The Impact of Wind Farm Turbine Coordination for Power Production Optimization, Reduced Fatigue Loads, and Enhanced Turbine Performance.

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Industrial Advisor: Rene Ramirez, Jr, P.E., PMP

RET Site: Integrating Data-driven research in Renewable Energy Across Disciplines (I-READ)

ABSTRACT

The overall research goal is to analyze the impact of turbine coordination strategies within a wind farm to optimize power production, reduce fatigue loads, and enhance overall performance. By implementing coordination techniques, such as wake steering, the research team aims to evaluate their effectiveness in mitigating wake effects, improving turbine reliability, and maximizing power output. The findings will provide insights into the benefits of turbine coordination and contribute to the development of more efficient and sustainable wind farm operations.

INTRODUCTION

- Texas is the current leader in wind energy at approximately 24% for the Texas grid. [1]
- Power production can be diminished due to turbulence between turbines.
- Fatigue can be increased due to turbulence between turbines.
- Wake effect causes turbulence and wind speed loss in different areas of a wind farm.

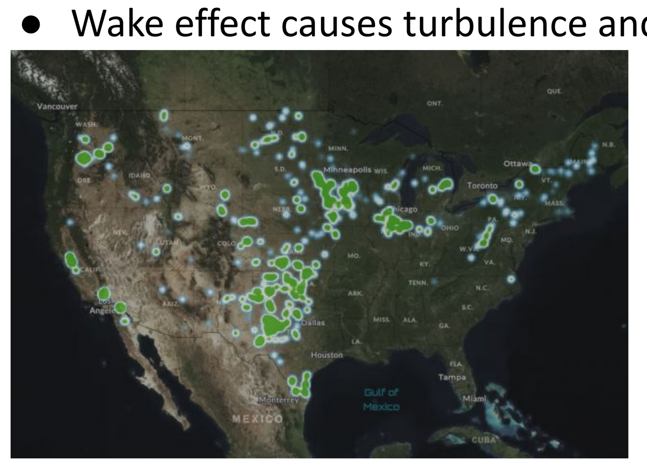

Figure 1: Interactive Map of Wind Farm Data for United States[2]

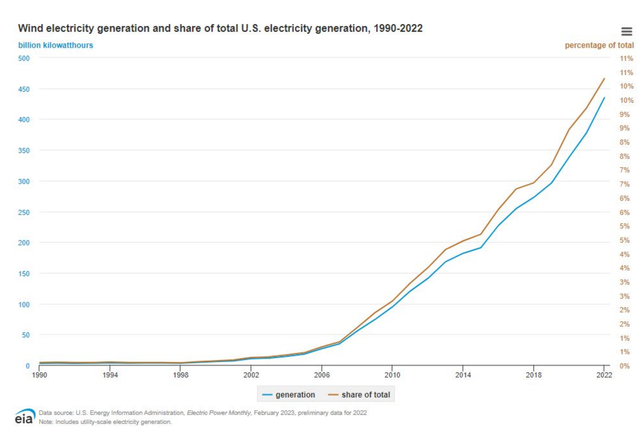

Figure 2: Wind Energy generation[3]

RESEARCH OBJECTIVES

- Investigate the effectiveness of turbine coordination techniques to optimize power production.
- Investigate how the use of turbine coordination techniques may enhance overall performance.
- Investigate the impact of turbine coordination techniques in reducing fatigue loads.
- Investigate the scalability and applicability of turbine coordination techniques.

METHODOLOGY

- Create models showing the wake effect of wind turbines.
  - -Source wind data for the south Texas region.
  - -Create database which calculates the wake effect and show the data in visuals.
- Create a scaled model to show the physical effects of the wake on a wind turbine.
- Create curriculum modules that will teach middle school and high school students about wind farm turbine coordination.

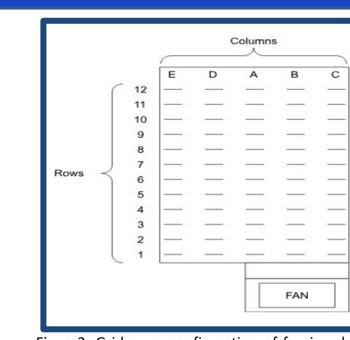

Figure3: Grid array configuration of fan in relation to placement positions. Rows spaced 18 in. apart and columns spaced 10 in. apart. Fan center is 31 in. from location 1B.

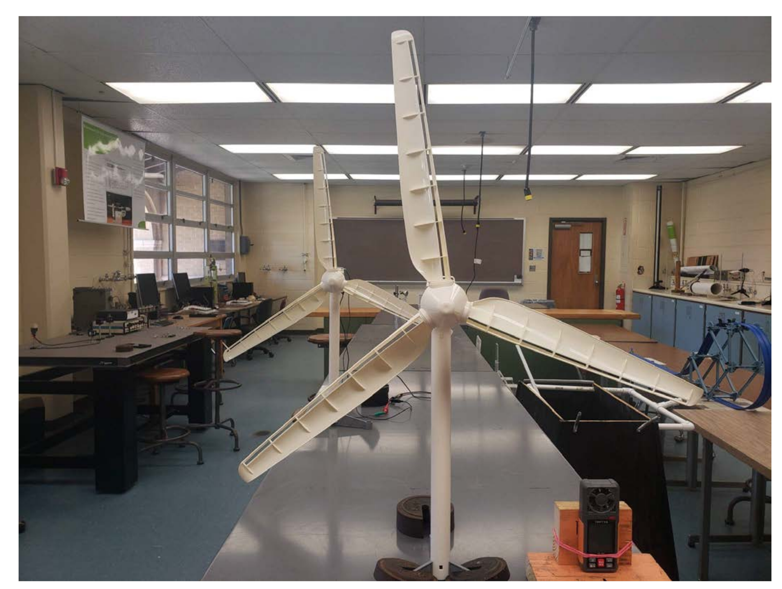

Figure 4: Frontal view of Turbine 'b' in the wake of Turbine 'a' while collecting voltage data. Fan towers offset by 10 inches.

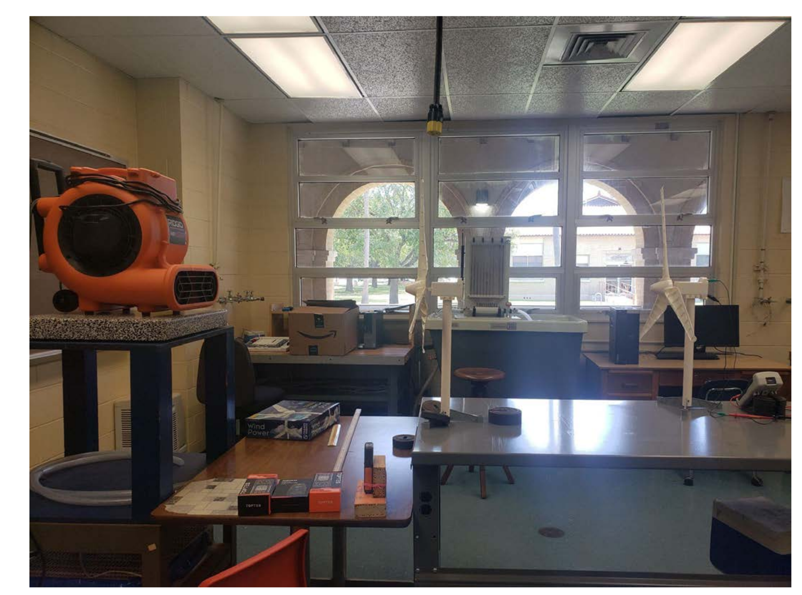

Figure 5: Side view of experimental setup. Distance from blower to fan is 31 inches. Fan spacing depicted is 36 inches horizontally.

RESULTS

EXPERIMENT 1
Baseline Average Wind Speed Readings

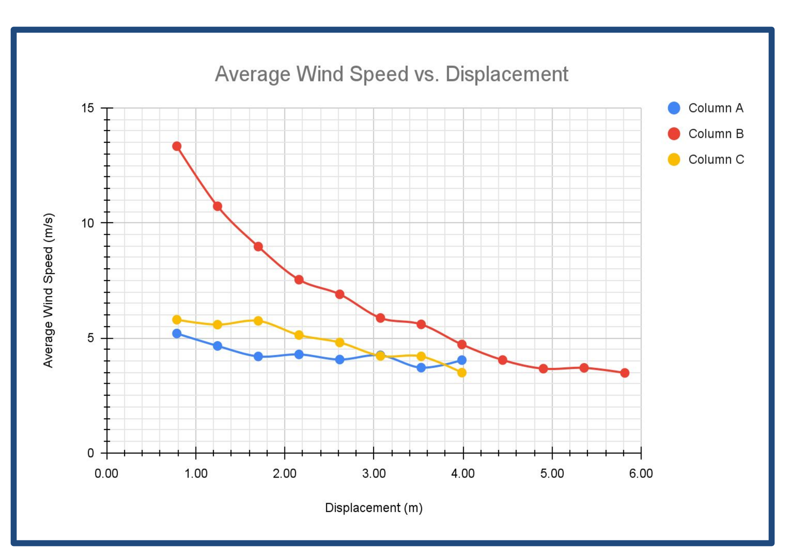

Figure 6: Displays the average wind speed readings of the blower only. Readings taken for locations 1A to 8A (blue), 1B to 12B (red), and 1C to 12C (yellow).

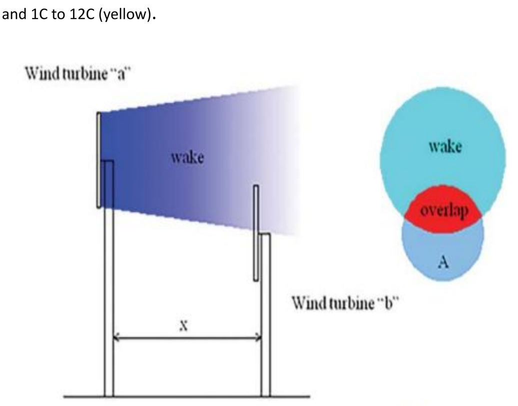

Figure 7: Schematic of how a wake interacts with a downstream turbine with a different hub height.[4]

EXPERIMENT 2
Investigating Wind Speed Changes of Turbine 'a' within Wake Effect of Turbine 'b'

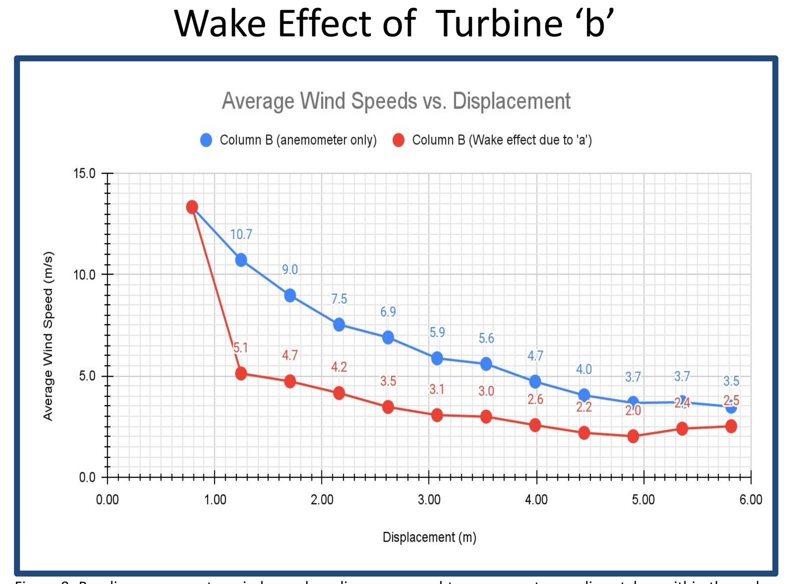

Figure 8: Baseline anemometer wind speed readings compared to anemometer readings taken within the wake effect of Turbine 'a'. Change in gradient and convergence to baseline shows subsiding of the wake effect as distance from the fan increases.

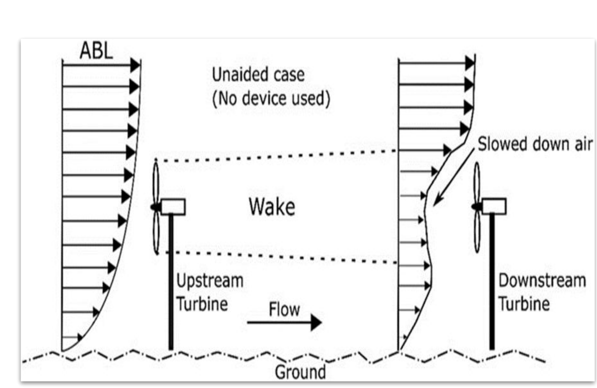

Figure 9: Image depicting the Wake Effect on a Downstream Turbine[4]

EXPERIMENT 3
Effect of Wind Speed on Turbine Power Production

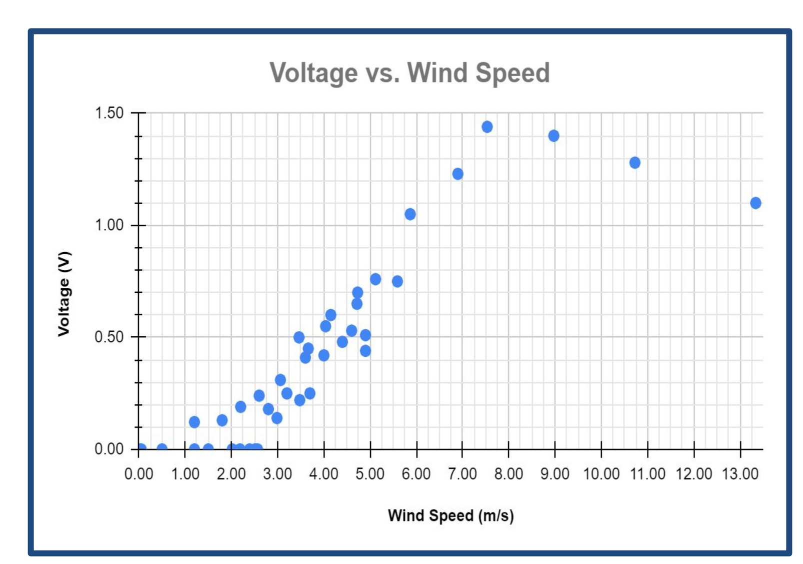

Figure 10: Displays an initial voltage response to wind speed followed by a linear increase which leads to a voltage plateau indicating the turbine has reached a maximum voltage output.

Turbine 'a' Only - No Wake Effect (Column B)

Row	Avg Wind Speed (m/s)	Voltage (V)	% of Max Voltage
1	13.34	1.10	76.39
2	10.73	1.28	88.89
3	8.97	1.40	97.22
4	7.53	1.44	100.00
5	6.90	1.23	85.42
6	5.87	1.05	72.92
7	5.59	0.75	52.08
8	4.72	0.65	45.14
9	4.04	0.55	38.19
10	3.66	0.45	31.25
11	3.70	0.25	17.36
12	3.48	0.22	15.28

Figure 11: Displays voltage and percentage of maximum voltage for turbine 'a' due to the blower using the baseline average wind speeds.

Heat Map of % of Maximum Voltage for Turbine 'b' in wake of Turbine 'a'

	Column			
Row	E	D	A	B
2	0.00	0.00	30.56	52.78
3	0.00	0.00	35.42	48.61
4	0.00	8.47	36.81	41.67
5	0.00	9.03	33.33	34.72
6	0.00	13.19	29.17	21.53
7	0.00	16.67	28.47	9.72
8	0.00	12.50	17.36	0.00

Figure 13: The voltage heat map displays the voltage data measured by Turbine 'b' within the wake of turbine 'a' at array locations 2 through 8 of columns E, D, A, and B. Higher voltage values (red) indicate better electrical performance, while lower values (green) indicate weaker electrical performance.

CONCLUSION

Analysis of wind farm turbine coordination techniques revealed that as the distance from the fan increased, the average wind speed progressively decreased, indicating spatial wind speed variations within the grid array. Examining the wake effect, it was observed that there was an initial sharp decrease in wind speed within the wake, followed by convergence towards the baseline, identifying an optimal turbine placement region. Analysis of voltage data in experiment 3 suggested potential locations (3B, 4B, or 5B) for maximizing power production. Offsetting turbines at locations 5A through 8A demonstrated matching power output, presenting an opportunity to optimize turbine placement within wind farms. These findings offer valuable insights to enhance wind farm design and turbine coordination strategies.

HIGH SCHOOL MODULES

Physics and Advanced Physics 1

- Modules will aid in student understanding of the following physics principles:
  - Kinematics (Speed, Velocity, and Vector Displacement)
  - Work, Energy, and Power
  - Rotational Motion (Angular velocity and acceleration, Torque, and angular momentum)
- Objectives [Wind Turbine Investigations: Exploring Physics Principles]
  - Wind Turbine Investigation #1
    - Students will measure wind speeds and analyze the implications of wake losses.
  - Wind Turbine Investigation #2
    - Students will convert wind energy into kinetic energy and analyze rotor energy capture.
  - Wind Turbine Investigation #3
    - Students will measure and calculate the angular velocity, acceleration, and torque.
- Student Assessments
  - Lab Based (Report, Excel Data Sheets with Graphical analysis)
  - Project Based (Create a Physical Turbine, Engineering Report)

Figure 14: Wind Turbine Kit used in experiment and for use with modules.

MIDDLE SCHOOL MODULE

Robotics and Career Exploration

- Modules will aid students in understanding the following principles and concepts of wind turbines:
  - Renewable Energy
  - Kinematics (Speed, Velocity, and Vector Displacement)
  - Work, Energy, and Power
  - Rotational Motion (Angular Velocity and Acceleration, Torque, and Angular Momentum)
  - Engineering Design Process
- Objectives
  - Understand the basic principles of wind turbines and their role in converting wind energy to electrical energy.
  - Explore the concept of rotational motion and its application in wind turbine operation.
  - Investigate the relationship between blade movement, wind speed, and energy production.
  - Apply simple mathematical concepts to analyze and compare wind turbine designs.
- Assessments
  - Lab Based (Reports, Journals)
  - Project Based (Create Physical Turbine)

Figure 15: photo of 3D designs of Turbines from Tinker CAD

ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under Award No. 2206864. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation..

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[1] America's Leader in Wind Energy (Feb, 2019) Power Up Texas https://www.poweruptexas.org/wp-content/uploads/2019/02/Powering-Texas-R15.pdf
[2]Interactive map of wind farms in the United States(2023 July,16) American Geosciences Institute(Retrieved July 16, 2023)
[3] Wind Energy Generation and Share of total U.S. electricity Generation, 1990-2022 (February 2023) U.S. Energy Information Administration (Retrieved July 16, 2023)
[4] Investigating the possibility of using different hub height wind turbines in a wind farm (Feb. 3, 2015) International Journal of Sustainable Energy (Retrieved June 19,2023)

Solar Radiation Big Data Analysis to Increase the Efficiency of Solar Panel

Daniel Garza, Cory Scarborough
Faculty Mentors: Dr. Mohammad M. Hossain, Dr. Marsha Sowell
Student Mentor: Lovekesh Singh
Industrial Advisor: Richard Martinez

Abstract

The purpose of this project was to use the National Renewable Energy Laboratory (NREL) Solar Position and Intensity (SOLPOS) Calculator data in a data processing software (MS Excel) to determine the power output of solar panels located in different positions of a house, and how this power output can be improved by increasing the efficiency of the solar cell through introduction of textures on the surface. The Texas A&M University – Kingsville (TAMUK) Dotterweich Hall was used as the site location and REC Alpha Series Black solar panels were used as a model. Extraterrestrial Solar Irradiance data was obtained for various angles in 30-minute increments during 2022 from NREL SOLPOS Calculator.

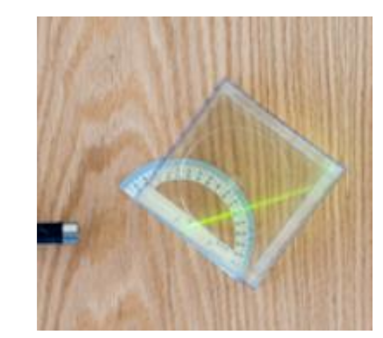
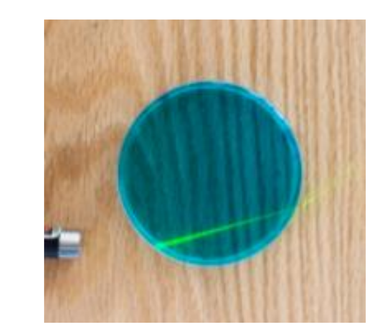
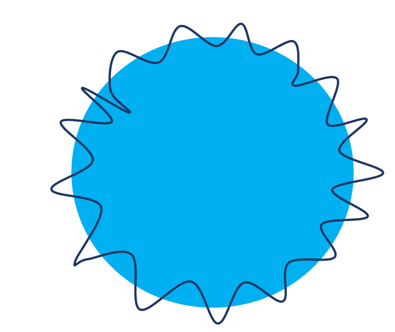
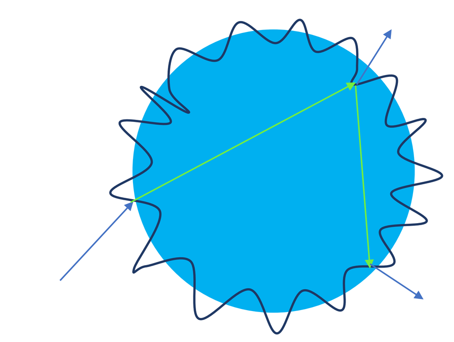
Methodology

1. Site information necessary for SOLPOS was determined.
2. Commercially available solar panels were researched and compared. For the purpose of this project the REC Alpha Series Black was used as a standard model with an area of $1.9m^2$ and efficiency of 21.2%.
3. Extraterrestrial Tilted Irradiance (ETI) data for 0°, 18.69°, and 33.5° titled surface were gathered at 30 minutes intervals during 2022.
4. Power of the solar panel was calculated (E = A*R*H*PR) at each time interval for every tilt orientation [E= Energy output from photovoltaic cell, A = Area of photovoltaic cell, R = Efficiency of photovoltaic cell, H = Solar Irradiance, PR = Performance rating with Industrial standard = 0.7].
5. Vertical organic solar cells were modelled by downloading 90° tilt and using 43% of the total ETI. The collected data was modelled in MS Excel.
6. Improvement in sunlight absorption was calculated for hemispherical cavity considering double reflection using MATLAB.
7. Improvement in solar panel power with introduction of texture was calculated in MS Excel.

Curriculum Module 1

Objective: Students will explore Snell's Law utilizing a Jell-O medium and laser lab/research activity and relate this to innovative research on solar panels.

1.Students will visualize the effects of multiple reflections after studying Snell's Law.
2.Students can shine a laser through a smooth and textured Jell-O mold and view the different reflection patterns.
3.Students can shine a laser through different color Jell-O and view absorption.
4.Discuss with students how the texture can improve the efficiency of solar panels, and how absorption of organic solar panels can be beneficial.

Results Comparing Flat Tilted Surfaces

- Figures 1 & 2 show the average yield of solar energy per hour throughout 2022.

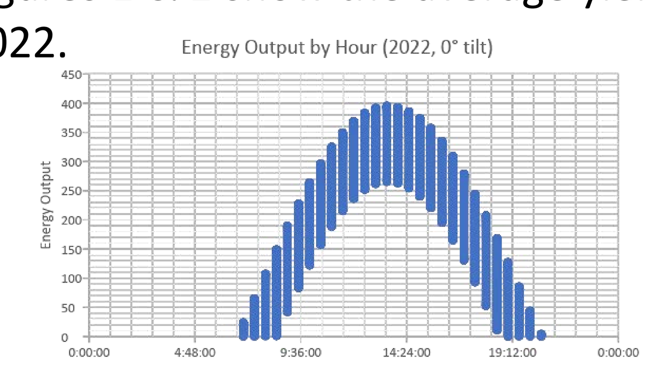


Figure 1

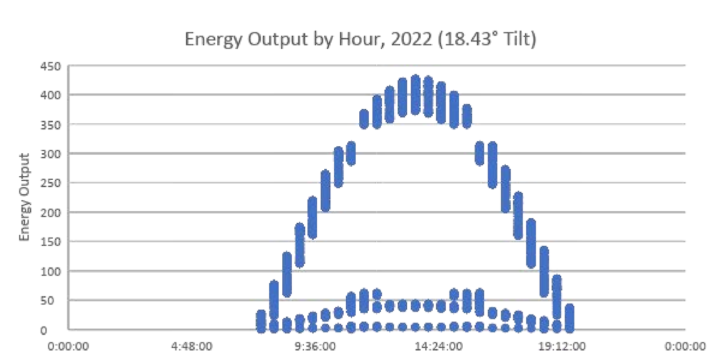


Figure 2

- Figures 3 & 4 show average output by day throughout the 2022 year for each tilt. An average of 0.414 kW-hr produced was found per 72 x 40 inch solar panel.

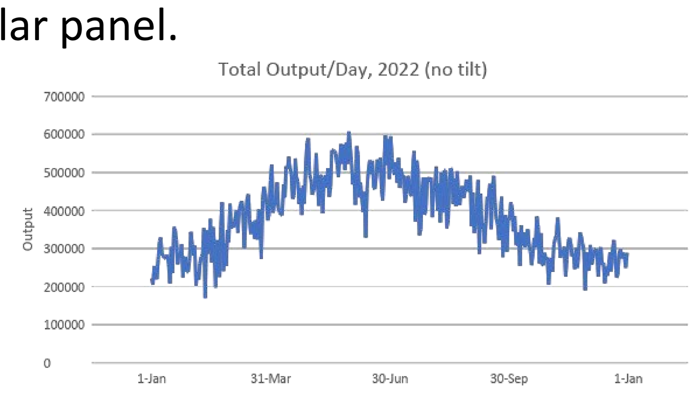


Figure 3

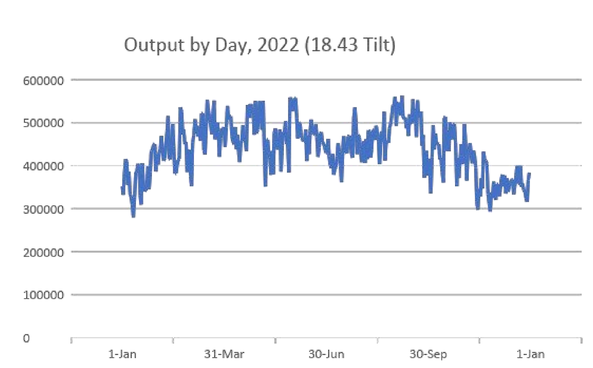


Figure 4

- Figure 5 & 6 shows average kW-hr output for each day during 2022.

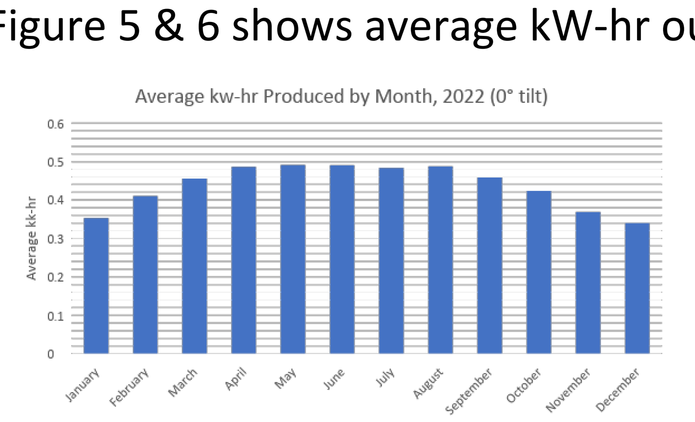


Figure 5

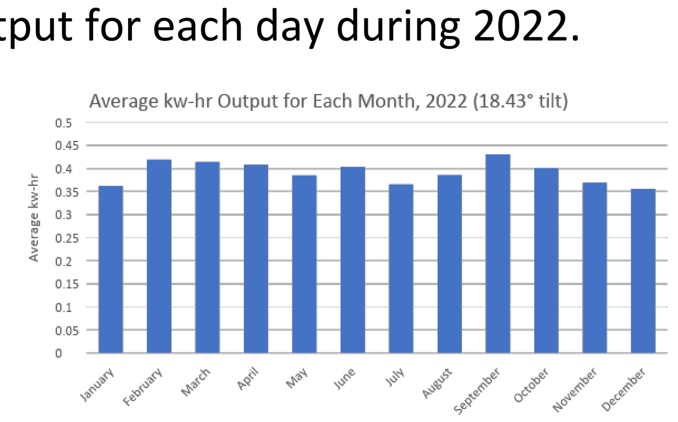


Figure 6

Results Comparing Textured and Flat Surfaces

- Figure 7 provides an example of how selective absorption allows certain wavelengths to pass through while utilizing other wavelengths for solar energy production. Figure 8 shows energy yield on a vertical surface that only absorbs visible light (400 - 700 nm spectrum).

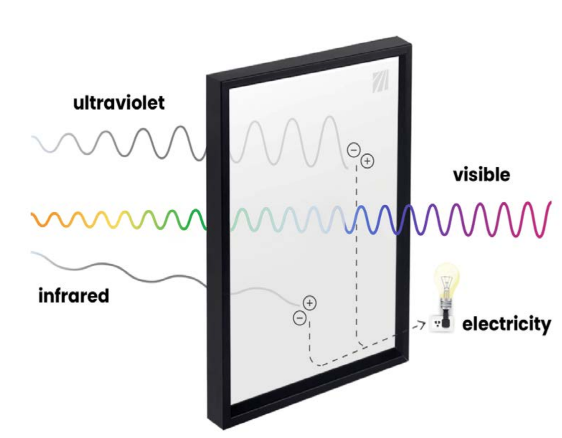


Figure 7

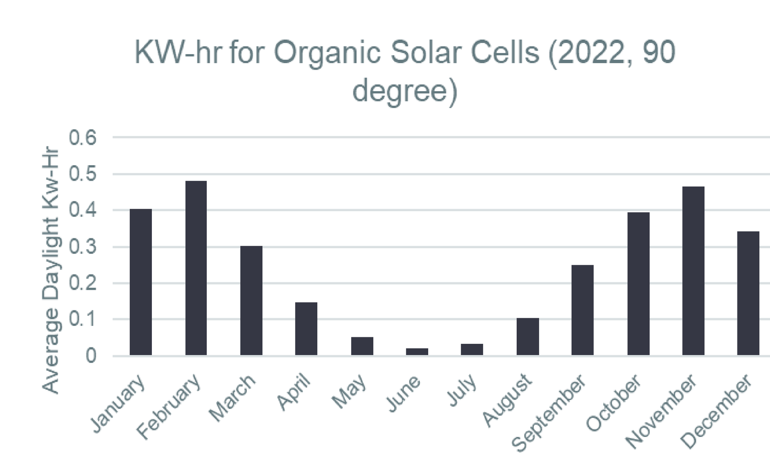


Figure 8

- Figure 9 shows the absorption of solar energy on a traditional flat surface solar panel while part of the sun's ray & energy reflects off. Figure 10 shows multiple reflections on a textured surface with an inverted hemisphere in a panel surface. Incident angles are shown by the red arrows and the angle of the surface is shown at each intersection.

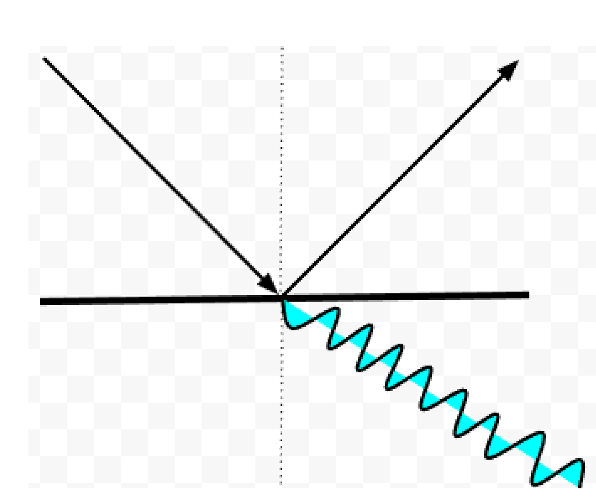


Figure 9

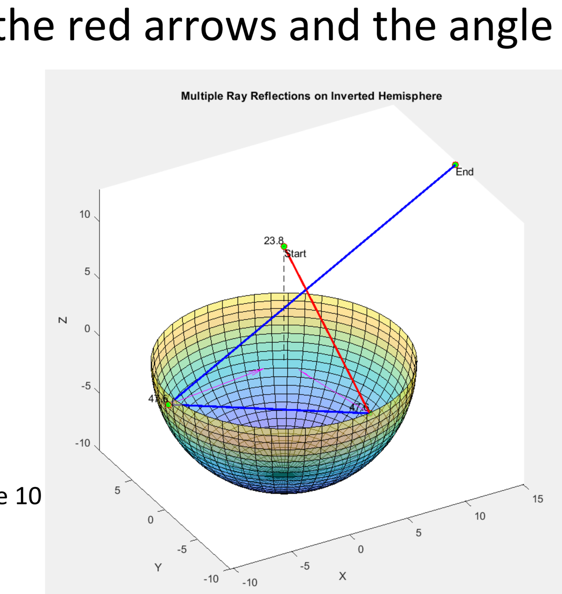


Figure 10

Curriculum Module 2

Objective: Students will utilize online platforms and science resources to conduct data analysis of current and ongoing research. Discuss solar energy as a renewable source of energy and what is NREL SOLPOS.

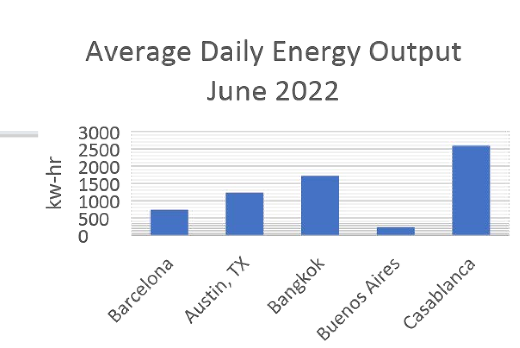
1.Discuss solar energy as a renewable source of energy and what is NREL SOLPOS.
2.Research necessary SOLPOS input information from various major cities around the world.
3.Show students how to manipulate data in excel and discuss differences in solar irradiance for various latitude/longitude sites.

	Start Date	End Date	Time Interval	Tilt
Solpos Inputs	1/1/2022	12/31/2022	30 minutes	0 degrees
	Lat	Long	Time zone	Surface Pressure
	27.525	-98.8825	-5	1011.5

Date	Time	Zenith (refracted)	ETR tilt	Energy Output
1/1/2022	8:30:00	88.876	225.2886	729.935064
1/1/2022	9:00:00	83.2679	379.3431	1229.071644
1/1/2022	9:30:00	77.695	529.9498	1717.037352
1/1/2022	10:00:00	72.3712	67.775	219.591
1/1/2022	10:30:00	67.3869	798.8958	2588.422392

Energy Output
729.935064

=1.8*2.4*D7*0.75



Summary

Data indicates a maximum solar output occurring around 1:30 p.m. regardless of tilt angle of solar panel. Throughout the year, regardless of tilt, maximum solar output for the different angles occurred between March and June. On average, for a non-textured solar panel the average hourly output was 0.414 kW-hr throughout 2022. For vertical window applications, a tilt of 90 degrees was used and 43% of total ETI modeled the selective absorption feature of the organic solar cell. The average expected kW-hr output for a vertical organic solar cell was 0.24 kW-hr during 2022. In the future, a hemispherical cavity texture will be modelled against a flat texture to estimate the efficiency of a textured surface.

References

1. SOLPOS Calculator at https://midcdmz.nrel.gov/solpos/solpos.html
2. Morales Pedraza, Jorge. (2016). Re: How to estimate the energy production from photovoltaic by using PDF?. Retrieved from: https://www.researchgate.net/post/How_to_estimate_the_energy_production_from_photovoltaic_by_using_PDF/57842169dc332d4a7a603711/citation/download.
3. factsheet_rec_alpha_series_en_us.pdf (aeesolar.com)
4. https://sos.noaa.gov/catalog/datasets/climatebits-solar-radiation/#description-data-source
5. https://ubiquitous.energy/
6. https://www.exploratorium.edu/snacks/laser-jello

Acknowledgements

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Effect of Daylighting on Students’ Learning and Classroom Electricity Consumption

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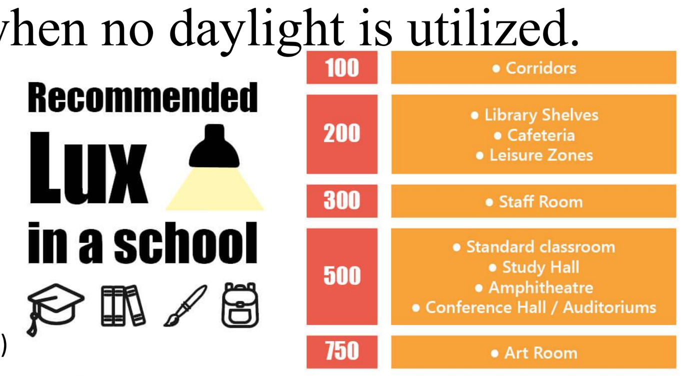
Faculty Mentors: Dr. Hui Shen, Dr. Marsha Sowell
Curtis Davenport (Student Mentor), Ralph Pitzer, P.E. (Industrial Advisor)
Texas A&M University – Kingsville

Abstract

Classrooms are critical areas for learning at all ages. Daylighting is defined as the illumination of buildings, like classrooms, by natural light. Daylighting in classrooms is said to play an important role in students' health, well-being, and overall performance. Recent studies show that daylighting in schools may significantly increase students' test scores, promote improved health and physical development; the study also shows it can be attained without an increase in school construction or maintenance costs (7) This study was meant to examine the effect of daylighting on students’ learning. Correlation analysis was to be used to compare the performance of college students in three classrooms with different daylighting scenarios. Students were also to complete a survey indicating their evaluation of the assignment difficulty level, light comfort level, and room temperature comfort level, among other parameters. Additional data was collected which measured the lighting levels in two rooms for a minimum of 48 hours. Using this data, differences in electric lighting power consumption are to be calculated and compared to that when no daylight is utilized.



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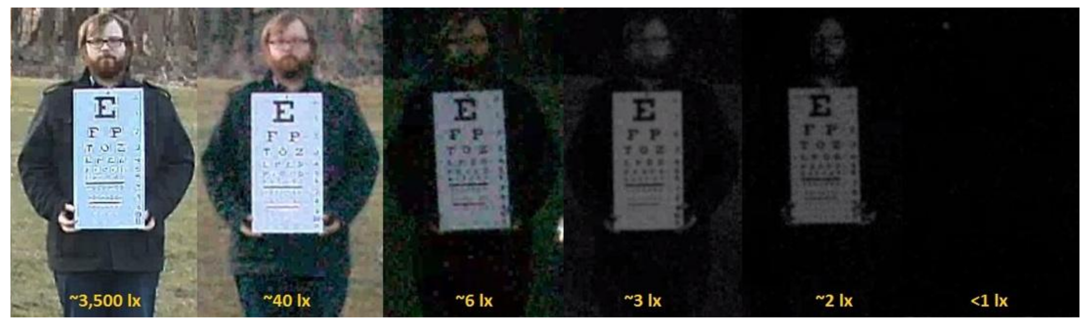


(2)

Key Definitions & Concepts

Daylighting - the illumination of buildings by natural light

Lux - the SI unit of illuminance, equal to one lumen per square meter.

Daylight Autonomy - an annual measure of how often a minimum work plane illuminance requirement can be met by daylight alone during occupied time. (4)

Useful Daylight Illuminance - the percentage when the work plane illuminance is between 100 lux and 2000 lux of the occupied space. (5)

Window-to-Wall Ratio-measure of the amount of window area there is on a building relative to the total amount of exterior wall area. (6)

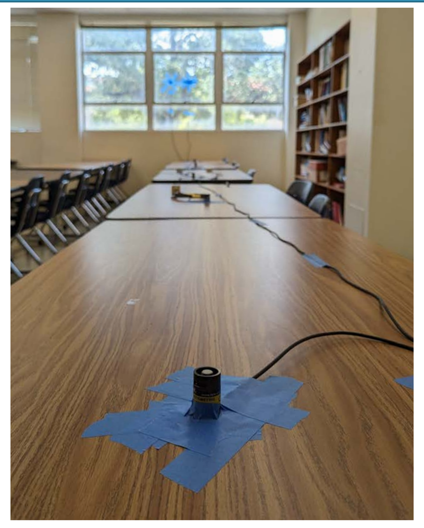
Methodology

Instrumentation

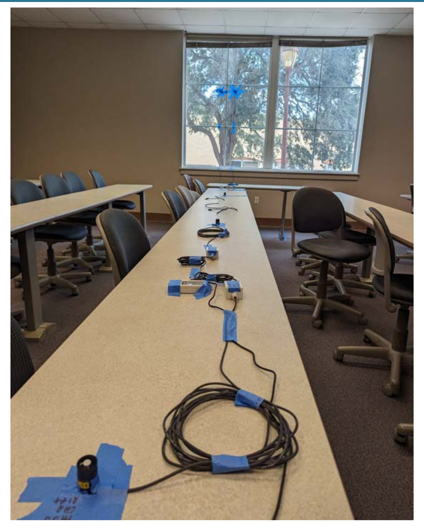
- LI-210R Photometric Sensors
- LI-200R Pyranometer
- HOBO 4-Channel Analog Data Logger

Measurements

- Sensors were placed and secured to window and desks accordingly.
- HOBO data loggers were programmed to measure and record every one-minute.
- Lights off/Room Secured
- Fore Hall 24.3 x 30
- EC 113 28.5 x 30 feet



Fore Hall Room 106 South Facing Window



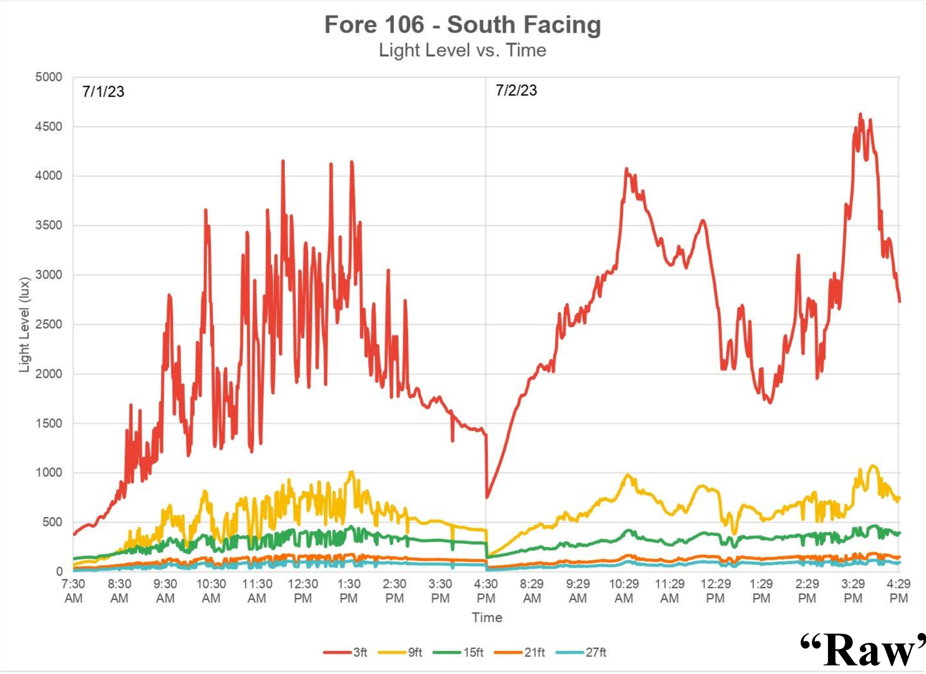
EC Room 113 East Facing Window

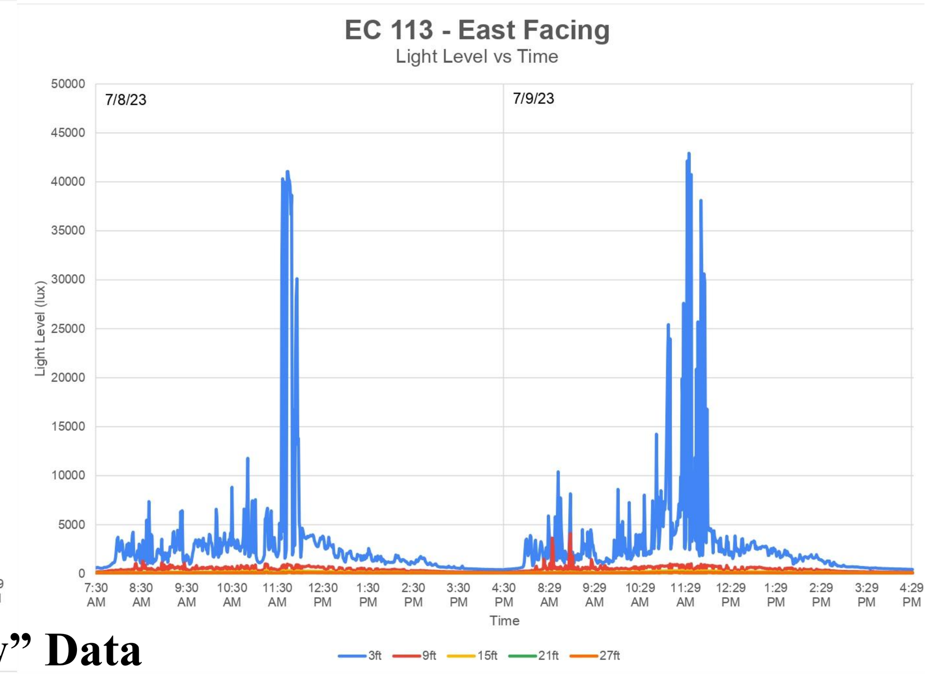
Human Data Collection (in Progress)

- Participants:
  - complete activities in settings with various daylight - lighting will be measured
  - Complete surveys on activities

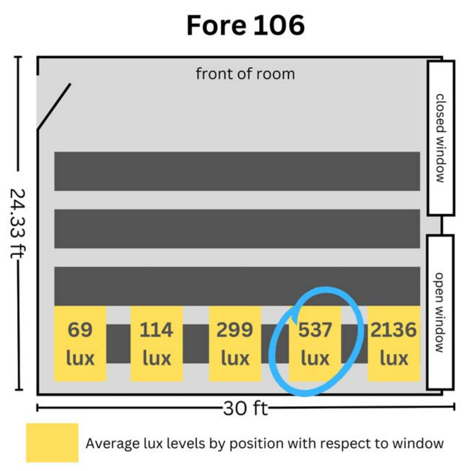
Wearable Light Sensor

Results

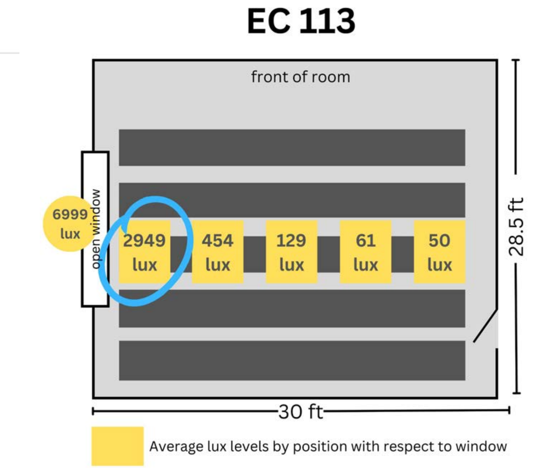




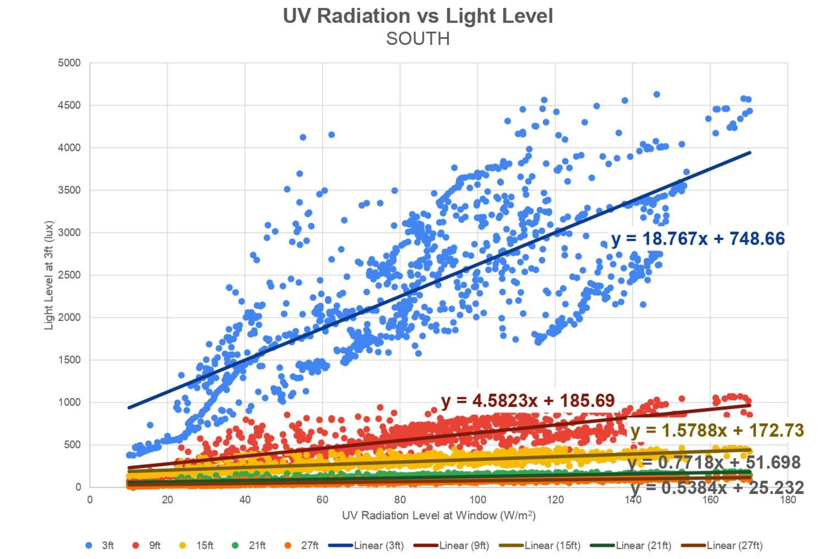
“Raw” Data

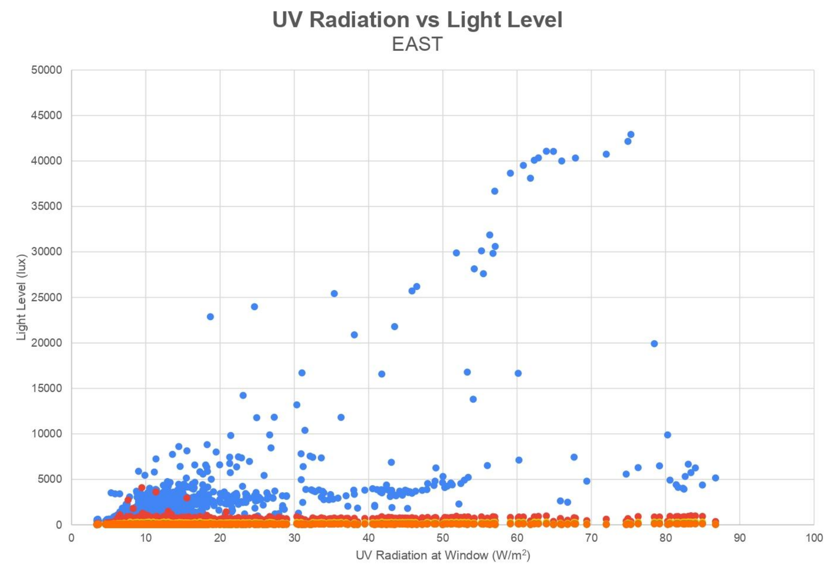


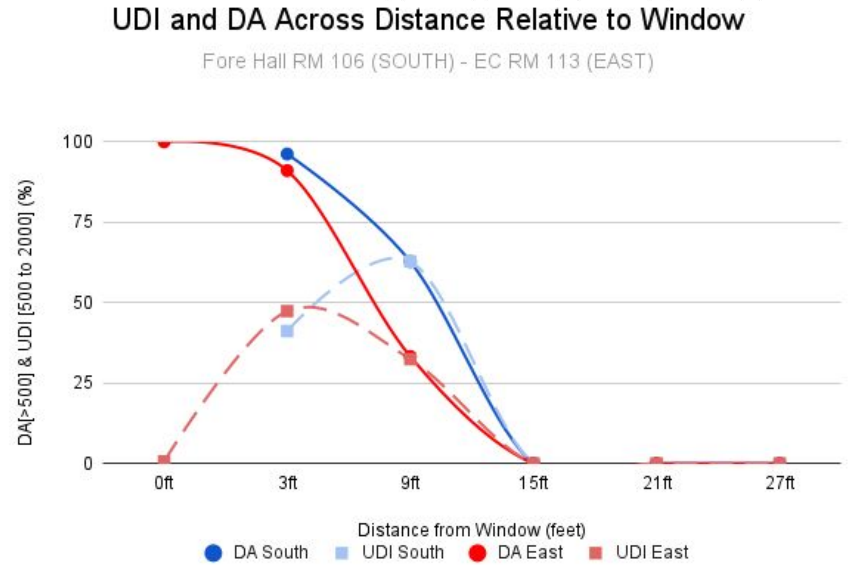
SOUTH facing window
Window: 10’3” x 5’
Wall: 24’4” x 9’7”
WWR: 21.98%



EAST facing window
Window: 9’5” x 6’7’
Wall: 28’6” x 10’
WWR: 22.33%







Energy Savings & Usage Profile

Window Direction	kWh without Daylighting use	kWh with Daylighting use	WWR	Percent Savings
South	1.97523	4.63752	21.98%	57.4%
East	5.43096	3.03579	22.33%	44.1%

Curriculum Modules

Analyzing the Effects of Light Level on Plant Growth 5.8(C) & 5.9(C)

Introduction to data collection (not in the math TEKS, but in science TEKS) as well as basic data analysis. Students will measure the growth of plants that are placed in various classroom locations under different lighting levels, also to be measured. Students will collect and graph the data and be asked to analyze the effect of the different levels of lighting and what it did to the plant(s).

Electricity Cost and Conservation

6.11(A) Earth and Space. The student understands how resources are managed and the students is expected to research and describe why resource management is important in reducing global energy

6.11(B) Earth and Space. Explain how conservation increased efficiency, and technology can help manage air, water, soil, and energy resources.

Conclusion

- In order to be within a working UDI range for the largest percentage of the school day (7:30a to 4:30p), the optimal workspace distance from the daylighting source was between 3 ft and 9 ft.
- Fore Hall 106 (South) – 57.4 % less lighting energy was used.
- EC 113 (East) – 44.1% less light energy was used.

Future Approaches

Six week time period to complete research and data collection was a restriction for this project.

- Time:
  - conduct testing throughout a school year.
- Participants:
  - use larger number of participants
  - preferably public K-12 students
- Classrooms:
  - conduct multiple experiments in K-12 classrooms with windows facing different directions.
- Materials:
  - Additional sensors for more data collection points & participants simultaneously
  - Additional functional data loggers

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Acknowledgements

This material is based upon work supported by the National Science Foundation under Award No. 2206864. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Study the Potential of Converting Food Waste into Renewable Energy in the Backyard

Students: Andy Hernandez & Crystal Reyes

Faculty Advisors: Dr. Xiaoyu Liu & Dr. Marsha Sowell

Industrial Advisor: Enrique Molina

Program Name: NSF RET I-READ Texas A&M University - Kingsville

ABSTRACT

- In the U.S. the estimated food waste at the household consumption level is 32% of purchased food.
- According to the USDA, 66% of the residential sector's wasted food enters into the landfills.
- One of the main goals to bring education and awareness to U.S. residents about conserving food waste is by composting in the backyard.

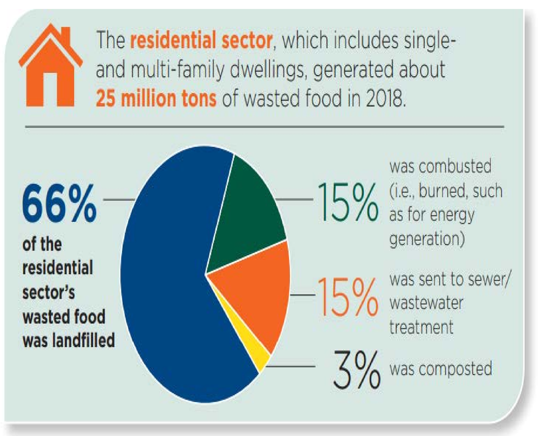


Fig 1.- USDA Food Waste [1]

INTRODUCTION

OBJECTIVE: Study the potential of converting food waste into renewable energy in the backyard through experiments with different combinations of food waste types.

RESEARCH QUESTION: How much thermal energy can be generated by a compost tumbler?

By setting up a simple compost bin, a barrel that rotates, food waste or biodegradable material can be added into the bin with a little bit of dirt/topsoil and water. There are compost bins that can be created at home or there are some that can be store-bought. A bin with fresh materials can be set up with temperature sensors or probes that can be set with a data collection over a few days or weeks at a time. The bin can be rotated manually on a schedule or can be set on a motorized rotation depending on what resources are available that make it possible. After the collection of data, the data points can be analyzed so see how much thermal energy can be generated. The optimal combination of variables is unknown to give the highest yield in thermal energy.

METHODOLOGY

Compost Bin:

•Bin #1 - Dry leaves, grass clippings, and topsoil

•Bin #2 - Food waste and topsoil

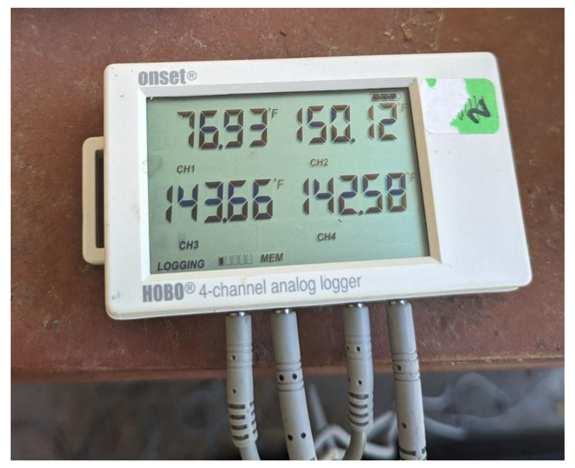
Hobo Logger:

(TOP) Ch.1 - Food Waste

(BOTTOM) Ch.2 - Food Waste

(TOP) Ch. 3 - Grass & Leaves

(BOTTOM) Ch. 3 - Grass & Leaves

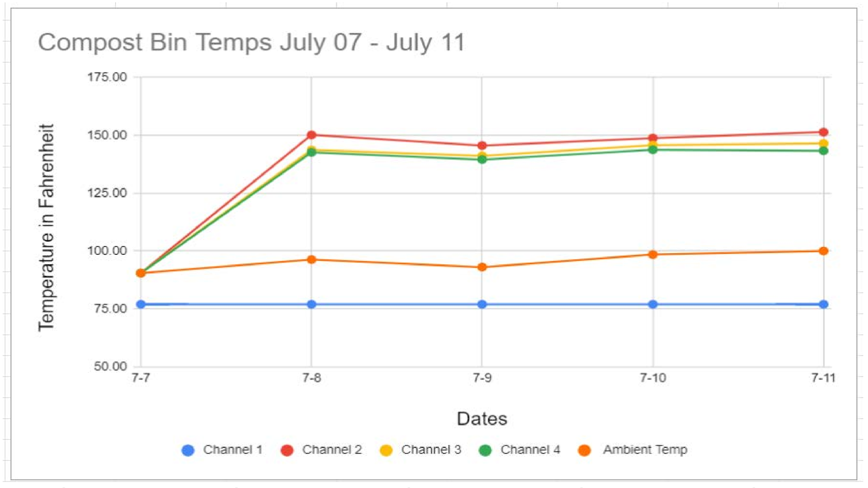


Collection Parameter:

- 5 minute intervals
- 7 days

RESULTS

- Data shows that on the line graph that temperatures peak range is between 12PM-5PM.
- Channel 2 temperature line is higher than channel 3 and 4 possibly due to higher water content from the food waste.
- The biggest temperature difference between channel 2 and the ambient temperature is 53.88°F at 3:58 PM.



			Probe/Sensor Input Temp. Fahrenheit				Ambient Temp.
Day	Time (PM)	Date	Channel 1	Channel 2	Channel 3	Channel 4	Sensor
0	3:00	7-7	76.93	90.42	90.42	90.42	90.42
1	3:58	7-8	76.93	150.12	143.66	142.58	96.24
2	12.03	7-9	76.93	145.51	141.10	139.51	93.00
3	4:00	7-10	76.93	148.74	145.70	143.74	98.43
4	5:07	7-11	76.93	151.35	146.43	143.30	99.96
	Average Temerature		-------	137.23	133.46	131.91	95.61

*Assumed materials were at ambient temperature

*Channel 1 - faulty

Channel 1: Surface temp of Foodwaste

Channel 2: Internal temp of Foodwaste

Channel 3: Surface temp of Grass and Leaves

Channel 4: Internal temp of Grass and Leaves

Average temperature for Channel 2 is 137.23

CONCLUSION

How much thermal energy can be generated by the food waste in a compost bin?

- The graphs show inconclusive results because the temperature probe in Channel 1 was faulty and the data logger malfunctioned.
- The measurements that were used as data points were obtained by pictures. Pictures were taken of the sensor every time a member of the team would go out and rotate the barrel to mix up the contents. The pictures were not taken at the same time of the day, so the time interval between readings was not constant. Also not constant were the time intervals between rotations of the bin.
- A future experiment must be set up to follow up on these results. In this future experiment, the food waste must be categorized by type and weighed individually. The temperature sensors must not interfere with the rotation of the bin. Rotation of the compost bin must be standardized, for example, the rotation must be on a set schedule. This is where the benefit of a motor for rotation must be taken into consideration. The rotation by motor will take more ingenuity.
- **This trial run gives a basic experimental model to try to improve on.** Taking this experience to the classroom and having students carry out this methodology may yield better performances of the experimental procedure, the expectation is that each experiment will be better than the previous one.

LEARNING MODULE DEVELOPMENT

<u>LEARNING MODULE:</u> *Compost: Generating Thermal Energy*

Lesson objective:

Students will learn that composting can generate thermal energy as a renewable resource.

<u>OVERVIEW:</u>

Brief overview of learning module:

1. Students will explore the connection between engineering and renewable energy.
2. Students will learn how to set up a compost bin.
3. Students will gather materials (food waste, grass, leaves, topsoil, water).
4. Students will measure and graph the changes in temperature over a 3 week period.

<u>LEARNING MODULE:</u> *Compost: A Scientific Investigation*

Lesson objective(s):

1. Students will learn that trash is composed of two types of waste: organic and inorganic.
2. Learn that decomposers such as fungi, microorganisms, and insects are important in the decomposition of organic waste.
3. Practice asking scientific questions.
4. Gain experience designing an experiment to answer a question by composting in a jar.

<u>OVERVIEW:</u>

In this four-part inquiry-based activity:

1. Students will practice using the scientific method while learning about decomposition, exploring how some types of garbage will decompose while others will not.
2. Students can then go on to design their own experiment to test different variables affecting the rate of decomposition.
3. The extension activity will consist of students learning about decomposition on a larger scale by setting up a compost bin outside near the classroom garden.
4. Students will gather and graph the change in temperature of the compost and then will use the compost in the garden to compare & contrast regular soil vs. compost soil to determine growth rate differences in the lima beans planted. Students will record results in a journal.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Award No. 2206864. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) & do not necessarily reflect the views of the National Science Foundation.

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Exploration and Investigation of the Impacts of Wind Farms and Hurricanes on Wind Speed Pattern Changes

National Science Foundation (NSF) Research Experiences for Teachers (RET) Site at Texas A&M University-Kingsville

Integrating data-driven research in Renewable Energy Across Disciplines (I-READ)

CCISD Teacher Participant: Charife Calpo
Research Faculty Mentor: Dr. Hua Li
Student Mentor: Erick Martinez-Gomez

KISD Teacher Participant: Christina Gonzales
Curriculum Faculty Mentor: Dr. Marsha Sowell
Industrial Advisor: Kevin Rees, P.E.

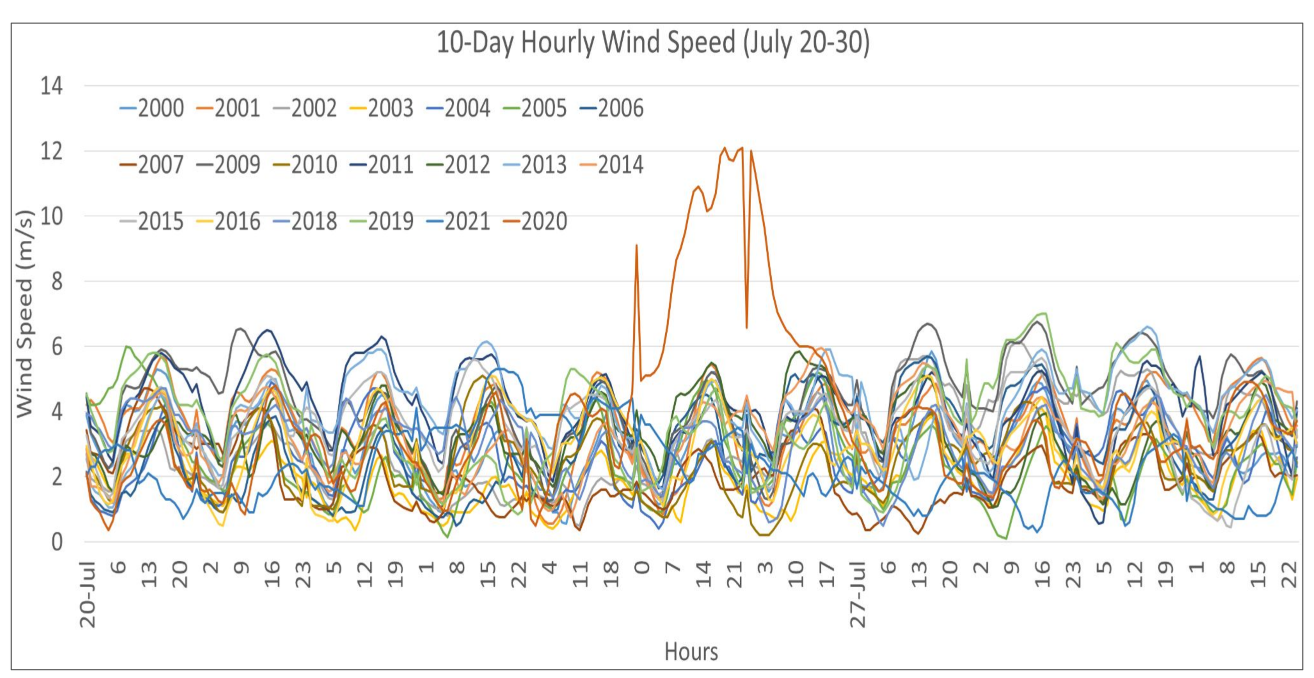
Abstract

This research aimed to analyze wind data to investigate the influence of different factors on wind speed patterns. The study began by collecting meteorological data from the National Solar Radiation Database (NSRDB), which was used to identify possible changes in wind speed patterns and correlations with different factors. Two separate wind speed analyses were conducted. One study focused on wind speed changes in Corpus Christi, TX, before and after the landfall of hurricanes. The other study analyzed and compared wind speed pattern change at selected locations near the Chapman Ranch and Papalote Creek Wind Farms before and after the wind farm commission dates.

The Influence of Hurricane Landfalls on Wind Speed in Corpus Christi, TX

Results

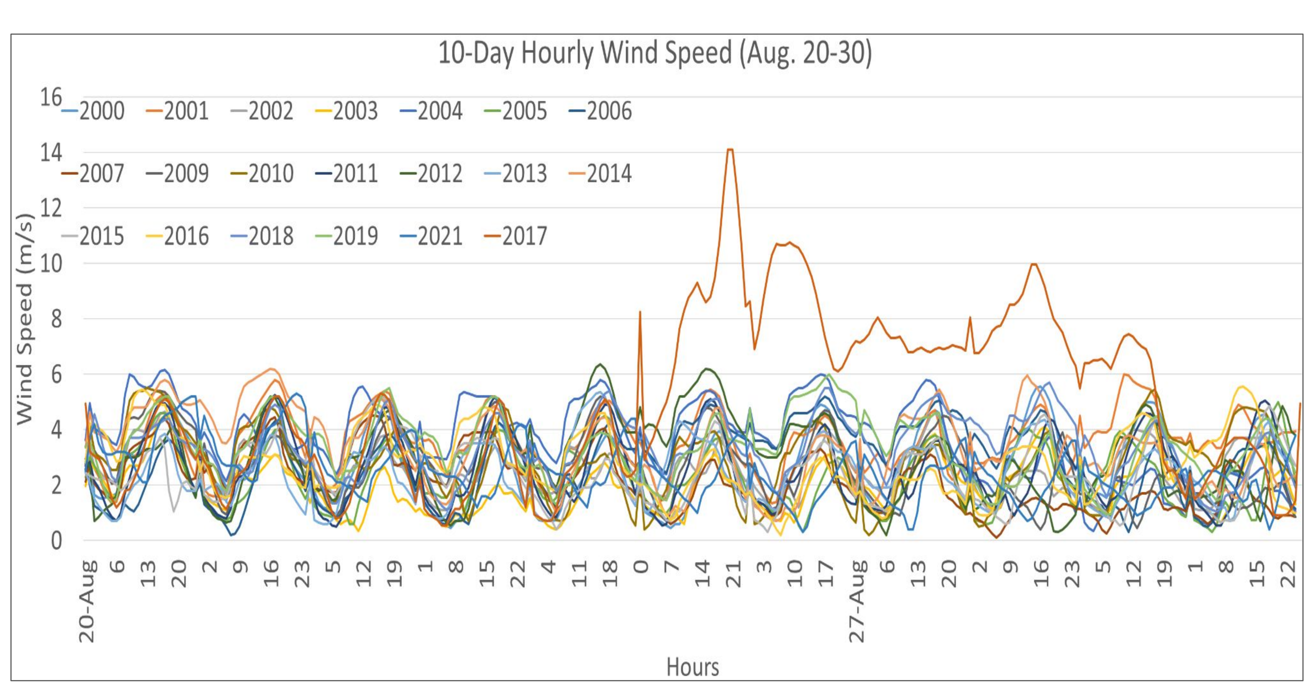
Hurricane Hanna, Landfall in Corpus Christi,TX on July 25, 2020, at 41m/s under Category 1 (H1)[2]. This analysis aimed to determine how Hurricane Hanna influenced the wind speed in Corpus Christi during the 10-day period of landfall, taken at 27.76, -97.43 coordinates.



The chart represents the average wind speed on July 20-30, 2020, vs. the wind speed on the same days in all other years. The table shows the two-tailed P-values of the average wind speed of the 10-day window vs. all other years on the same days.

Two Tailed P-Values											
Dates	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul
P-Value	1.237E-15	0.01000736	0.610073513	0.0319823	0.084952579	2.69921E-13	6.364E-06	0.013857906	5.12684E-11	0.461415163	8.04678E-07

Hurricane Harvey, Landfall in Corpus Christi, TX on August 26, 2017, at 59 m/s under Category 4 (H4)[2]. This analysis aimed to determine how Hurricane Harvey influenced the wind speed in Corpus Christi during the 10-day period of landfall, taken at 27.76, -97.43 coordinates.



The chart represents the average wind speed on Aug. 20-30, 2017, vs. the wind speed on the same days in all other years. The table shows the two-tailed P-values of the average wind speed of the 10-day window vs. all other years on the same days.

Two Tailed P-Values											
Dates	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug	27-Aug	28-Aug	29-Aug	30-Aug
P-Value	0.600489	0.037443533	0.782612287	0.0024233	0.402448242	1.62753E-09	5.184E-12	5.93475E-16	1.84803E-22	4.80023E-07	0.931148061

Conclusion

The current analysis shows significant differences in wind speed on the days the hurricanes made landfall in the Corpus Christi area compared to the years when there were no hurricanes. The results from the T-Test conducted on the 10-day window for both hurricanes showed statistically significant results because most of the p-values were less than 0.05.

Classroom Lesson Module

Optimal Placement of Renewable Energy Sources

Lesson Objective

The students use critical thinking and problem-solving skills to analyze and interpret data to derive meaningful insights, identify future patterns, and discover relationships that aid in efficient utilization of renewable electric sources.

Lesson Research Questions

Knowing that good places for wind turbines are where the annual average wind speed is at least 4 m/s[3]...

- How do weather conditions influence the wind speed?
- What is the best location on campus to install a small wind turbine?

Knowing that solar panels are comprised of photovoltaic cells that react to UV rays and transform them into electricity[4]....

- How do weather conditions influence UV radiation?
- What is the best location on campus to install a solar panel?

Lesson Criteria

- Use reputable published data (NSRDB)
- Use weather instruments to measure and collect data.
- Filter through the data and refine it to its specific attributes.
- Statistical analysis of the data using excel.
  - Average, Standard Deviation, Coefficient of Variation, T-Test
- Create an excel interface, report, and poster to communicate the results.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Award No. 2206864. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

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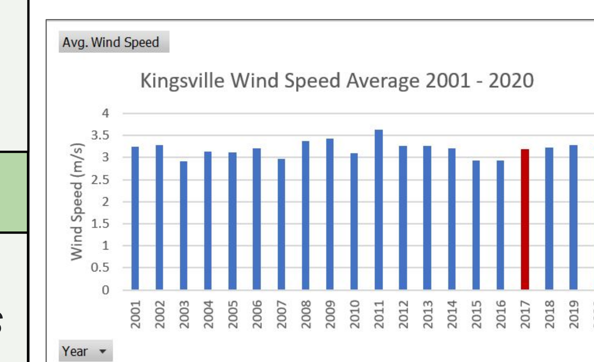
[6] The Papalote Creek Wind Farm Project Project. (n.d.). Power Technology.

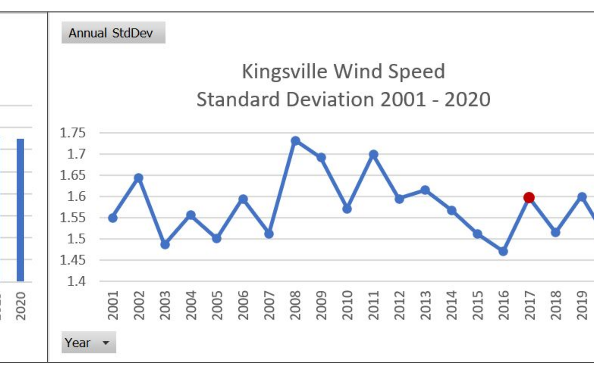
The Influence of Wind Farms on Wind Speed in Neighboring Cities

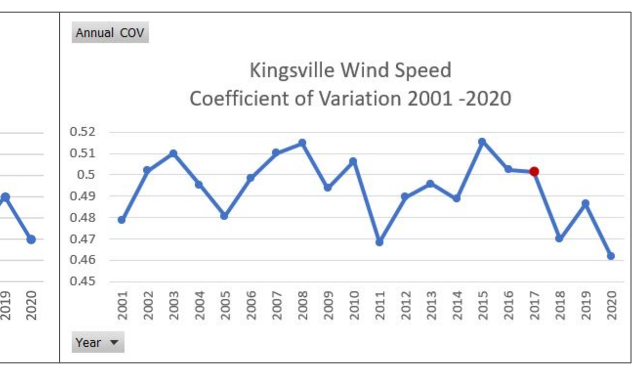
Results

Chapman Ranch Wind Farm's influence on wind speed in Kingsville, TX

The wind speed in Kingsville, TX, was specifically analyzed for changes before and after the Chapman Ranch Wind Farm October 2017 commission date.[5]

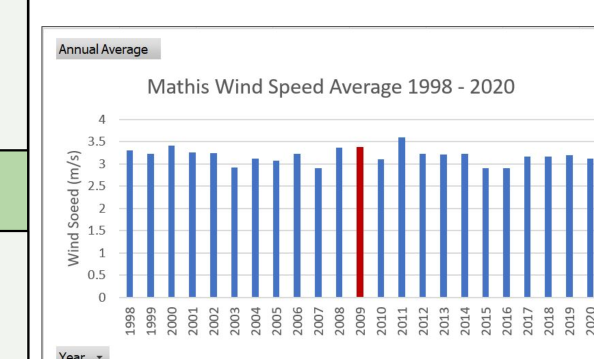


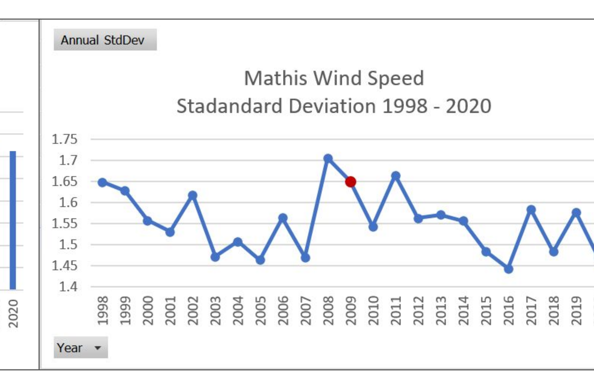


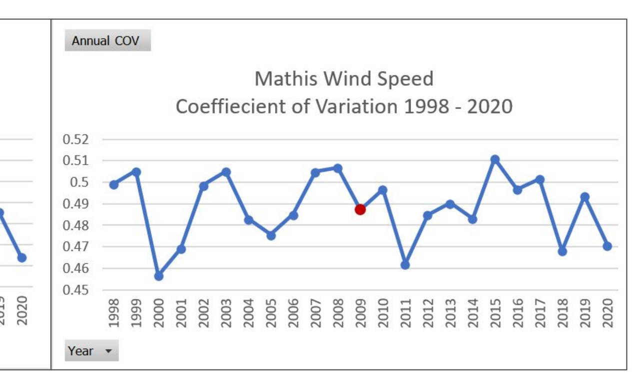


Papalote Creek Wind Farm's influence on wind speed in Mathis, TX

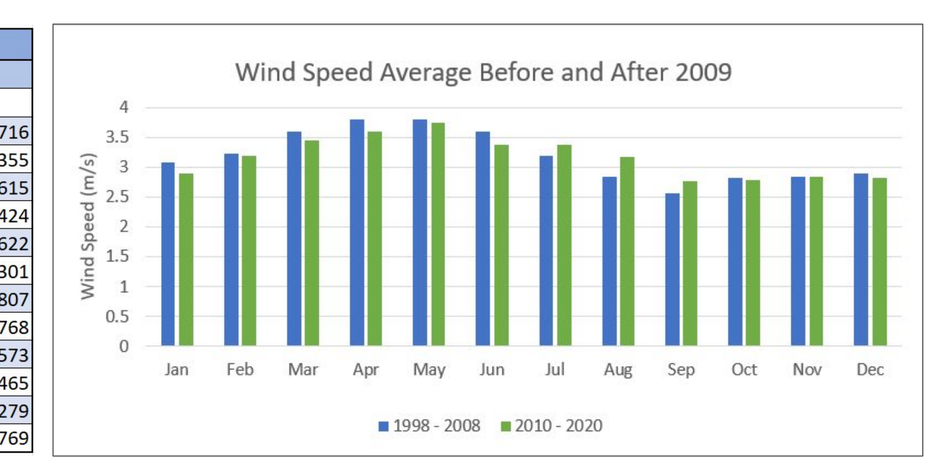
The Papalote Creek Wind Farm is approximately 38 km from Mathis, TX, sharing a similar distance as Kingsville from the Chapman Ranch Wind Farm. However, the Papalote Creek Wind Farm was commissioned in November 2009[6], which yielded more pre and post-data analysis of the wind speed.







Mathis Wind Speed (m/s) Comparision						
	1998 - 2008			2010 - 2020		
Month	Average	StdDev	CoV	Average	StdDev	CoV
Jan	3.07490836	1.56411116	0.50937923	2.90295699	1.61285512	0.55616716
Feb	3.23318289	1.64617292	0.50998933	3.19331897	1.61428035	0.50758355
Mar	3.58948558	1.73297191	0.48600708	3.43998045	1.61676863	0.47499615
Apr	3.80545455	1.62295682	0.42906858	3.58837121	1.57055049	0.44225424
May	3.79689638	1.41752705	0.37459876	3.73940616	1.49530949	0.40007622
Jun	3.5961048	1.37406475	0.38805618	3.36734848	1.32405699	0.39854301
Jul	3.19554008	1.25877725	0.3973393	3.36610459	1.2942676	0.38560807
Aug	2.84425098	1.29078594	0.45590453	3.17710777	1.39774892	0.43889768
Sep	2.5598548	1.28313949	0.50106113	2.75981061	1.24923754	0.45312573
Oct	2.81679497	1.3539057	0.48401287	2.78288123	1.34345636	0.48368465
Nov	2.83369318	1.46883917	0.51973179	2.83469066	1.46141954	0.51628279
Dec	2.89067693	1.61750785	0.55943716	2.81312928	1.61726162	0.57766769



t-Test: Mathis Wind Speed Average (Jan - Dec)		
	1998 - 2008	*2010 - 2020*
Mean	3.18640362	3.16375887
Variance	0.17809635	0.11626317
Observations	12	12
Pearson Correlation	0.91632091	
Hypothesized Mean Difference	0	
df	11	
t Stat	0.44806875	
P(T<=t) one-tail	0.33140012	
t Critical one-tail	1.79588482	
P(T<=t) two-tail	0.66280024	
t Critical two-tail	2.20098516	

t-Test: Mathis Wind Speed Standard Deviation (Jan - Dec)		
	1998 - 2008	*2010 - 2020*
Mean	1.46923	1.46643439
Variance	0.0264801	0.01975221
Observations	12	12
Pearson Correlation	0.92705745	
Hypothesized Mean Difference	0	
df	11	
t Stat	0.15651286	
P(T<=t) one-tail	0.43923218	
t Critical one-tail	1.79588482	
P(T<=t) two-tail	0.87846436	
t Critical two-tail	2.20098516	

t-Test: Mathis Wind Speed Coefficient of Variation (Jan - Dec)		
	1998 - 2008	*2010 - 2020*
Mean	0.46788216	0.46957391
Variance	0.0034505	0.00381101
Observations	12	12
Pearson Correlation	0.92246946	
Hypothesized Mean Difference	0	
df	11	
t Stat	-0.24519628	
P(T<=t) one-tail	0.40540937	
t Critical one-tail	1.79588482	
P(T<=t) two-tail	0.81081874	
t Critical two-tail	2.20098516	

Conclusion

The current analysis shows no significant change in wind speed before and after the wind farm commission dates. Specifically, the results from the T-Test conducted on the Mathis, TX data resulted in statistically insignificant results because the p-value was greater than 0.05. Further investigation would need to be conducted to see if wind farms show any true influence on wind speeds.