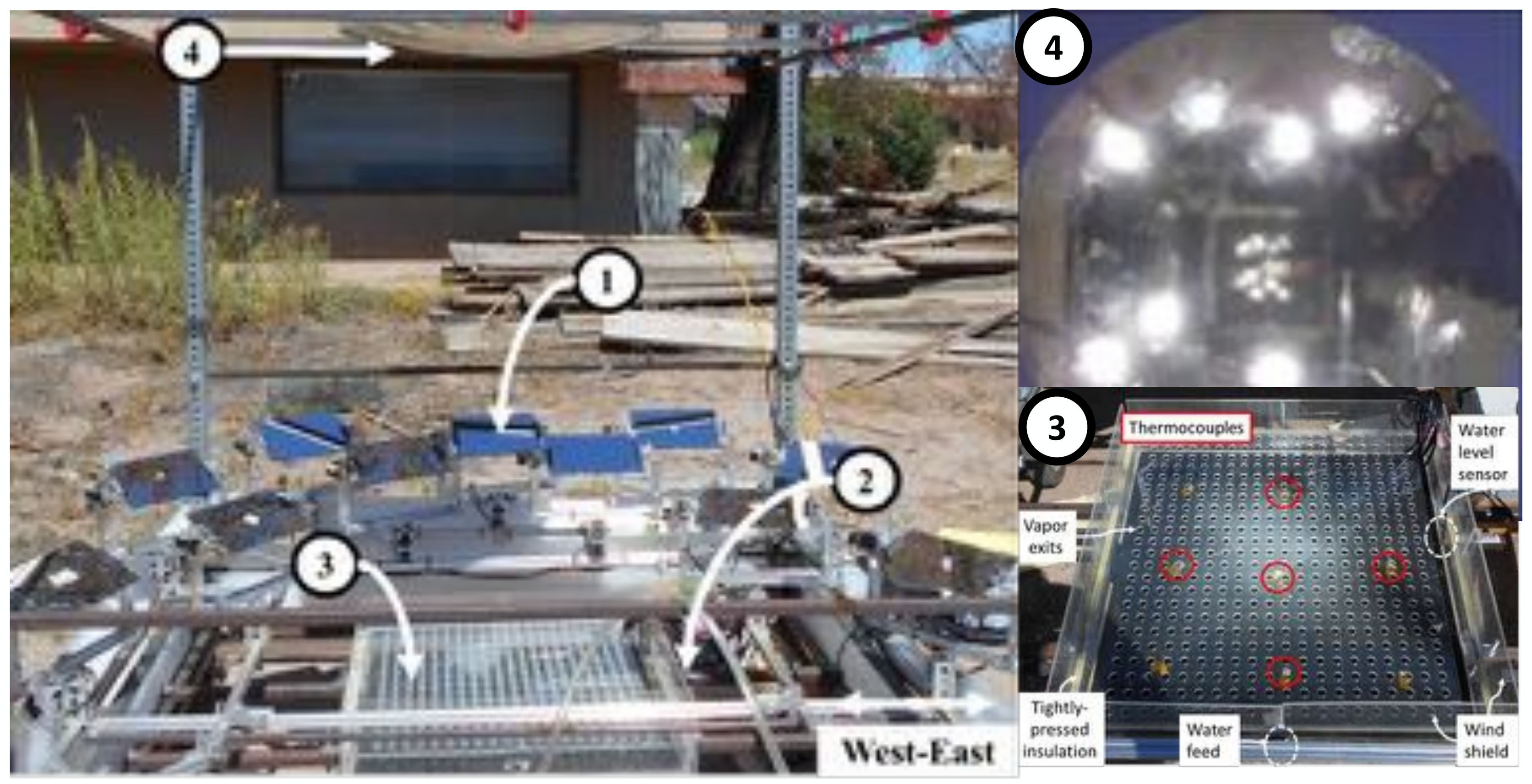

Figure 1. Main components of the experimental setup. 1) Heliostat field distribution, 2) Water level controller, 3) Polycarbonate basin and 4) circular hyperbolic central mirror (for the BDC configuration).

Methods

Three configurations were tested: baseline (BL), Direct-Down concentration (DDC), and Beam-Down solar concentrator (BDC), with the hybrid DDC + BDC configuration also explored. Additionally, an in-house model [1] was used to further analyze the DDC and BDC configurations based on cosine efficiency and solar irradiation.

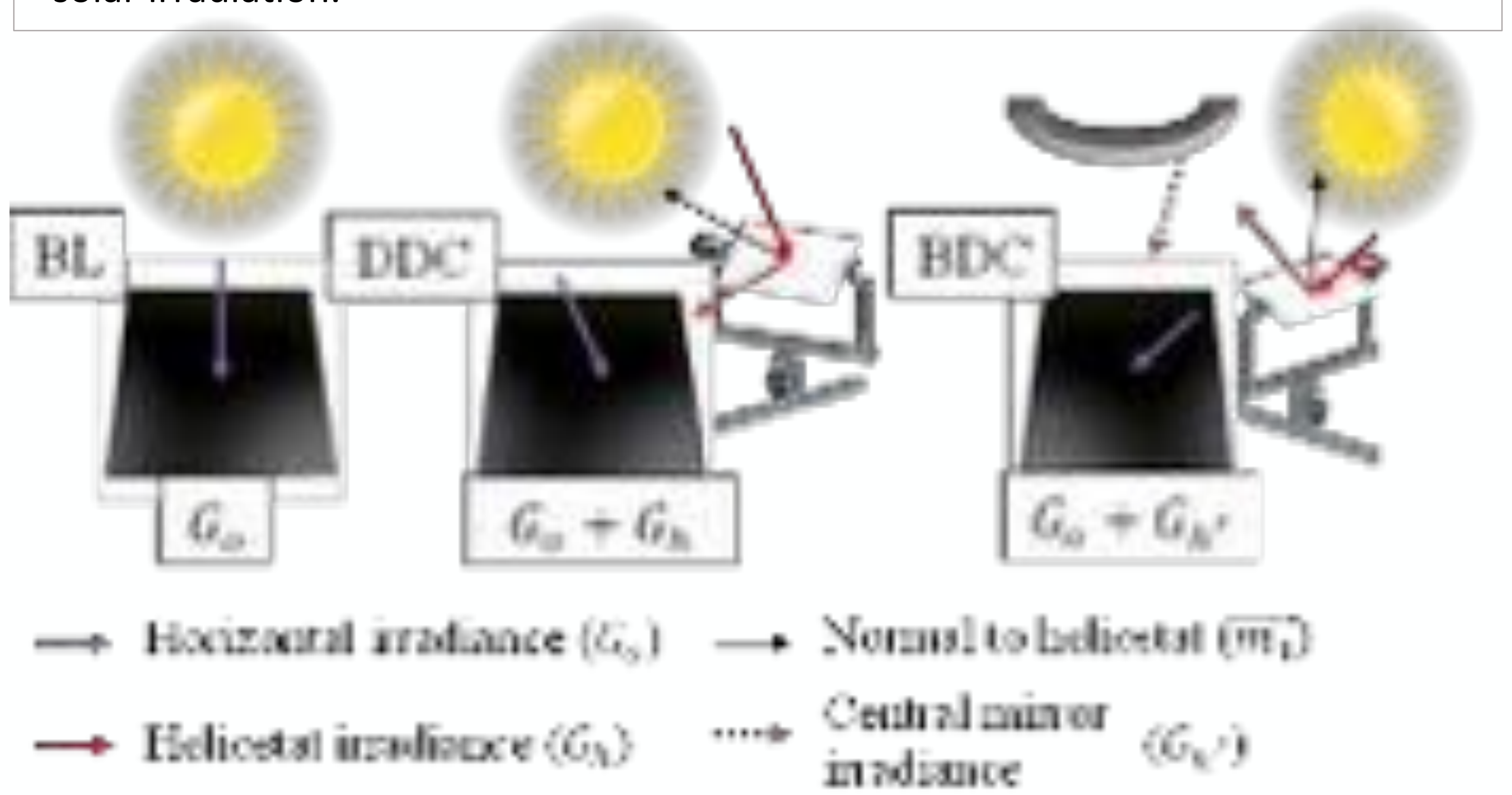

Figure 2. Different configurations tested for water desalination.

Results and discussion

The characterization of the 8 days in which experiments were conducted is presented in Fig. 3. Fig. 3 clearly shows that all days exhibit a certain level of repeatability, with discrepancies between repeated experiments mainly attributed to variations in the wind speed (V_∞).

The results of the 8 experiments (4 configurations repeated twice) are shown in Fig. 4. Fig. 4(a) shows the average temperature ($T_{s,avg}$) calculated from the five measured surface temperatures. Fig. 4(b) displays the maximum temperature ($T_{s,max}$) among the five surface temperatures, typically corresponding to the central temperature. Fig 4(c) presents the experimental net and normalized water yield per unit area for the different configurations, comparing them against the best-performing baseline run (BL#1).

Comparing the DDC and BDC configurations individually, both have their draw-backs, which are mitigated when combined. The DDC configuration is not significantly affected by the inclusion of the second reflection (lower optical efficiency due to imperfect reflectivity). However, the required positioning leads to more abrupt changes in cosine efficiency, shortening the system's full-operating window. In contrast, the BDC configuration provides greater stability but is susceptible to the impact of imperfect reflectivity in the central mirror. However, by incorporating less efficient heliostats from the DDC configuration into the BDC setup, an enhanced performance is achieved, as evidenced in the hybrid: DDC + BDC configurations.

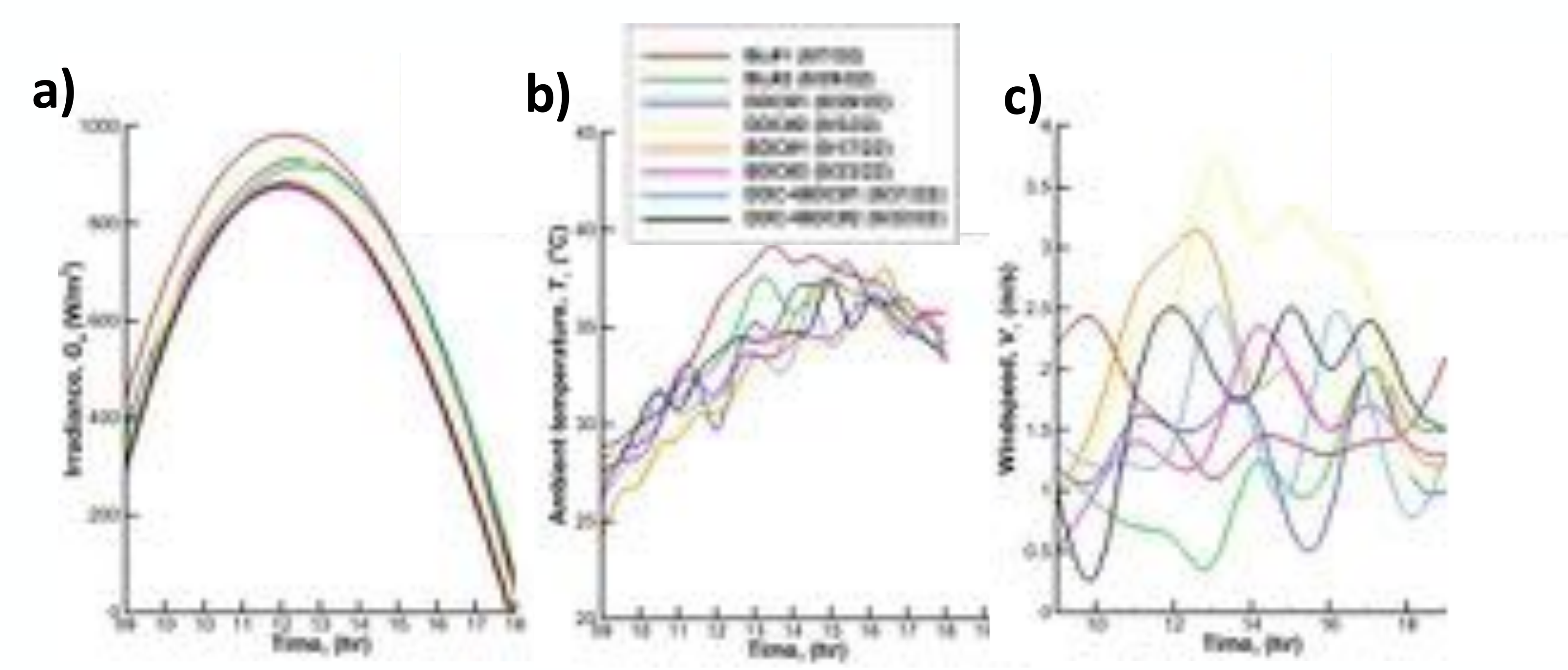

Figure 3. Characterization of days in which experiments were conducted. (a) Irradiance, (b) ambient temperature and (c) windspeed,

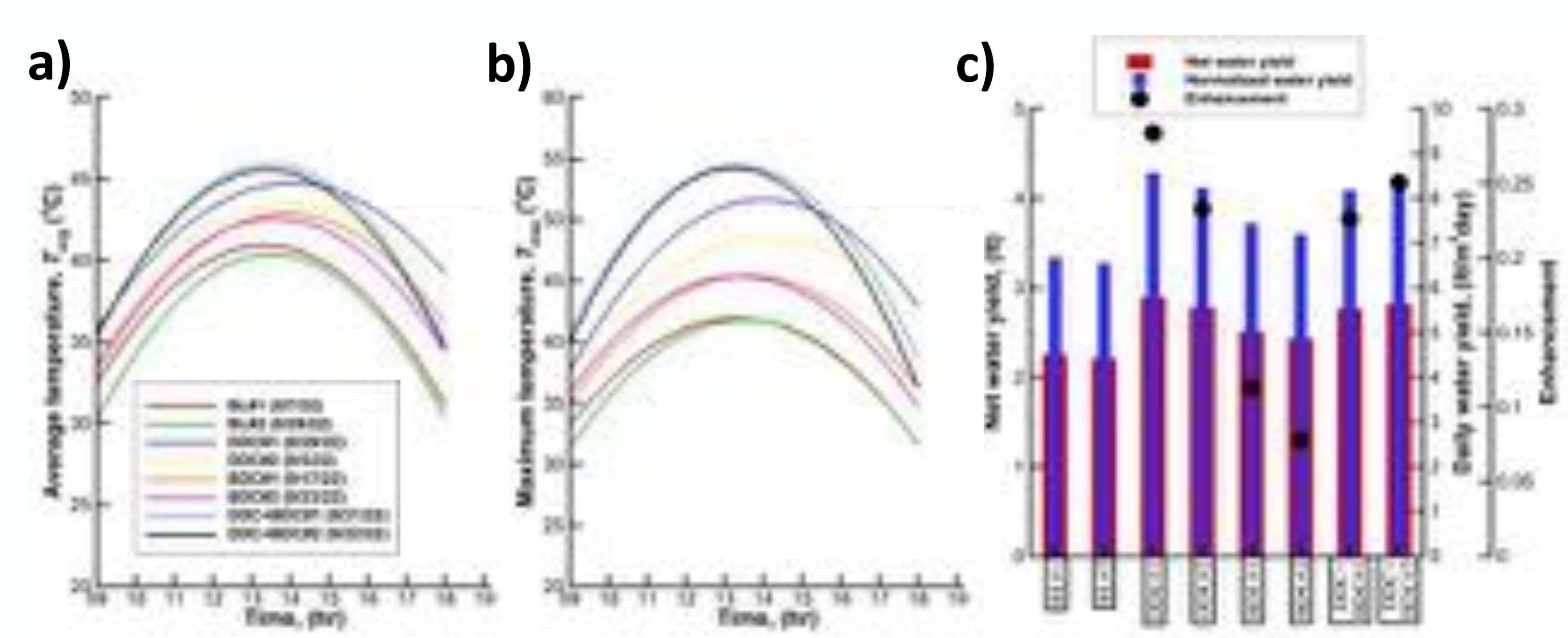

Figure 4. Experimental results for the tested configurations. (a) Average water temperature, (b) maximum water temperature and (c) water yield.

Conclusions

The present study successfully tested and compared three different configurations utilizing direct solar thermal energy for water desalination. The results demonstrated significant improvements in water yield and surface temperature. However, certain limitations were observed for each configuration.

Beam-Down solar concentrator (BDC) configuration:

1. Showed higher and less varying cosine efficiency.
2. Operated throughout the day except for shading constraints.
3. Experienced additional shading effects that hindered performance.
4. Required a minimum central mirror reflectivity for inclusion.
5. Magnified irradiance did not significantly increase water temperature or achieve high evaporation rates compared to Direct-Down concentration (DDC).
6. Emphasized the importance of cohesion between the central mirror, basin, and heliostat to maximize useful heat and collection efficiency.
7. Enabled more design options and applications through the inclusion of a second reflection.
8. Demanded higher precision servomotors to maintain expected collection efficiency.
9. Considered easily scalable.

Direct-Down concentration (DDC) configuration:

1. Exhibited lower and highly varying cosine efficiency.
2. Had a limited full operating window due to heliostat limitations in reflecting sunlight towards the basin, especially for heliostats located in the west and east demi circles.
3. Experienced lesser shading effects due to the absence of certain structural elements.
4. Induced higher water temperature and achieved higher evaporation rates without the magnification provided by the central mirror.
5. Required less accurate servomotors due to the absence of the second reflection.
6. Lacked versatility in design and low-temperature applications.
7. Suited for smaller-scale systems when the basin is located below the helio-stats' z-plane and all heliostats are in the same z-plane.

Hybrid DDC + BDC configuration:

1. Proved advantageous when central mirror reflection was not very high.
2. Offered potential to mitigate the limitations of individual configurations, such as the limited full operating window of DDC and the inclusion of the imperfect second reflectivity in BDC.
3. Required careful selection of heliostats based on cosine efficiencies and central mirror reflectivity.
4. Enabled the use of larger basins with regions of higher evaporation rates by combining the "high" irradiance over a smaller area (DDC configuration) with the magnified irradiance over a larger area (BDC).

This study provides valuable insights into the performance and characteristics of the BDC, DDC, and hybrid DDC + BDC configurations for direct solar thermal water desalination and other low-thermal applications. These findings can inform the development of optimized and efficient systems for various scale applications in the future.

Publication and References

➢ [1] E. Moreno Resendiz et al., "Analysis of a small-scale modified beam-down solar concentrator system for low temperature applications," Renewable Energy, vol. 215, p. 119007, 2023. doi:10.1016/j.renene.2023.119007

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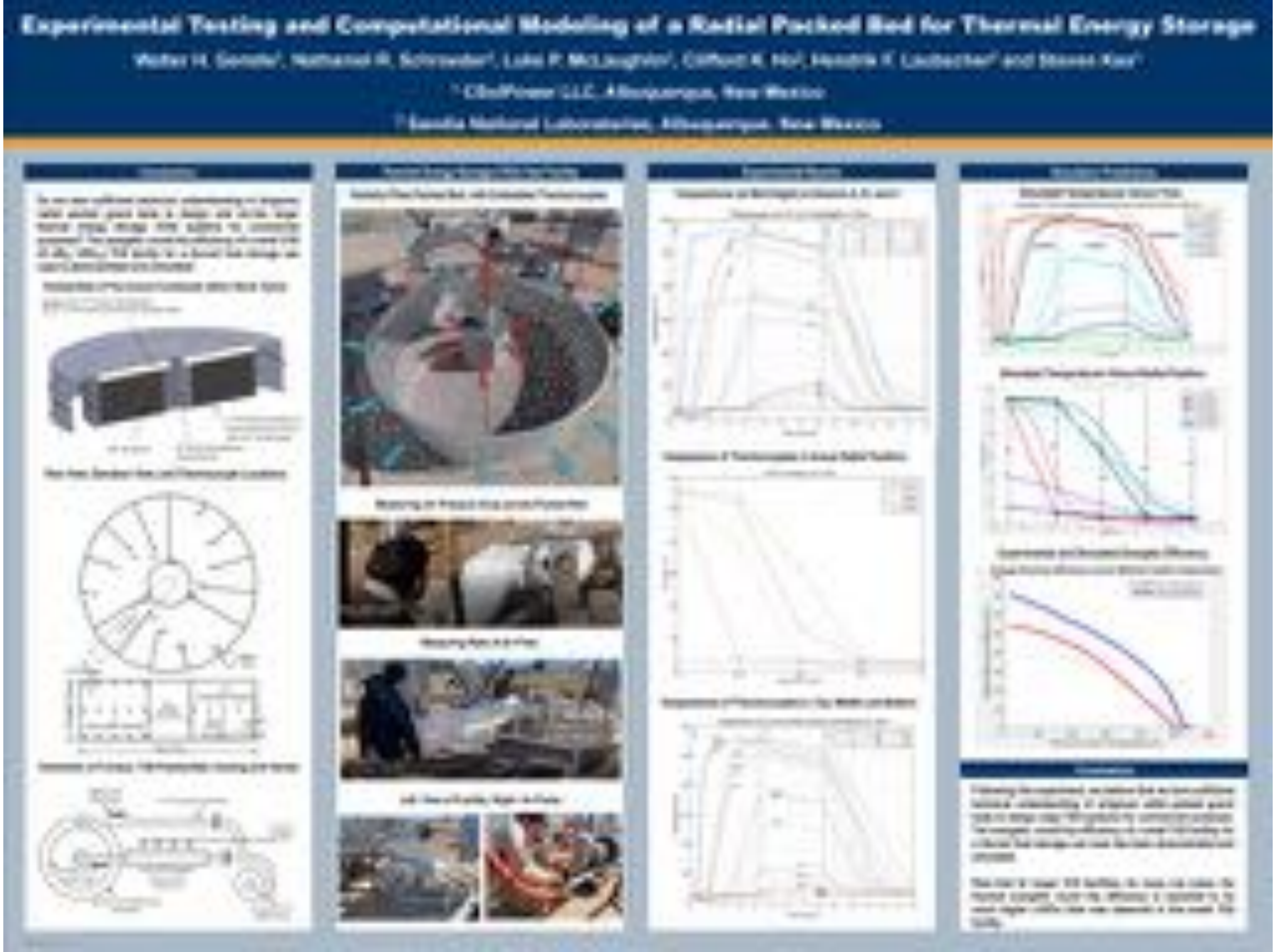
Experimental Testing and Computational Modeling of a Radial Packed Bed for Thermal Energy Storage
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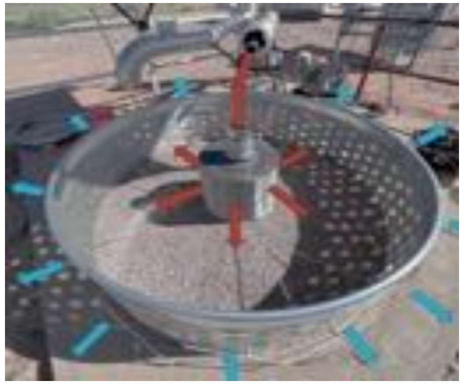
Experimental Testing and Computational Modeling of a Radial Packed Bed for Thermal Energy Storage

Walter Gerstle, walter@csolpower.com, CSolPower LLC

Summary

- Do we have sufficient technical understanding of air/gravel radial packed gravel beds to design and de-risk larger thermal energy storage (TES) systems for commercial purposes?
- The exergetic round-trip efficiency of a small (100 25 kWth, kWh$_{th}$) TES facility for a diurnal heat storage use case is demonstrated and simulated.



Results

- Following this experiment, we believe that we have sufficient technical understanding of air/gravel radial packed gravel beds to design large TES systems for commercial purposes.

- The exergetic round-trip efficiency of a small TES facility for a diurnal heat storage use case has been demonstrated and simulated.

Conclusions/Implications

- Note that for larger (1 GWhth) TES facilities, for many use cases, the thermal exergetic round trip efficiency is expected to be much higher (>90%) than was observed in this small TES facility.

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