Solar Radiation Big Data Analysis for Strategic Positioning of Solar Panels

Solar Team: I-READ

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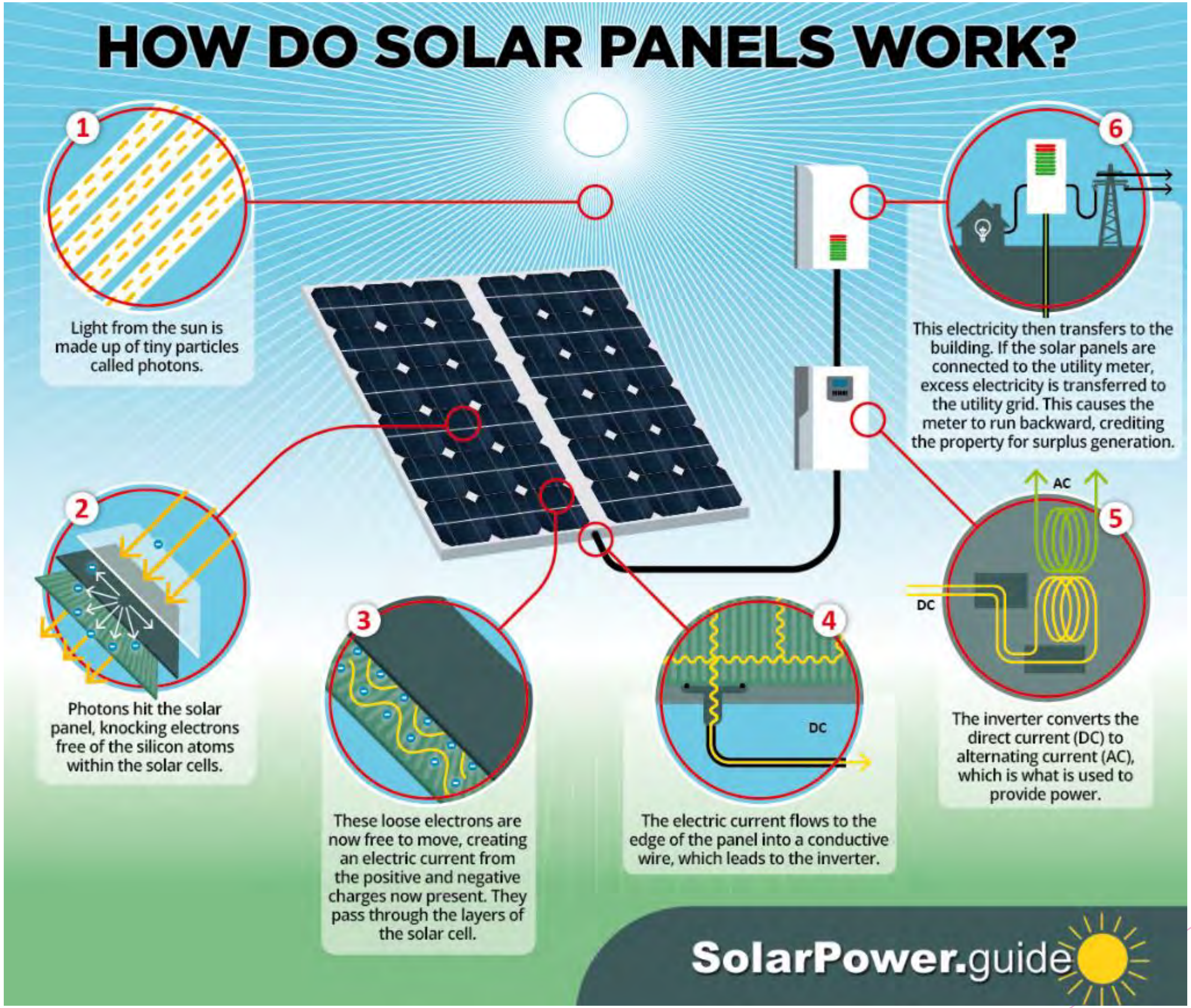
Background


HOW DO SOLAR PANELS WORK?
1
Light from the sun is made up of tiny particles called photons.
2
Photons hit the solar panel, knocking electrons free of the silicon atoms within the solar cells.
3
These loose electrons are now free to move, creating an electric current from the positive and negative charges now present. They pass through the layers of the solar cell.
4
DC
The electric current flows to the edge of the panel into a conductive wire, which leads to the inverter.
5
AC
DC
The inverter converts the direct current (DC) to alternating current (AC), which is what is used to provide power.
6
This electricity then transfers to the building. If the solar panels are connected to the utility meter, excess electricity is transferred to the utility grid. This causes the meter to run backward, crediting the property for surplus generation.
SolarPower.guide

Types of Solar Panels

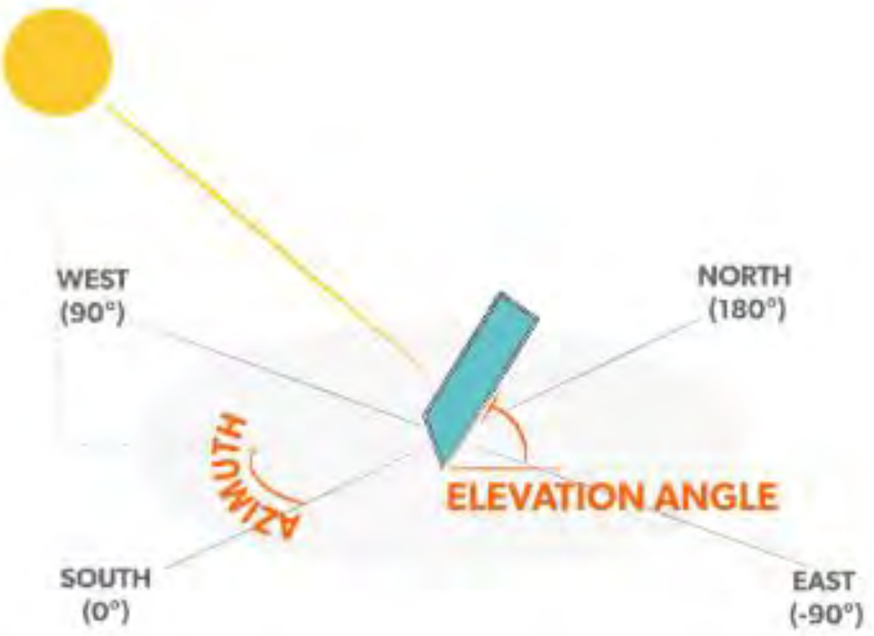
- 4 different types of solar panels:
  - 1) Monocrystalline: Also known as single-crystal panels, these are made from a single pure silicon crystal that is cut into several wafers. Since they are made from pure silicon, they can be readily identified by their dark black color. The use of pure silicon also makes monocrystalline panels the most space-efficient and longest-lasting among all solar panel types.
  - 2) Polycrystalline: As the name implies, these come from different silicon crystals instead of one. The silicon fragments are melted and poured into a square mold. This makes polycrystalline cells much more affordable since there is hardly any wastage and gives them that characteristic square shape. However, this also makes them less efficient in terms of energy conversion and space, since their silicon purity and construction are lower than monocrystalline panels.
  - 3) Passivated Emitter and Rear Cell (PERC) panels are an improvement of the traditional monocrystalline cell. This relatively new technology adds a passivation layer in the rear surface of the cell that enhances efficiency in several ways. It reflects light back into the cell, increasing the amount of solar radiation that gets absorbed. It reduces the natural tendency of electrons to recombine and inhibit the flow of electrons in the system. It allows greater wavelengths of light to be reflected. Light waves over 1,180nm can’t be absorbed by silicon wafers and simply pass through, so they end up heating the cell’s metal back sheet and reduce its efficiency. The passivation layer reflects these higher wavelengths and stops them from heating up the back sheet.
  - 4) Thin-film panels are characterized by very fine layers that are thin enough to be flexible. Each panel does not require a frame backing, making them lighter and easier to install. Unlike crystalline silicon panels that come in standardized sizes of 60, 72, and 96-cell counts, thin-film panels can come in different sizes to suit specific needs. However, they are less efficient than typical silicon solar panels.

Types of Solar Panels (Cont.)

Information for each type of panel	Monocrystalline	Polycrystalline	PERC	Thin Film
Cost	1 to 1.50 per watt	.7 to 1 per watt	.32 to .65 per watt	.5 to 1 per watt
Life Expectancy	25+ years	15 to 20 years	Not Rated yet	10 to 20 years
Efficiency/Rating	20+ %	17 to 15%	Add up to 5%	15 to 8%
Advantage	Best efficiency without use of PERC. Longest life expectancy without PERC.	Lower cost.	Least space needed. Highest Power.	Use on any shape. Can be bent around surface. Not required to be sheet or rectangle size.
Disadvantage	Cost.	Low heat tolerance.	Most expensive. Quicker to lose effectiveness. Reduces results at high temperature.	Requires more space - for less energy generated. Not durable.

Solar Irradiance at Location: latitude vs. longitude

- Elevation angle in SOLPOS is the azimuth angle - giving that the panel is facing North to South (180)
- Tilt Angle in SOLPOS is degrees tilt from horizontal panel



Tilt and azimuth angle in relation to the Equator.

Extraterrestrial Solar Irradiance (ETR) is the amount of solar radiation that would reach a location on Earth's surface measured in (Watts)/(Meter)^2

Power Output

Global formula for estimating the electricity generated from a solar panel

$$E = ArHPR$$

- E - Energy output in Wh
- A = Area of panel in m^2
- r = Efficiency
- H = Solar Irradiance in W/m^2
- PR = .75, Industry Standard

Thunderbolt

- $E = (.75m X .75m) X (.237) X (1161\ W/m^2) X .75$
- E = 116.08 W

Research Questions

- Using the Big Data available on SOLPOS (Solar Position and Intensity) calculator at NREL (National Renewable Energy Laboratory) website, obtain the solar energy yield throughout each day of the year at different locations and for a variety of tilt to find the best location and tilt.
- Compare the solar energy obtained from SOLPOS and experimental observation at various locations to understand the reliability of SOLPOS. Is there significant difference between simulation data from SOLPOS and experimental data?
- Measure the temperature on front and back of solar panels throughout the daytime hours to determine if there is a significant difference that can cause damage in the panel.
- Knowing that affordable solar panels are most commonly less than 25% efficient, what happens to the remaining energy gathered? Does the radiant energy transform to thermal?

Research Methodology

Methodology

- Conduct research on requirements to measure output from a solar panel.
- Determine the necessary properties of a solar panel in order to conduct the experiment.
- Download data from NREL SOLPOS Calculator, for different angles for different cities. Some cities had similar longitude and some cities had similar latitude.
- Use Microsoft Excel to analyze and graph data for different cities and angles.
- Determine if cities with similar longitude and latitude have variation in solar irradiance.
- Use actual solar panels to measure the output collected to observe the collected values compared to SOLPOS data for same location.

SOLPOS Interface

SOLPOS Calculator

Compute the solar position and intensity from time and location using NREL's SOLPOS.

Required input values:

Enter start date:

Year: 2005 Month: January Day: 1

Enter end date:

Year: 2005 Month: January Day: 1

Enter output time interval:

Interval: 10 Units: ○Second ◉Minute

Enter site location information:

39.743 Latitude, degrees north (south negative)
-105.178 Longitude, degrees east (west negative)
-7.0 Time zone, east (west negative)
835.0 Surface pressure (mbar)
10 Ambient dry-bulb temperature (°C)

Optional input values:

180 Azimuth of panel surface
67 Degrees tilt from horizontal of panel
1361.1 Solar constant (W/m^2)
7.6 Shadow-band width (cm)
31.7 Shadow-band radius (cm)
0.04 Shadow-band sky factor
0 Interval of a measurement period (sec)

Date	Time	Cos incidence	ETR tilt
1/1/2005	7:30:00	0.4827	680.0884
1/1/2005	7:40:00	0.5146	724.9449
1/1/2005	7:50:00	0.5462	769.4406
1/1/2005	8:00:00	0.5772	813.2216
1/1/2005	8:10:00	0.6077	856.0837
1/1/2005	8:20:00	0.6373	897.8829
1/1/2005	8:30:00	0.6662	938.5144
1/1/2005	8:40:00	0.6941	977.8844
1/1/2005	8:50:00	0.7211	1015.9075
1/1/2005	9:00:00	0.7471	1052.51
1/1/2005	9:10:00	0.772	1087.6155
1/1/2005	9:20:00	0.7958	1121.1552
1/1/2005	9:30:00	0.8185	1153.0638
1/1/2005	9:40:00	0.8399	1183.2784
1/1/2005	9:50:00	0.8601	1211.7417
1/1/2005	10:00:00	0.879	1238.3986
1/1/2005	10:10:00	0.8966	1263.1968
1/1/2005	10:20:00	0.9129	1286.089
1/1/2005	10:30:00	0.9278	1307.0327
1/1/2005	10:40:00	0.9412	1325.9868
1/1/2005	10:50:00	0.9532	1342.9152
1/1/2005	11:00:00	0.9638	1357.785
1/1/2005	11:10:00	0.9729	1370.5685
1/1/2005	11:20:00	0.9804	1381.2407
1/1/2005	11:30:00	0.9865	1389.7814
1/1/2005	11:40:00	0.991	1396.1742
1/1/2005	11:50:00	0.994	1400.4069
1/1/2005	12:00:00	0.9955	1402.4714
1/1/2005	12:10:00	0.9954	1402.3638
1/1/2005	12:20:00	0.9938	1400.0841
1/1/2005	12:30:00	0.9907	1395.6366
1/1/2005	12:40:00	0.986	1389.0303
1/1/2005	12:50:00	0.9797	1380.2769
1/1/2005	13:00:00	0.972	1369.3936
1/1/2005	13:10:00	0.9628	1356.4012
1/1/2005	13:20:00	0.9521	1341.3247
1/1/2005	13:30:00	0.9399	1324.1924

Research Data

- Using SOLPOS collect data at different location around the USA to determine if it is the longitude or latitude that makes a difference in the amount of solar ETR available
- Angle of the sun is different for different geographic location
- Determining the best locations - what is the best angle at each location
  - Looking at differences in Latitudes: Corpus Christ (27◦ N) to Minneapolis (44◦N)
  - Looking at different Longitudes: San Diego (117◦W) to Charleston SC (79◦W)

Comparison of Cities

Conditions/ City	Charleston, SC	Dallas, TX	Tucson, AZ	San Diego CA	CC, TX	Bishop, TX	KC, MO	OK, OK	MPLS, MN
Latitude	32.47	32.4645	32.1318	32.4254	27.4434	27.357	39.0559	35.287	44.5855
Longitude	79.555	96.4832	110.5535	117.0945	97.247	97.4758	94.3442	97.3117	93.1609
Time Zone	-5	-6	-7	-8	-6	-6	-6	-6	-6
STD	1atm/10	970/10	970/10	1atm/10	1 atm/12	1 atm/ 12	960/9	970/10	960/11

Experimental Work

- There are 48 panels for this set up.
- Each panel is rated at 250 watts.
- They are monocrystalline panels that were installed in 2021.
- The panels are facing North-South at a tilt angle of 20°
- The house runs mostly on these panels - the excess is sold back to the grid.

Bishop Solar Farm

Experimental Work (Cont.)

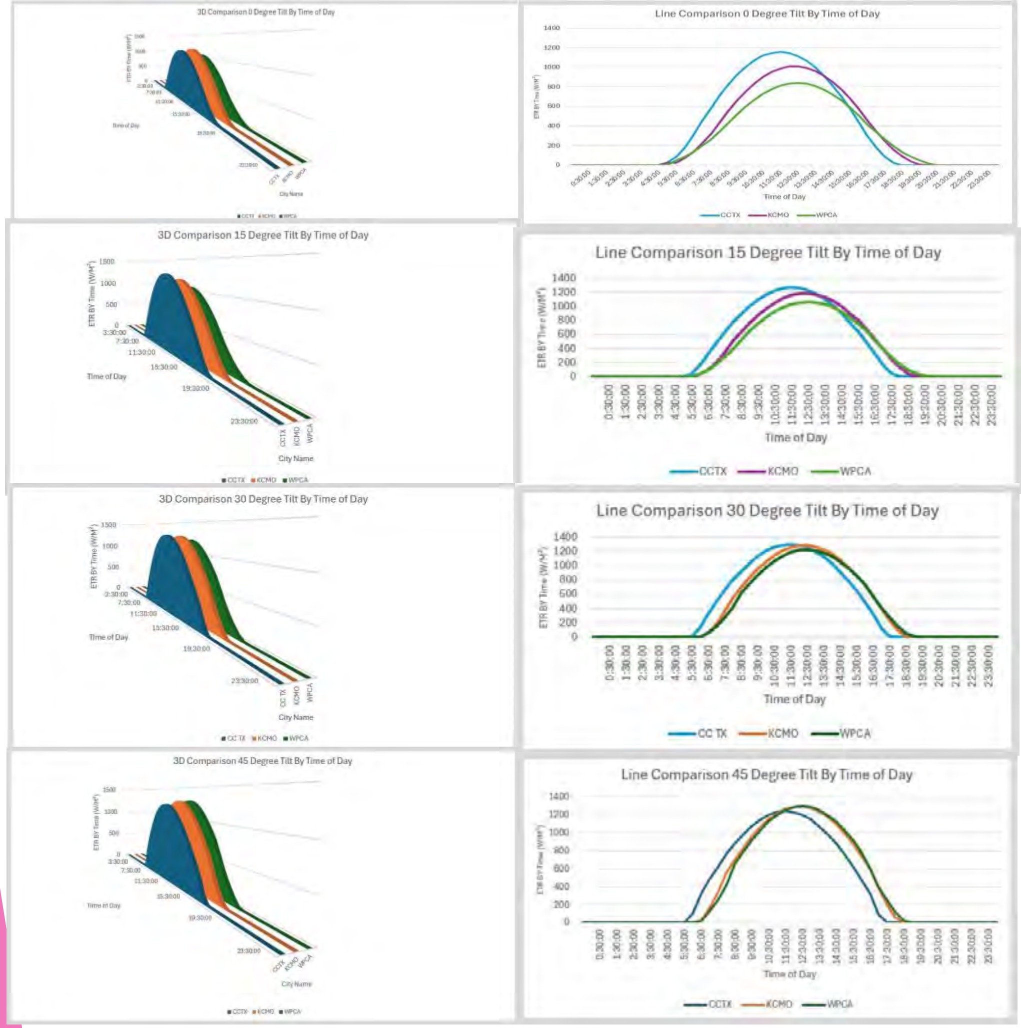
- Segway Panel
- 100 W panel
- Monocrystalline
- Efficiency rating at 23.7%

Segway Solar Panels (Corpus Christi, Texas)

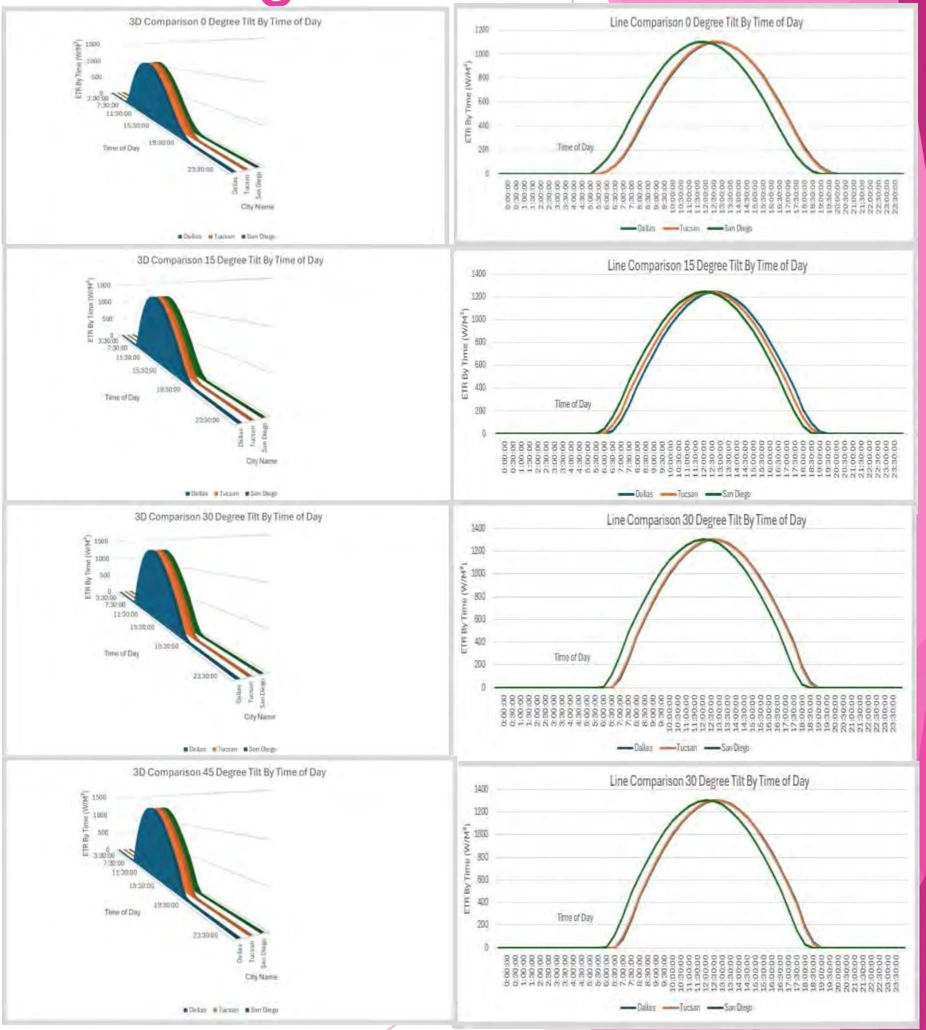
Results and Discussion

Big Data Analysis

Latitude N<->S

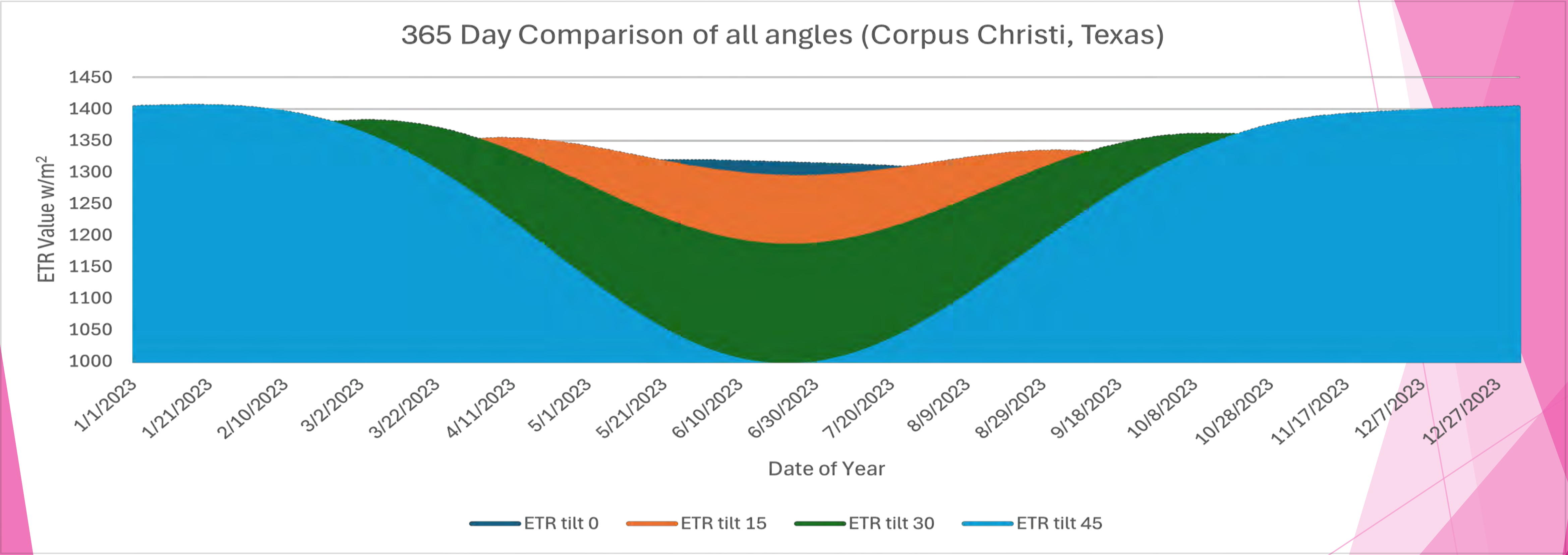


Longitude W<->E

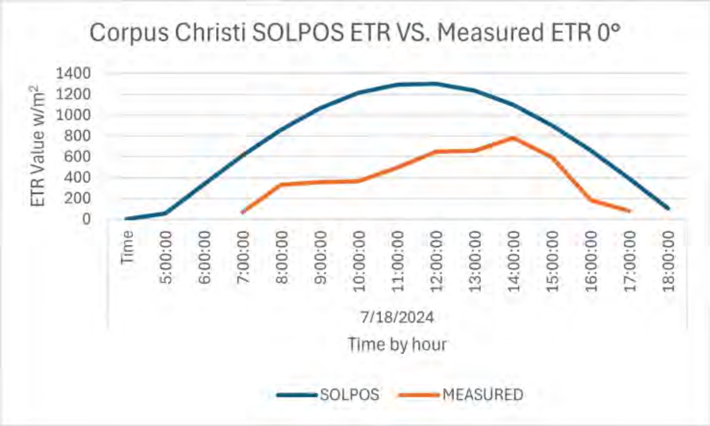


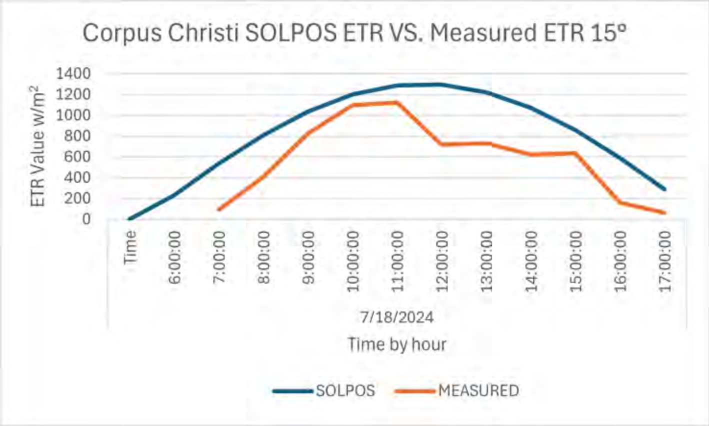
The data clearly demonstrated the variation of ETR differed greatly between cities of similar latitude while cities of similar longitude differed slightly.

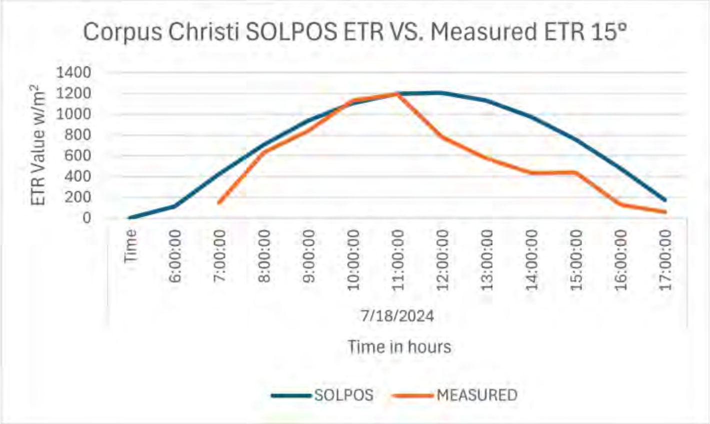
Big Data Analysis
1 Year Analysis of ETR by Angle

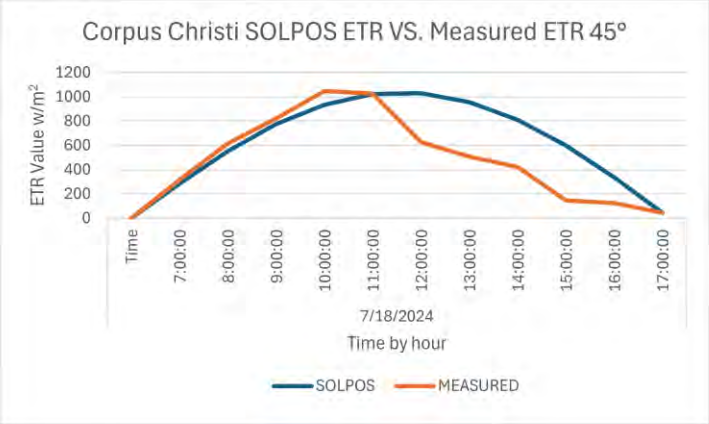


SOLPOS ETR VS MEASURED ETR
Corpus Christi, Texas



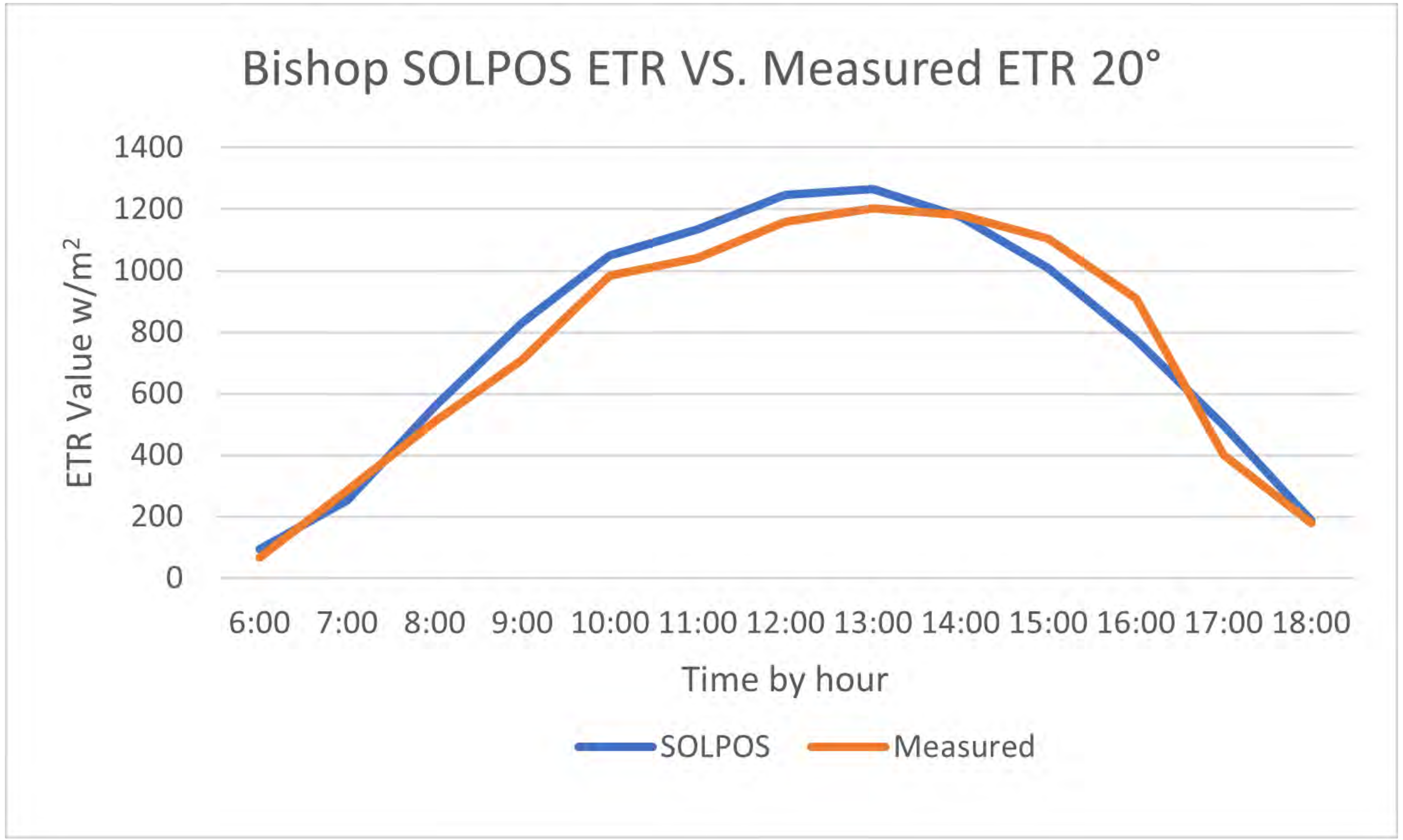






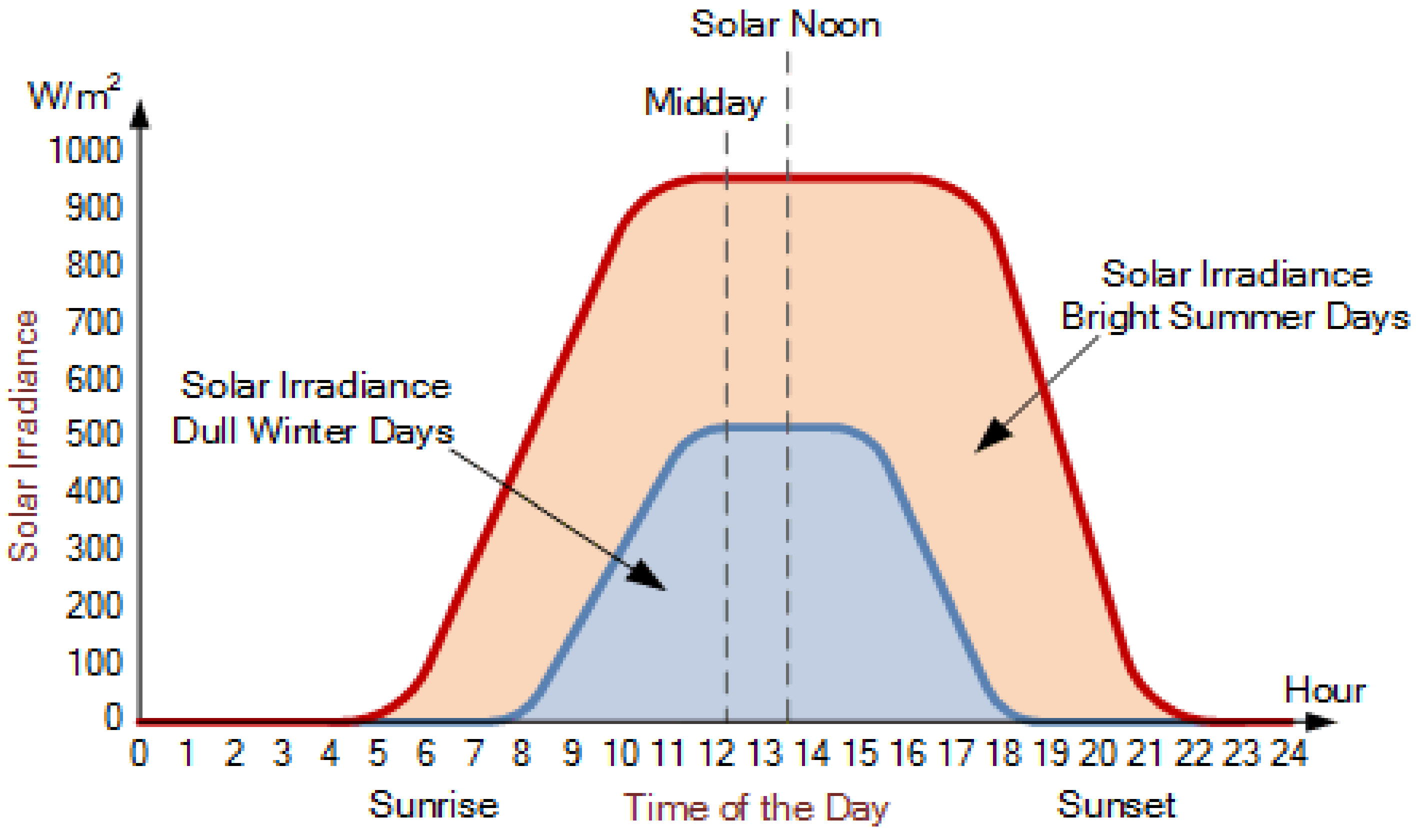
The experimental data is consistently lower than the SOLPOS simulation data.
Cloud cover or obstructions – trees / buildings – possible explanations

SOLPOS ETR VS MEASURED ETR
Bishop, Texas



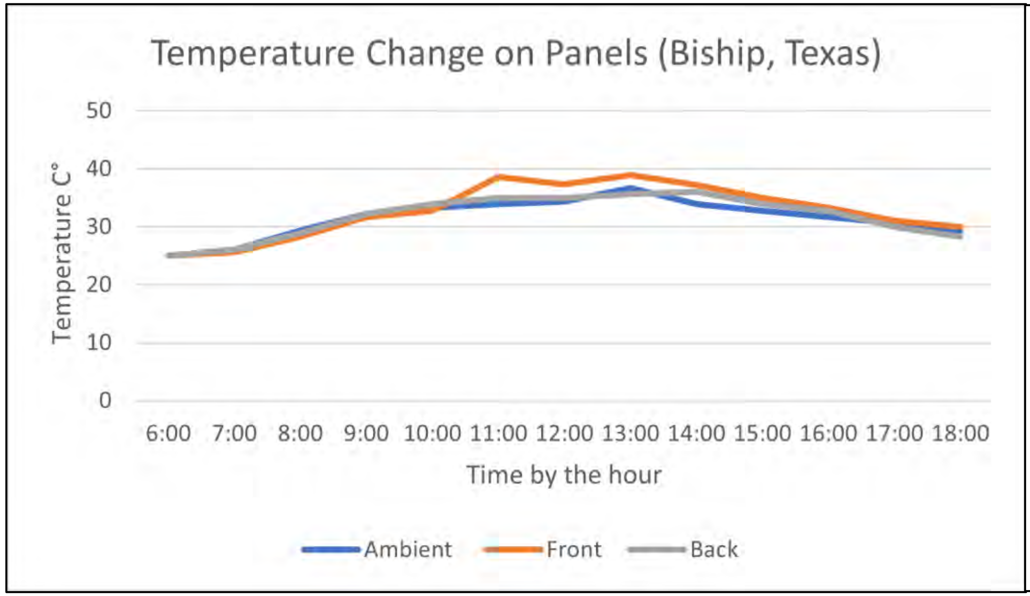
The Bishop data is tracking close between the SOLPOS simulation data and experimental data. Possible explanation: High quality solar panels / no obstruction (open field)

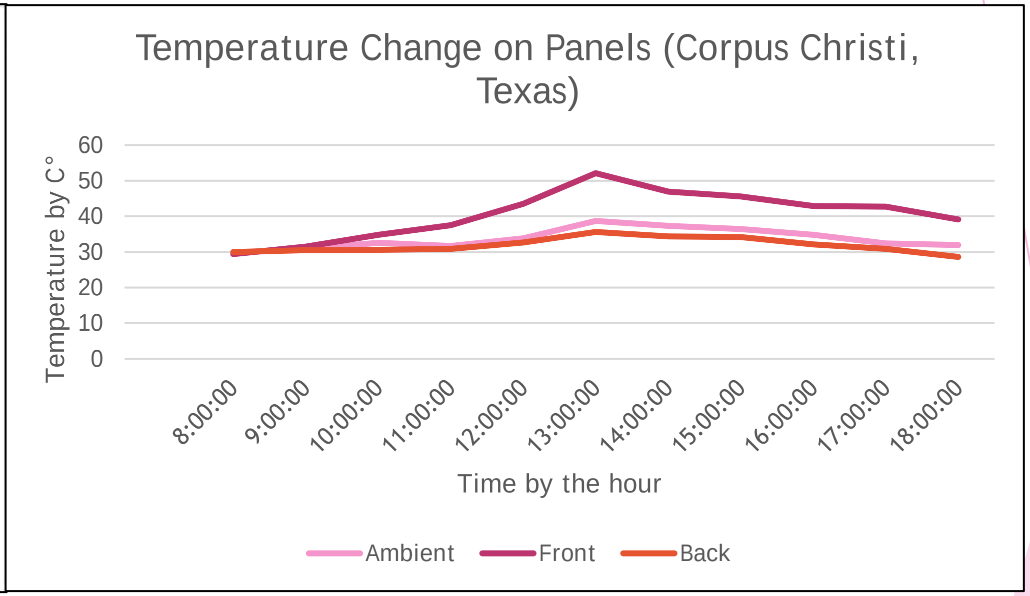
Solar Irradiation During the day, according to Alternative Energy



Partly cloudy days can create a result less than optimal ETR, such as the lower 2 areas shown in brown and blue.

Panel Temperature
Bishop, Texas and Corpus Christi, Texas





<u>Bishop</u>: Difference in temperatures between the front and the back of the solar panels is insignificant

<u>Corpus Christi</u>: Significant difference in temperature between the front and the back of the solar panels

Learning Modules

TEKS – P.1(A)-(G) P.2(A)-(D)

Module 1: Teaching students to use data to plot, interrupt and extrapolate information

- Each small group table will be given a city and the simulation data for Corpus Christi. The students will select their own city and locate the latitude and longitude for that city. Then using the SOLPOS - students will collect the simulation data, create graphs with the data using Microsoft Excel or Google Sheets.
- After the students have made their graphs - all cities' charts have been made, they will be displayed for the students to answer questions based on the information the student generated graphs and data information.
- Students will gather experimental data to compare with the simulation data then analyze using Microsoft Excel.
- Students will identify if the latitude or longitude changes the intensity for the city using Microsoft Excel to graph the class data.
- Students will provide report and presentation of their findings. D:\solar module haley data analysis v3 pdf.pdf
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Module 2: Teaching the students to use data to plot, interrupt and extrapolate information

- Part 2 Extrapolate Information
- Each group will learn to find the maximum

(highest solar intensity value) without being

given a formula - trail and error.

- Learn how to find highest solar intensity value

by changing the tilt angle D:\Cherie_Nelson_mod2_and_mod3 combined.pdf

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Module 2 -Calculating SD, Mean and Range

- Range: The smallest to the largest number in a set of points
- Mean: The average value for a given set of data
- SD - Standard Deviation: How much a number is away from the middle score.
- SD = $\sum\left(\frac{abs\ (X-\mu)^2}{(n-1)}\right)^{1/2}$
- Here are the Steps to finding SD (standard Deviation)
- 1. Find the mean, (X) average, value for the data set
- 2. For each point (μ), find the square of its distance from the mean
- 3. Sum (add) the values from step 2
- 4. Divide the sum of step 3 by the sample size minus 1 (this is called the variance)
- 5. Take the square root of the variance to get SD

Date	Time (n)	ETR value μ	Change from mean X - μ	Change value Squared $(X - \mu)^2$
8/1/2025	6 am	231.8769		
8/1/2025	7 am	528.3141		
8/1/2025	8 am	793.3874		
8/1/2025	9 am	1008.422		
8/1/2025	10 am	1158.635		
8/1/2025	11 am	1233.758		
8/1/2025	12 pm	1228.632		
8/1/2025	1 pm	1143.6		
8/1/2025	2 pm	984.4446		
8/1/2025	3 pm	762.0406		
8/1/2025	4 pm	491.6748		
8/1/2025	5 pm	192.5114		
8/1/2025	6 pm	65.6425		
	Mean ETR value (X)		Sum of the $(X-\mu)^2$	

Calculating the Efficiency of a Solar Panel

- From the first part - 300 Watts maximum panel output for the highest solar panel (monocrystalline)
- Efficiency = Work out/Work In
- Efficiency = 300 W/ 1366 W = 0.2196 or 22%
- That means 78% of the energy is lost

TEKS 1(A)-(F), 2(A)-(C) 3(A)-(C) 4(A)-(C)

Calculating the Efficiency of a Solar Panel

- To calculate error, you need to use the following formula for the Fluke meter:
- E = ArHPR where the E is what it should read (corrected value) A is the area of the panel r is the efficiency of the panel H is the solar constant (1161 kW/hr) PR is a default by the industry the accepted value is 0.75.
- E = (0.0002)(.25)(1161)(.75) = +/- 3%
- The SOLPOS values are not including any of the following: solar flares or extra solar activities, any cloud or storms that will diminish the solar capacity.

Time	ETR From SOLPOS (W/m^2)	Reading ETR Fluke (W/m^2)	Change in Values	% error
6:00	44.8457	62	17	38 +/- 3 = 35%
7:00	326.1114	277	49	15 +/- 3 =12%
8:00	603.6946	499	105	17 +/- 3 = 14%
9:00	855.0256	722	133	16 +/- 3 = 13%
10:00	1062.6797	987	76	7 +/- 3 = 4%
11:00	1212.4233	1050	162	13 +/- 3 = 10%
12:00	1294.0376	1135	159	12 +/- 3 = 9%
13:00	1301.9274	1201	101	8 +/- 3 = 5%
14:00	1235.5479	1180	55	4 +/- 3 = 1%
15:00	1099.4076	980	119	11 +/- 3 = 8%
16:00	902.1545	805	97	11 +/- 3 =8%
17:00	385.2481	353	32	8 +/- 3 = 5%
18:00	101.4754	111	10	10 +/- 3 = 7%

TEKS 5(A) 8(D)

Module 3: Interference with Solar Panel

- This is a week long experiment:
- TEKS Science 5(A) 8(D)
- Equipment needed:

Solar panel, Fluke measuring device with temperature gauges, level, polarized panels, colored panels to lay over the solar panel (Red, Blue, Yellow, Green, Purple/Violet, Orange), mirrors

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Teacher Instruction:

- Students will take a solar panel and place it outside and collect the following information each hour:
- Students will be asked for the leading question
- What is solar power? - energy from the sun that comes to the earth on electromagnetic waves
- How is it measured? - W/m^s
- What about temperature? Is this transferred by the sun? (yes) How is it measured?
- What effects would happen when you … (questions for them to think about and answer individually) - this is what we will be studying this week.
- use a mirror?
- Does color make a difference in the reading?
- Does polarization make a difference?
- What things can interfere with your readings?

Conclusions

Concluding Remarks

- The irradiance (ETR) was found to differ significantly between North and South locations, however little difference can be found between cities from West to East.
- The measured ETR for Corpus Christi, Texas was found to be consistently lower than the SOLPOS ETR data. Bishop, Texas experimental data matches well with the SOLPOS.
- Temperature difference between the front and back of the solar panels showed dependence on the location and positioning of the panel.
- Using the simulated data collected from SOLPOS suggests that changing angles during the day can increase the amount of energy collected.
- Learning modules were developed based on the research experiences and findings, to be implemented in the upcoming school year.

References

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8) https://solarpower.guide/solar-energy-insights/how-do-solar-panels-work

Acknowledgement

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Why is there no plant life here?

Analysis of Wind Speed Pattern Changes Before and After Wind Farm Operations

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Marisa Hamilton

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Educational Mentor:
Dr. Marsha Sowell
Graduate Mentor:
Yahya Al Bustanji
Industry Mentor:
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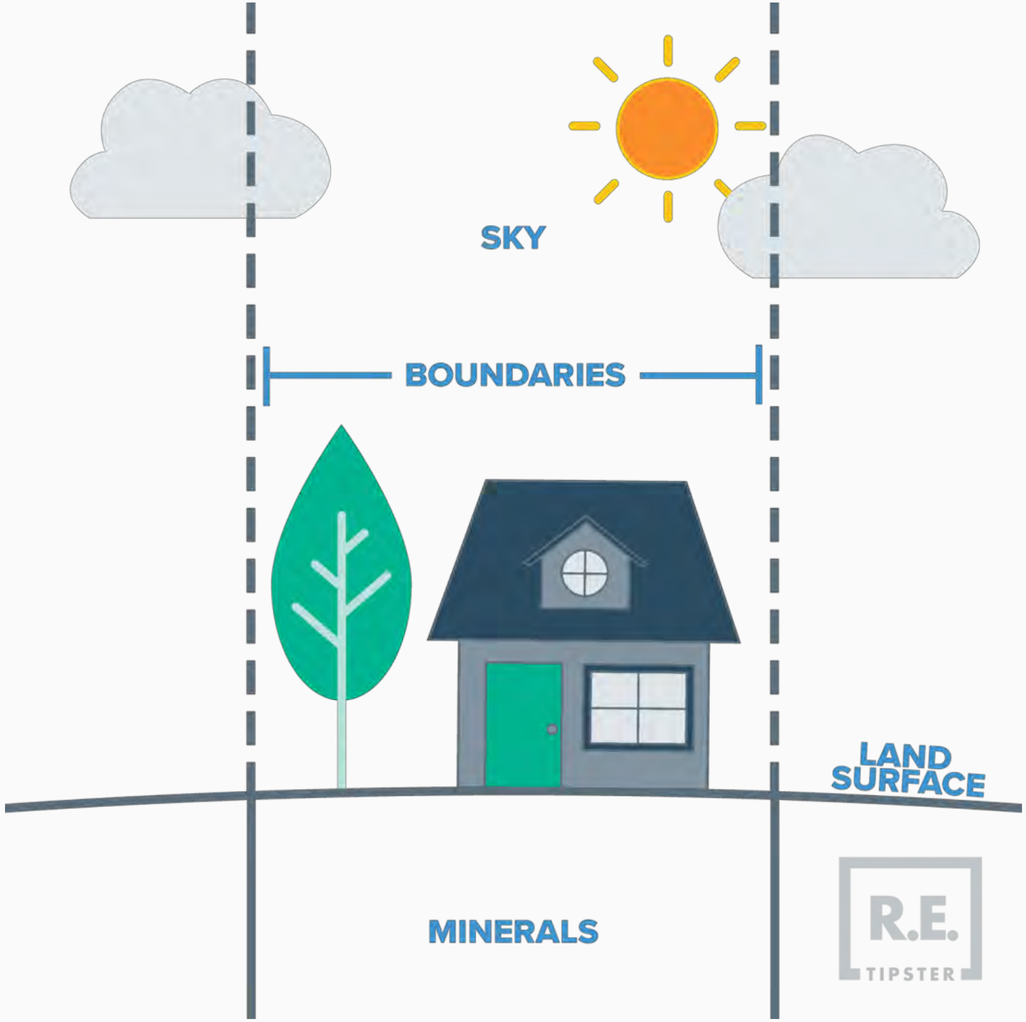
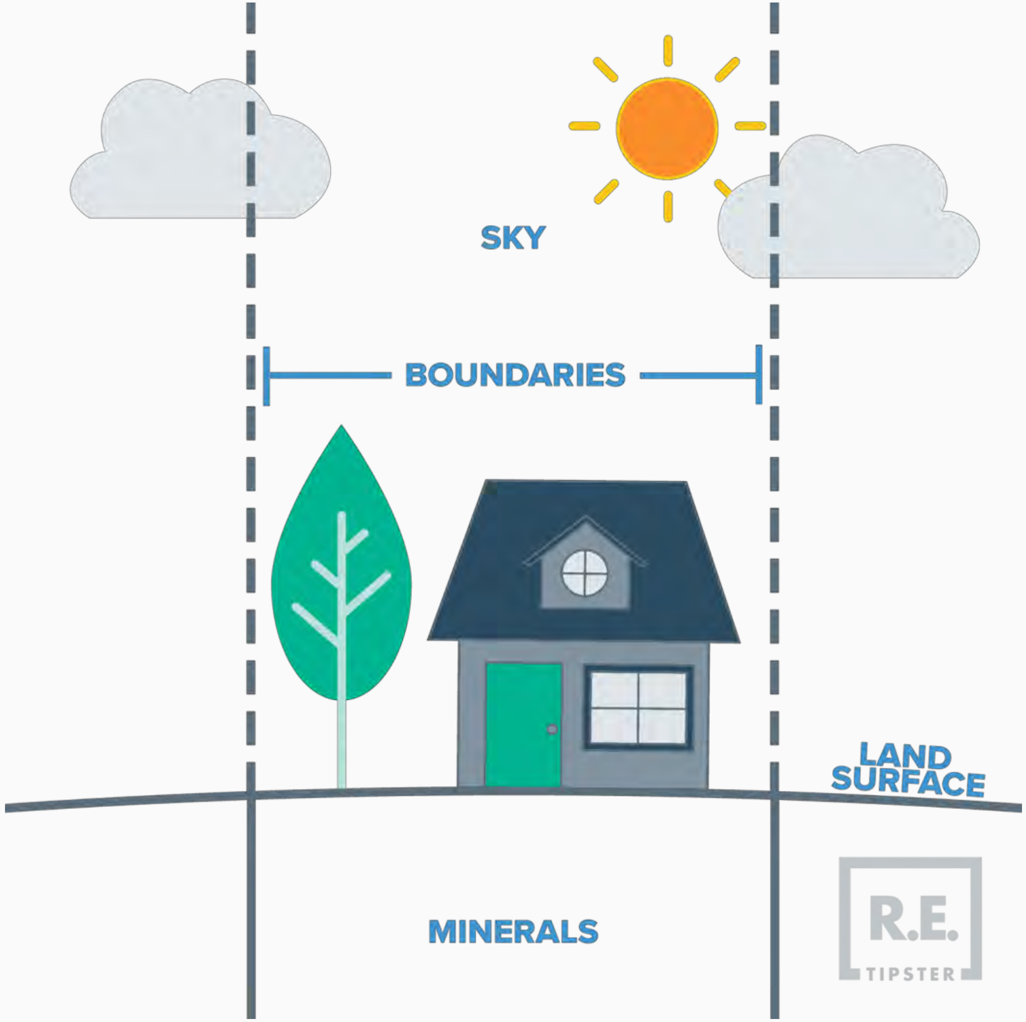
Land Rights

Surface Rights: include building structures, farming, trees for timber, accessing water below ground



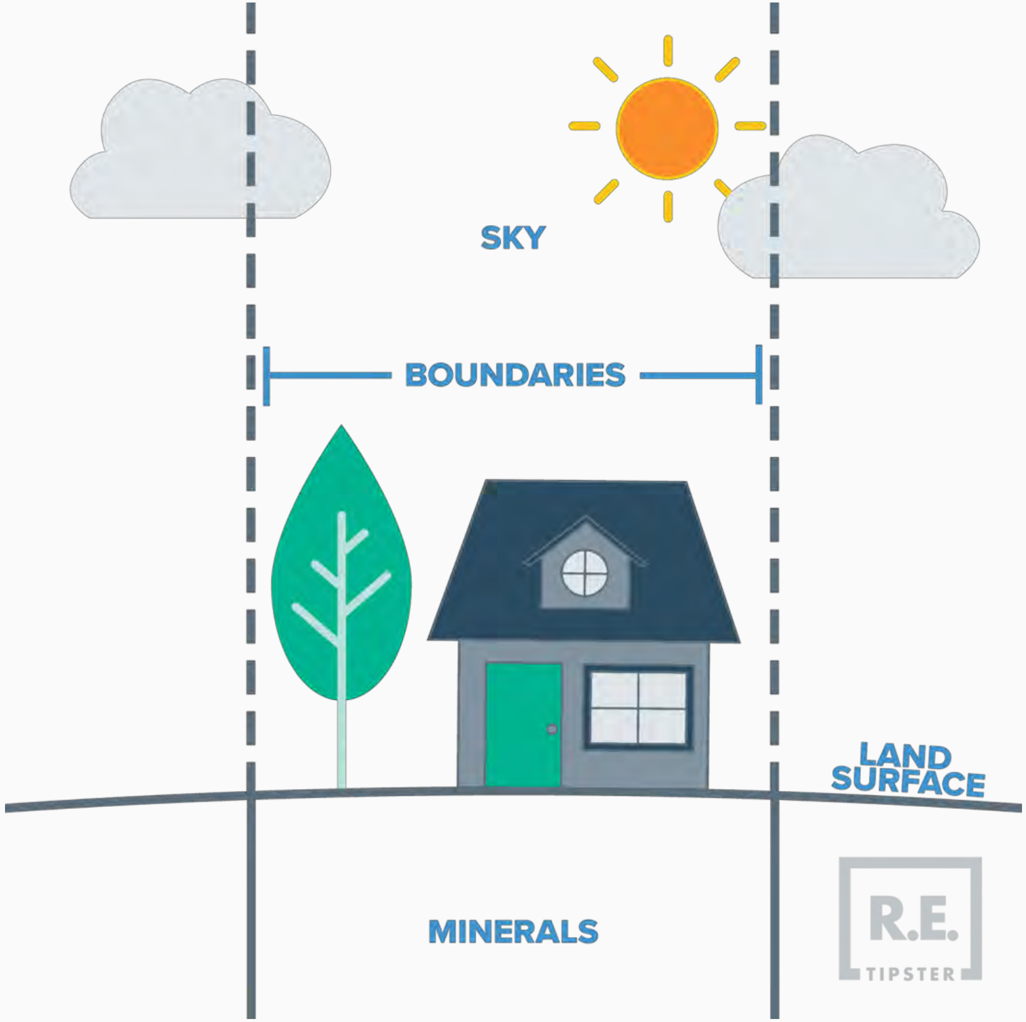
Land Rights

Mineral Rights: include oil, gas, coal, and other minerals below the ground



Land Rights

But what about the air above the land?



What can you do with the air above your property?

What can you do with the air above your property?

More landowners are now adding wind farms.

Wind Energy Facts[1] In Texas

- In 1999, mandated 2,000 megawatts of renewable energy by 2009
- Goal achieved by 2005
- New challenge:10,000 megawatts by 2025
- By April 2016, 19,000 megawatts of renewables

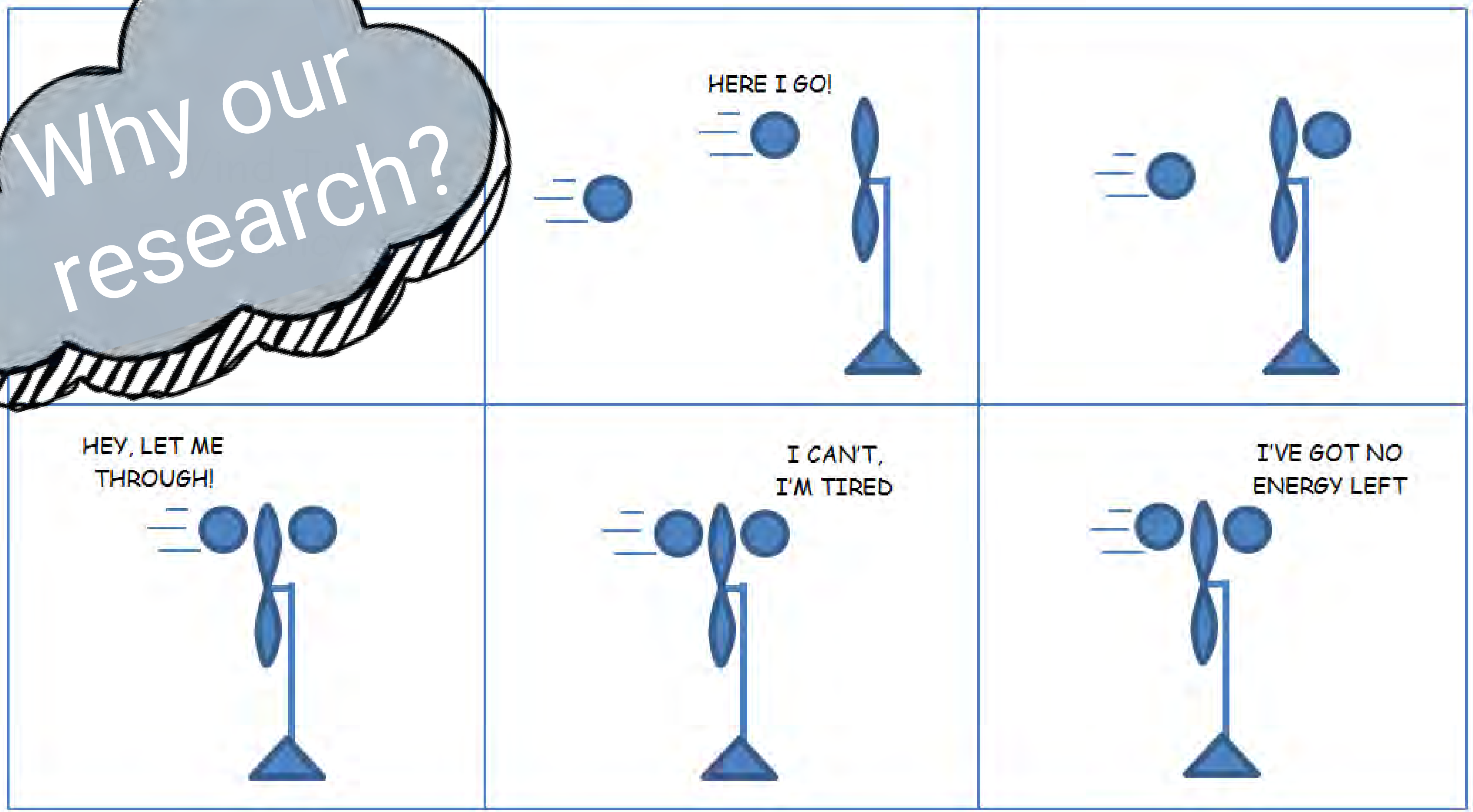
[1] George W. Bush Helped Make Texas a Clean-Energy Powerhouse

Wind Energy Facts[2] in Texas

- In 2023, wind represented 28.6 percent of Texas energy generation, second to natural gas
- There are 239 wind-related projects in Texas and more than 15,300 wind turbines, the most of any state.
- In 2021, gross domestic product for wind electric power generation was $1.7 billion

[2] GOOD FOR TEXAS TOUR: ENERGY

Why our research?



Why Our Research?

RESEARCH QUESTION

Does a wind farm influence the wind speed of surrounding areas?

RATIONALE

The operation of a wind farm may diminish the potential energy production of nearby sites.

Research Plan

PHASE 01

Determine a location of a wind turbine using the US Wind Turbine Database

PHASE 02

Download data pre- and post- operation of wind turbines using National Solar Radiation Database

PHASE 03

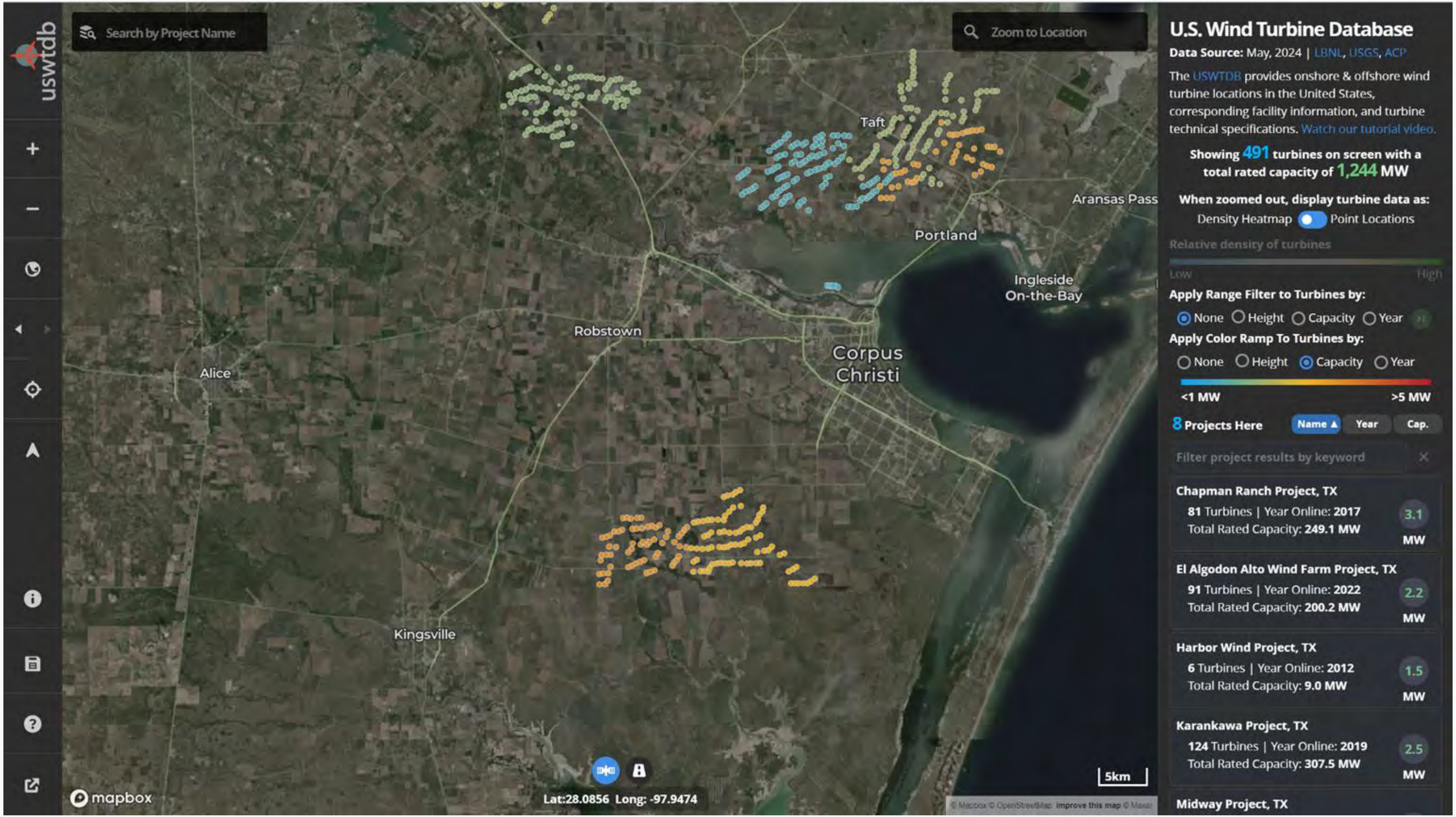
Locate 4 sites to analyze: three 8 km to the east, west, and downwind and one 16 km downwind using RouteCompass & Google Earth

PHASE 04

Analyze data pre- and post- operation to calculate average wind speeds across 4 downwind sites.

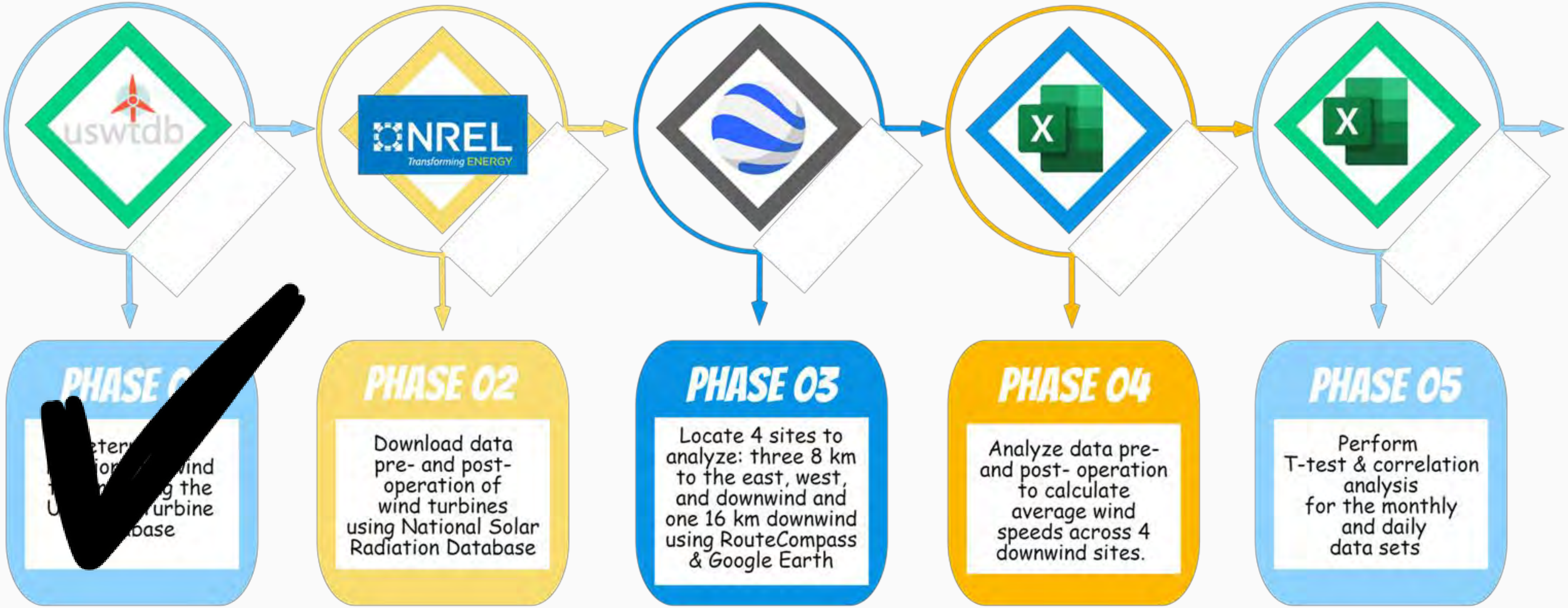
PHASE 05

Perform T-test & correlation analysis for the monthly and daily data sets

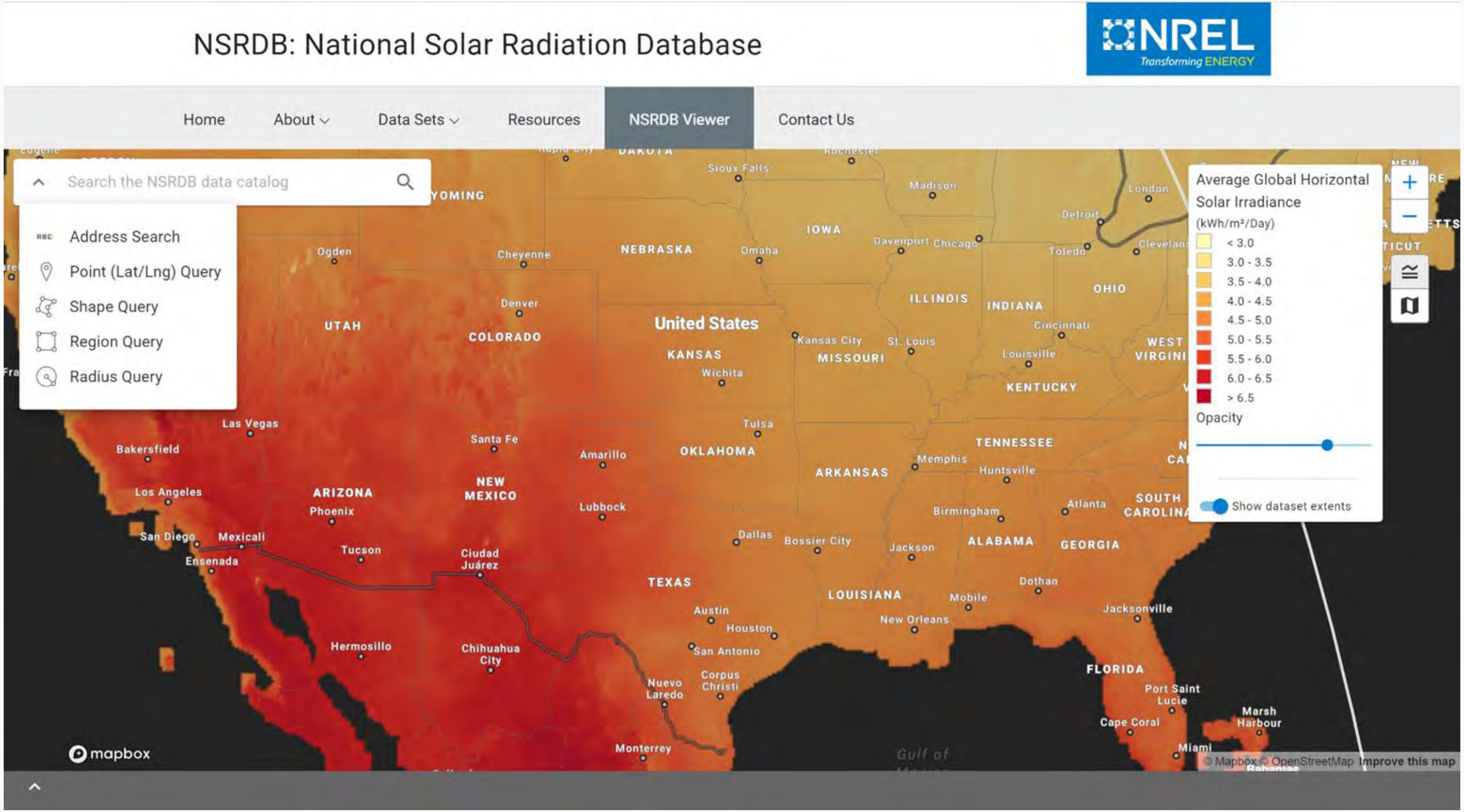


Phase 1: U.S. Wind Turbine Database was used to locate turbines to analyze

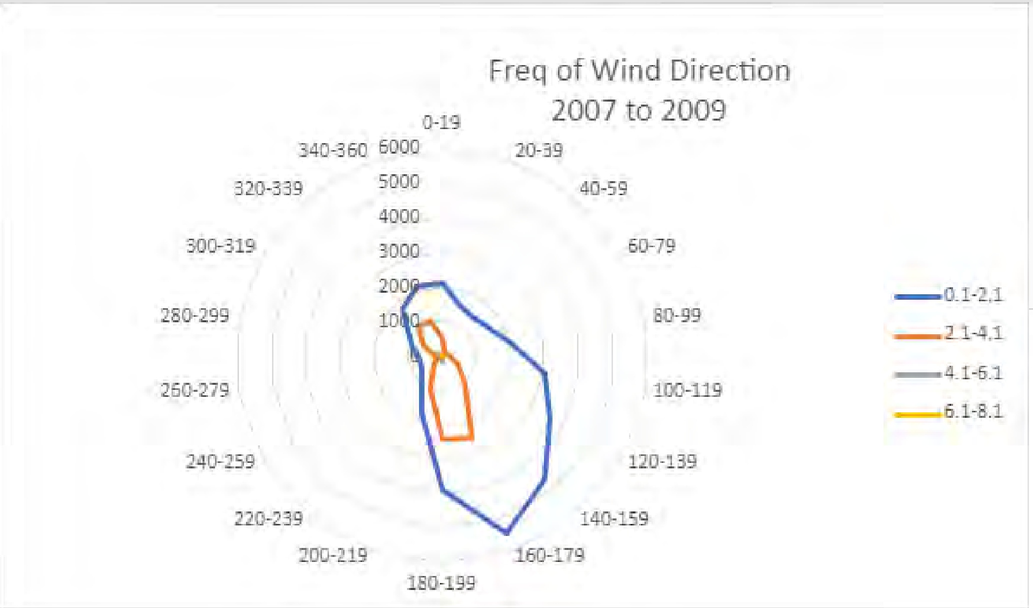
Research Plan

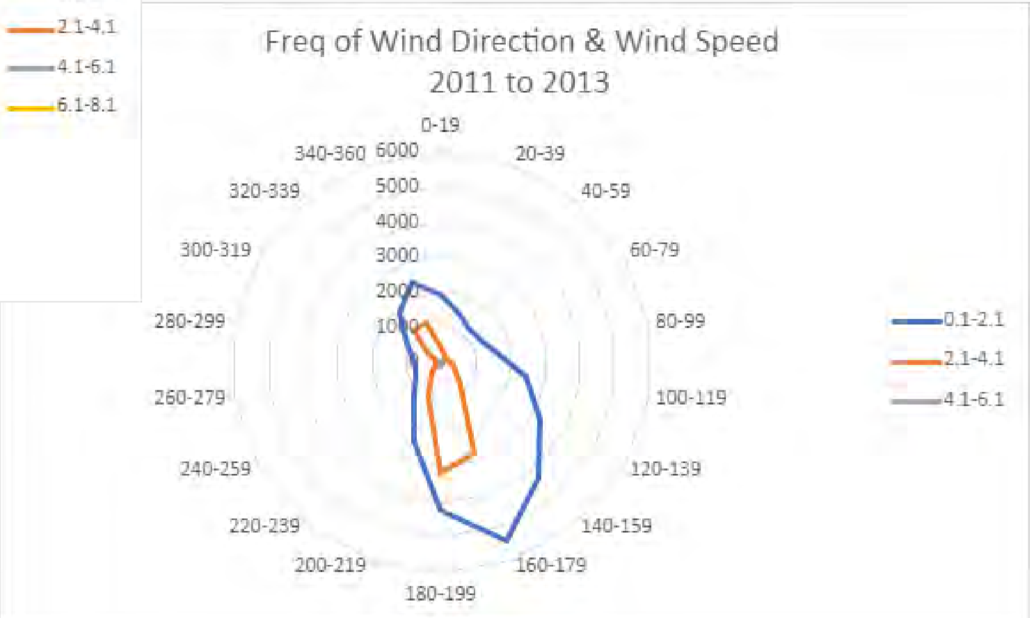


Phase 2: Data Acquisition from the National Solar Radiation Database to analyze wind speed & direction

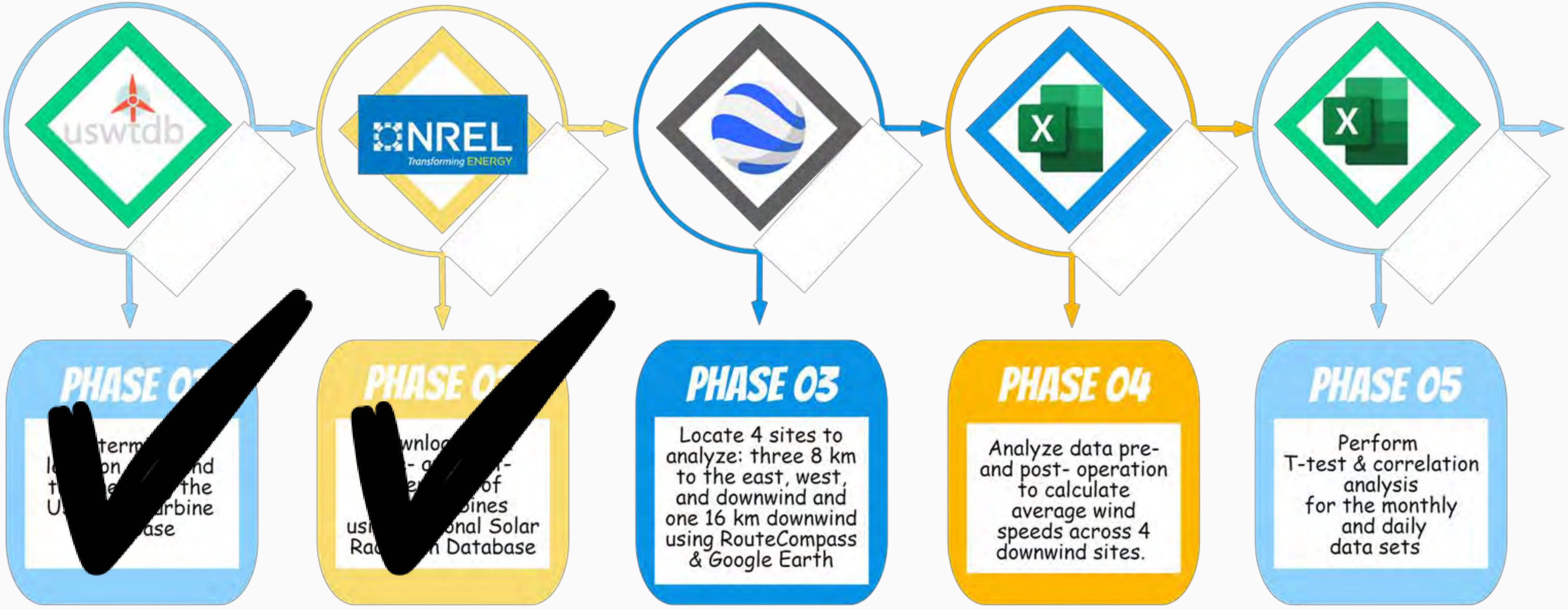


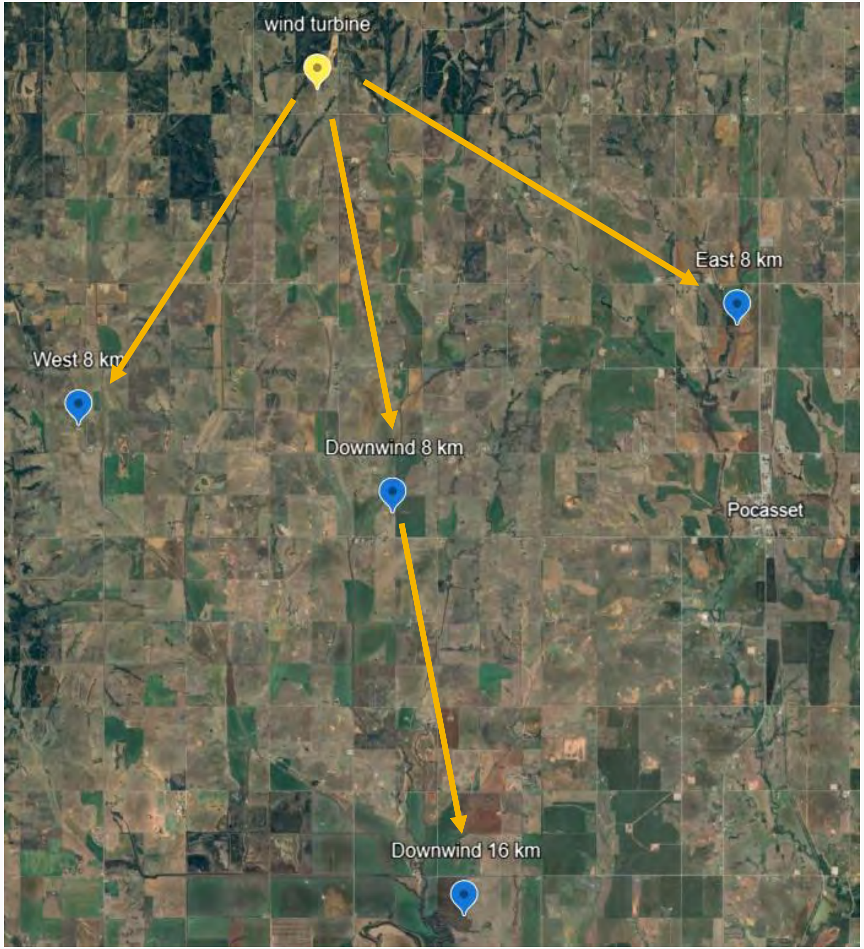
Phase 2 Results: wind speed & direction pre- and post- construction of wind turbine

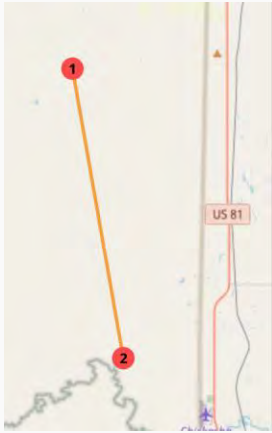


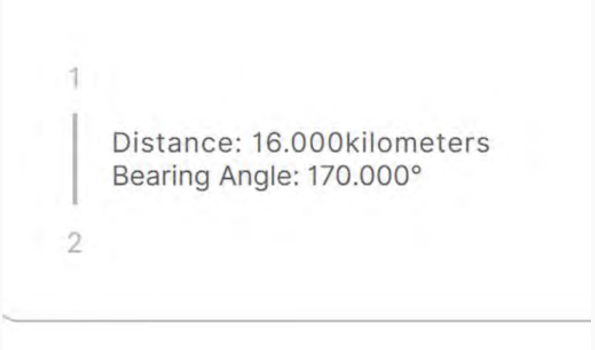


Research Plan



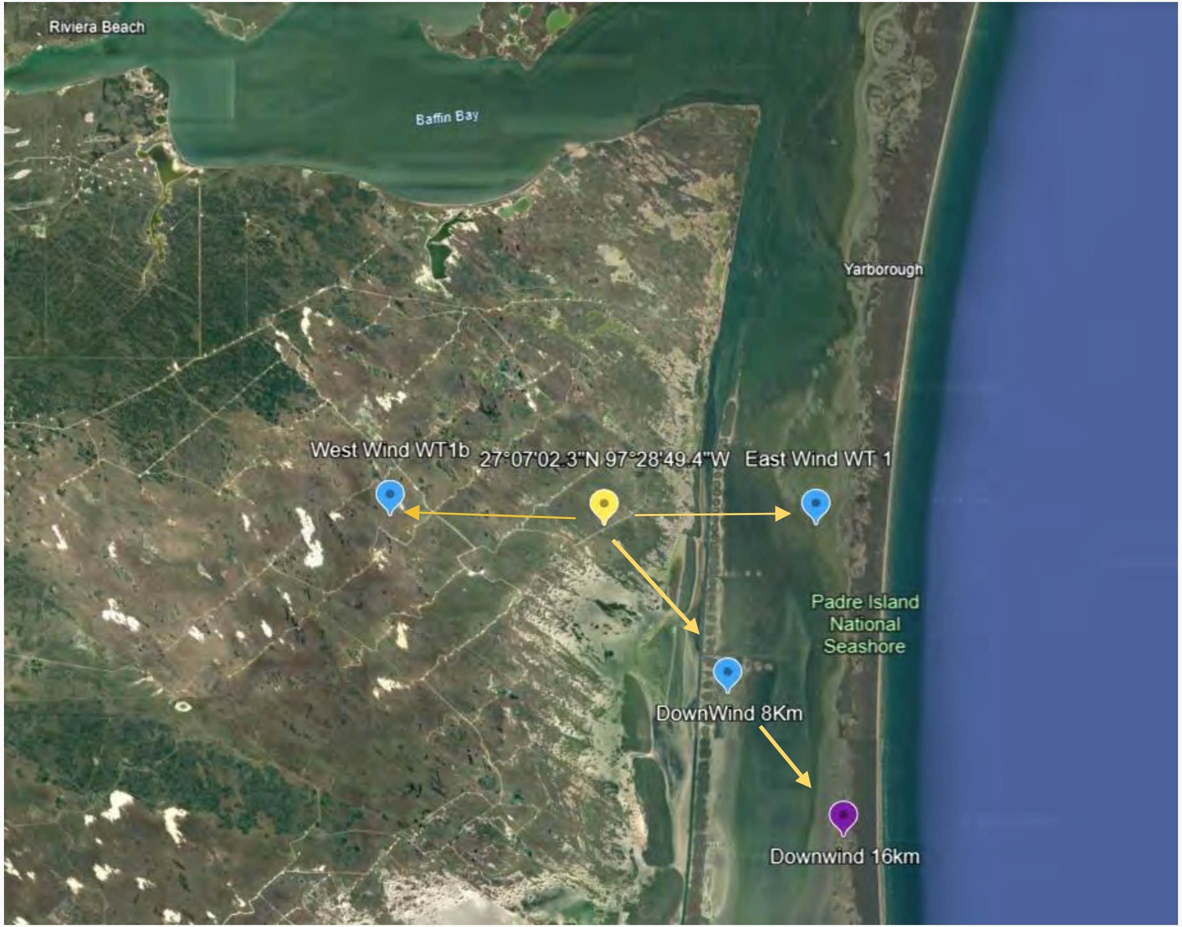


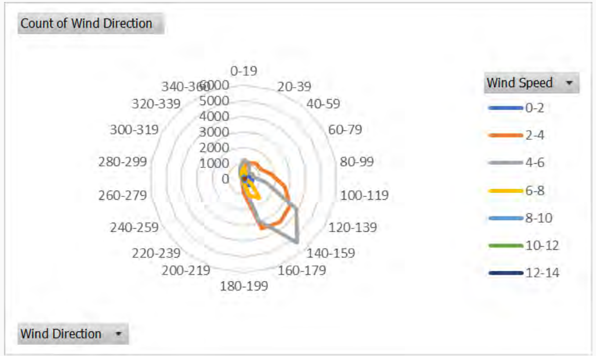




Routecompass.mapog.com was used to locate 4 sites. Those locations were translated using Google Earth

Phase 3: Determine 3 sites downwind 8 km and 1 16 km from turbine

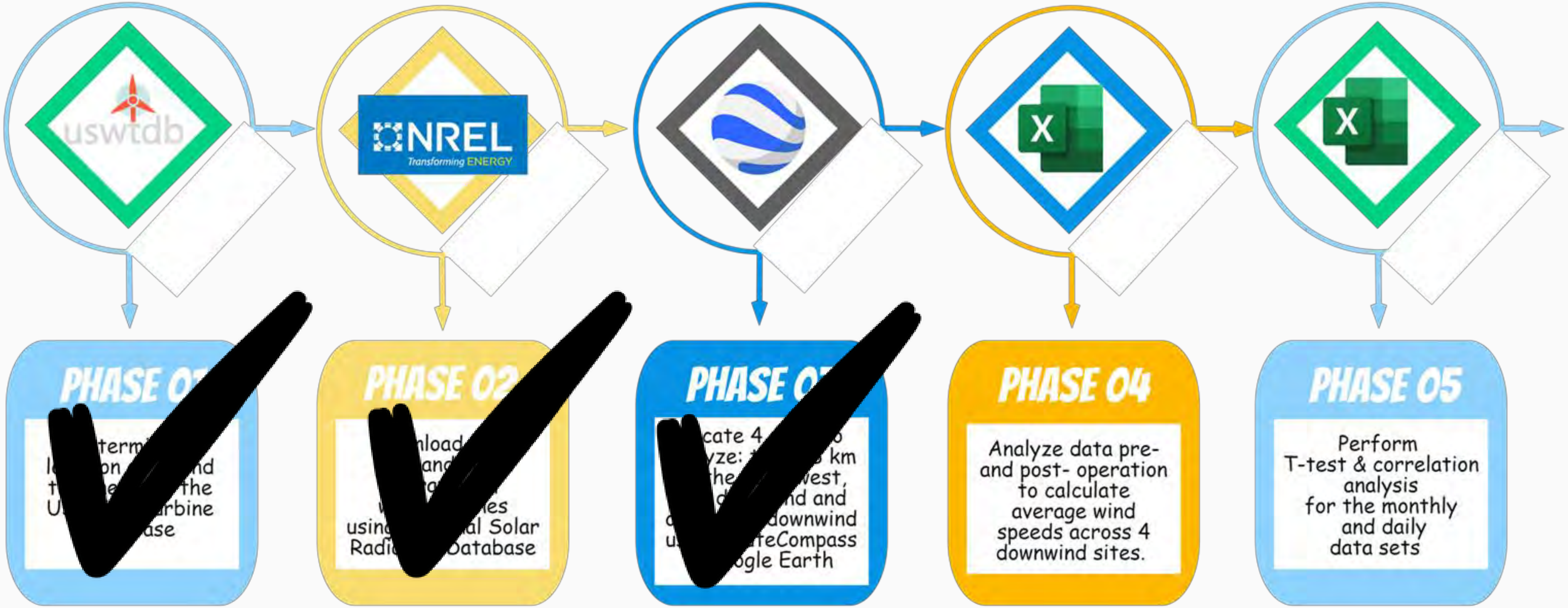




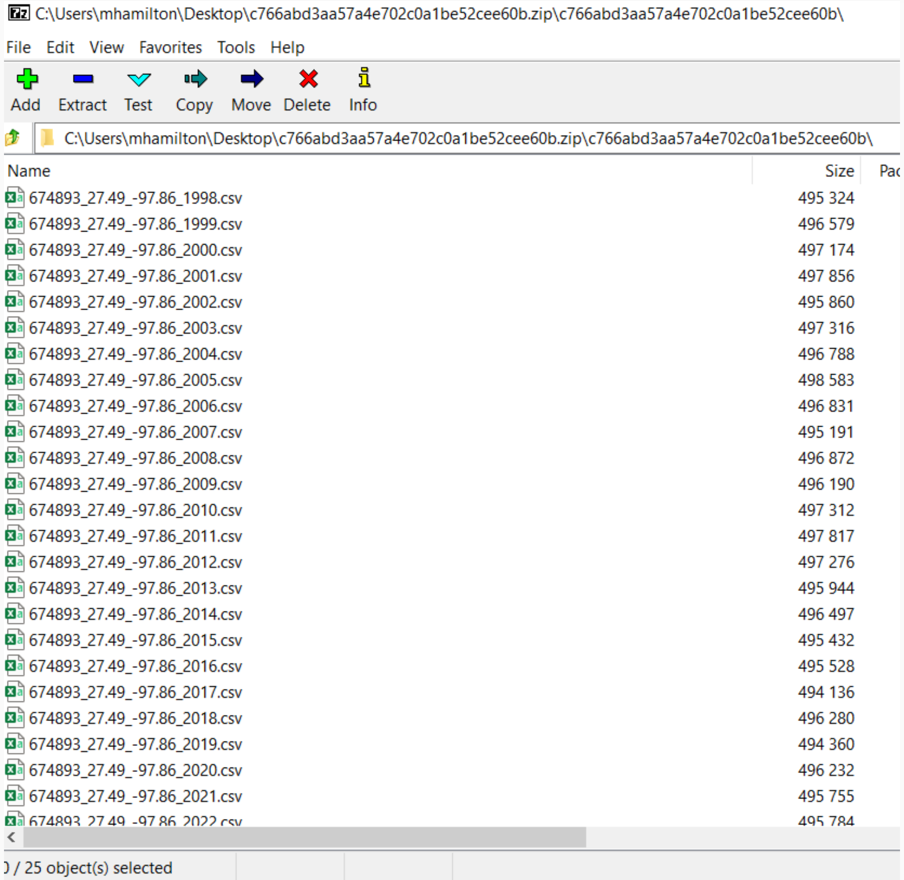
Downwind determined by a Radar Chart using excel and data received online at National Solar Radiation Data Base (NRDB)

Phase 3: Determine 3 sites downwind 8 km and 1 downwind 16 km from turbine

Research Plan



Making the data useful aka creating a pivot table



Making the data useful aka creating a pivot table

	A	B	C	D	E	F	G	H	I	J	K	L
1	Year	Month	Day	Hour	Minute	Temperatu	GHI	Pressure	Precipitab	Wind Dire	Wind Speed	
2	1998	1	1	0	0	3.2	0	1013	0.9	152	0.9	
3	1998	1	1	0	30	3	0	1013	0.9	153	0.9	
4	1998	1	1	1	0	2.8	0	1013	0.9	154	1	
5	1998	1	1	1	30	2.6	0	1013	0.9	155	1.1	
6	1998	1	1	2	0	2.5	0	1013	0.9	156	1.1	
7	1998	1	1	2	30	2.3	0	1013	0.9	157	1.2	
8	1998	1	1	3	0	2.1	0	1013	0.9	158	1.2	
9	1998	1	1	3	30	1.8	0	1012	0.9	160	1.2	
10	1998	1	1	4	0	1.5	0	1012	0.8	162	1.2	
11	1998	1	1	4	30	1.2	0	1012	0.8	165	1.2	
12	1998	1	1	5	0	0.9	0	1012	0.8	167	1.2	
13	1998	1	1	5	30	0.6	0	1012	0.8	170	1.2	
14	1998	1	1	6	0	0.2	0	1012	0.8	172	1.2	
15	1998	1	1	6	30	0	0	1012	0.7	175	1.2	

Making the data useful aka creating a pivot table

1 file

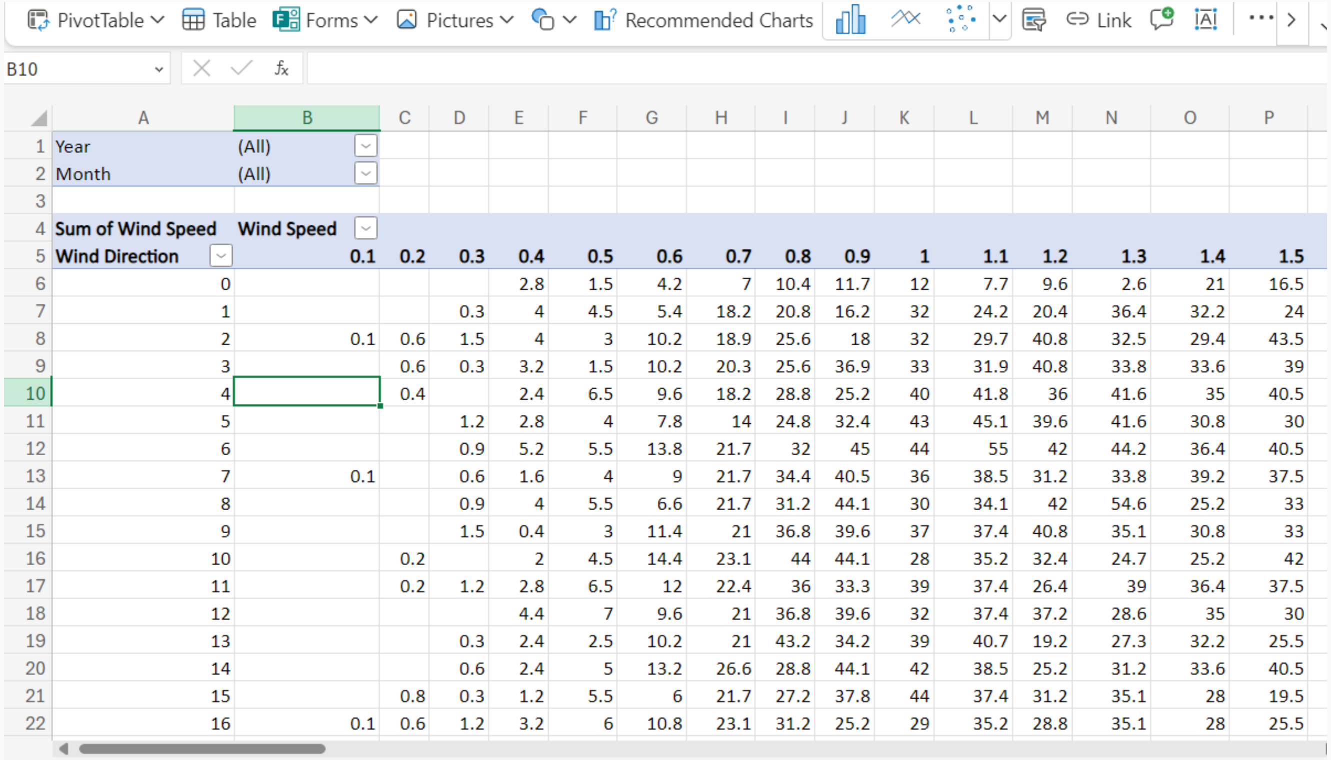
	A	B	C	D	E	F	G	H
17511	1998	12	31	17	30	2.8	113	
17512	1998	12	31	18	0	2.8	117	
17513	1998	12	31	18	30	2.7	120	
17514	1998	12	31	19	0	2.7	124	
17515	1998	12	31	19	30	2.6	125	
17516	1998	12	31	20	0	2.6	126	
17517	1998	12	31	20	30	2.4	125	
17518	1998	12	31	21	0	2.3	123	
17519	1998	12	31	21	30	1.9	119	
17520	1998	12	31	22	0	1.5	115	
17521	1998	12	31	22	30	1.3	109	
17522	1998	12	31	23	0	1.1	103	
17523	1998	12	31	23	30	1.1	103	
17524								
17525								
17526								

Making the data useful aka creating a pivot table

	A	B	C	D	E	F	G	H	I	J
192707	2008	12	31	16	30	7.1	482	1011	0.6	37
192708	2008	12	31	17	0	8	535	1010	0.6	40
192709	2008	12	31	17	30	8.7	572	1010	0.6	43
192710	2008	12	31	18	0	9.4	594	1009	0.6	45
192711	2008	12	31	18	30	9.8	599	1009	0.6	48
192712	2008	12	31	19	0	10.3	588	1008	0.6	50
192713	2008	12	31	19	30	10.4	561	1008	0.6	52
192714	2008	12	31	20	0	10.5	519	1008	0.6	55
192715	2008	12	31	20	30	10.4	462	1008	0.6	58
192716	2008	12	31	21	0	10.2	392	1007	0.6	60
192717	2008	12	31	21	30	9.1	312	1007	0.6	63
192718	2008	12	31	22	0	7.9	223	1007	0.6	66
192719	2008	12	31	22	30	5.9	132	1007	0.6	68
192720	2008	12	31	23	0	3.9	48	1007	0.6	70
192721	2008	12	31	23	30	3.9	0	1007	0.6	70

Pre- and Post- construction in groups of 10 years

Making the data useful aka creating a pivot table



Year	(All)
Month	(All)

Sum of Wind Speed	Wind Speed														
Wind Direction	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
0				2.8	1.5	4.2	7	10.4	11.7	12	7.7	9.6	2.6	21	16.5
1			0.3	4	4.5	5.4	18.2	20.8	16.2	32	24.2	20.4	36.4	32.2	24
2	0.1	0.6	1.5	4	3	10.2	18.9	25.6	18	32	29.7	40.8	32.5	29.4	43.5
3		0.6	0.3	3.2	1.5	10.2	20.3	25.6	36.9	33	31.9	40.8	33.8	33.6	39
4		0.4		2.4	6.5	9.6	18.2	28.8	25.2	40	41.8	36	41.6	35	40.5
5			1.2	2.8	4	7.8	14	24.8	32.4	43	45.1	39.6	41.6	30.8	30
6			0.9	5.2	5.5	13.8	21.7	32	45	44	55	42	44.2	36.4	40.5
7	0.1		0.6	1.6	4	9	21.7	34.4	40.5	36	38.5	31.2	33.8	39.2	37.5
8			0.9	4	5.5	6.6	21.7	31.2	44.1	30	34.1	42	54.6	25.2	33
9			1.5	0.4	3	11.4	21	36.8	39.6	37	37.4	40.8	35.1	30.8	33
10		0.2		2	4.5	14.4	23.1	44	44.1	28	35.2	32.4	24.7	25.2	42
11		0.2	1.2	2.8	6.5	12	22.4	36	33.3	39	37.4	26.4	39	36.4	37.5
12				4.4	7	9.6	21	36.8	39.6	32	37.4	37.2	28.6	35	30
13			0.3	2.4	2.5	10.2	21	43.2	34.2	39	40.7	19.2	27.3	32.2	25.5
14			0.6	2.4	5	13.2	26.6	28.8	44.1	42	38.5	25.2	31.2	33.6	40.5
15		0.8	0.3	1.2	5.5	6	21.7	27.2	37.8	44	37.4	31.2	35.1	28	19.5
16	0.1	0.6	1.2	3.2	6	10.8	23.1	31.2	25.2	29	35.2	28.8	35.1	28	25.5

Making the data useful aka creating a pivot table

Year	(Multiple Items)
Month	1

Average of Wind Speed	Column Labels						
Row Labels	0.1-2.1	2.1-4.1	4.1-6.1	6.1-8.1	8.1-10.1	10.1-12.1	Grand Total
0-19	1.557534247	3.141587302	4.930672269	6.940740741	8.495		3.90325
20-39	1.377717391	3.022580645	4.771875	6.92173913	9.25	10.3	3.320266272
40-59	1.325179856	2.975694444	4.838461538	6.375			2.624778761
60-79	1.227659574	2.686666667	4.86				1.578947368
80-99	1.230701754	2.65	4.1				1.406976744
100-119	1.295945946	2.316666667					1.438372093
120-139	1.3	2.495652174	4.4				1.61875
140-159	1.424719101	3.072868217	4.84				2.605042017
160-179	1.44496124	3.30104712	4.688888889	6.75			3.486678832
180-199	1.426315789	3.075545852	5.006690141	6.767625899	8.290909091		4.205778894
200-219	1.538666667	3.015357143	4.950510204	6.835869565	8.4125		3.77630854
220-239	1.471311475	2.974146341	4.85	6.573076923	9.266666667		3.155733945
240-259	1.387218045	2.782258065	4.603703704		9.266666667		2.374912892
260-279	1.445038168	2.93253012	4.38		9.1		2.158222222
280-299	1.411764706	2.98045977	4.541666667		9.3		2.274545455
300-319	1.417482517	2.978169014	4.634693878	6.5	9.3		2.727873563
320-339	1.459060403	3.092916667	5.077586207	6.8875	8.266666667		3.450626118
340-360	1.51862069	3.06102719	4.880978261	6.909722222	8.6		3.963647491
Grand Total	**1.414651368**	**3.037390081**	**4.874621442**	**6.839735099**	**8.629333333**	**10.3**	**3.31688172**

Making the data useful aka creating a pivot table

17,520,000 data points

Making the data useful aka creating a pivot table

17,520,000
data points

approx.
20 miles tall

Phase 4: Examples of Pivot tables of inland average wind speed data monthly and daily

SITE 2 Average Wind Speed 8 km downwind from turbine

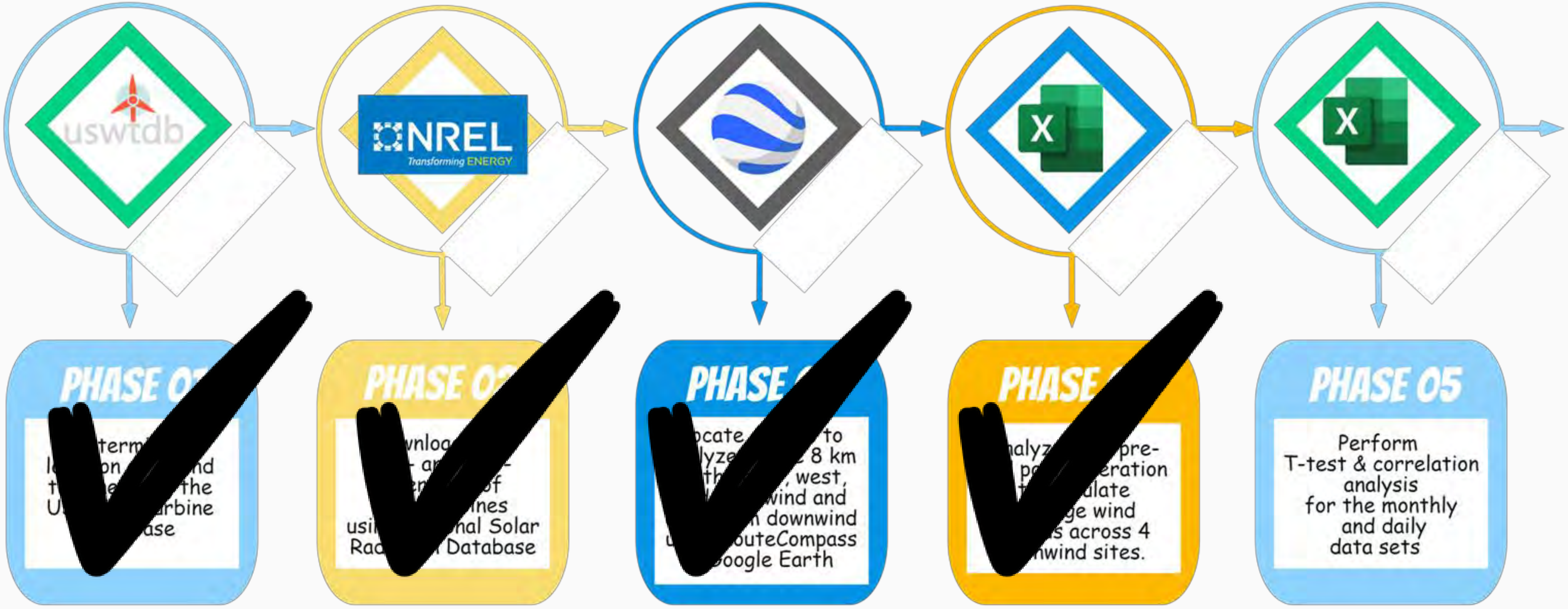
PRE-

	10 years prior
January	3.251631232
February	3.489779491
March	3.677871457
April	3.915984848
May	3.458620479
June	3.28292298
July	3.004282747
August	2.8153348
September	2.940593434
October	3.304062805
November	3.213787879
December	3.259133675

POST- Wind Turbine Operation

	1 year	2 years	3 years	5 years	10 years
January	2.860618	3.234577	3.179256	3.295336	3.317036
February	3.643527	3.515662	3.526935	3.501086	3.5416
March	3.765457	3.78498	3.725605	3.601909	3.652702
April	4.381389	3.949861	3.930324	3.9275	3.822139
May	4.36297	4.048051	4.011246	3.824341	3.582137
June	4.625972	3.940764	3.780486	3.642347	3.395896
July	2.940457	3.014348	2.983938	3.001774	2.860168
August	2.943884	2.989483	2.850851	2.80207	2.75496
September	3.145347	2.990104	2.929722	2.990986	2.924903
October	3.223589	3.363743	3.433356	3.248038	3.362036
November	3.876944	3.563056	3.60125	3.631972	3.424493
December	2.862298	3.132964	3.078651	3.10457	3.09328

Research Plan



Phase 5: Analysis of Data

- T-Test Analysis of average wind speed data
- Null hypothesis: There is no significant difference of average wind speed between pre- and post-operation of a wind farm in surrounding areas.
- $\alpha = 0.05$

Phase 5: Monthly Avg Wind Speed T-Test Analysis Results

Data: Minco, Oklahoma Wind Turbine Location

	West 8 km	Downwind 8 km	East 8 km	Downwind 16 km
1 year	0.1027	0.1194	0.1043	0.078
2 year	0.0330	0.0459	0.0335	0.037
3 year	0.0733	0.1064	0.1139	0.008
5 year	0.1169	0.1745	0.1252	0.061
10 year	0.5798	0.7721	0.6004	0.495

Average Wind Speed 8 km		
	Pre-constr	Post-constr
1 year	3.288	3.369
2 year		3.353
3 year		3.404
5 year		3.314
10 year		3.284

Phase 5: Monthly Avg Wind Speed T-Test Analysis Results

Data: Baffin Bay Wind Turbine Location

	West 8 km	East 8 km	Downwind 8 km	Downwind 16 km
1 year	0.0284	0.0292	0.0292	0.029
2 year	0.044	0.0458	0.0456	0.046
3 year	0.0159	0.0164	0.0163	0.017
5 year	0.107	0.1067	0.1067	0.108
10 year	0.93	0.9285	0.9323	0.952

Average Wind Speed 8 km		
	Pre-constr	Post-constr
1 year	4.012	4.283
2 year		4.142
3 year		4.133
5 year		4.092
10 year		4.032

Correlation Analysis

Correlation Coefficients for various weather variables at 8 km downwind

Wind Speed and --	**Coastal**	**Inland**
Temperature	-0.045	0.090
Pressure	-0.040	-0.241

Conclusion

1

A significant increase in the average wind speed for both the inland and coastal wind farms and the surrounding areas.

Conclusion

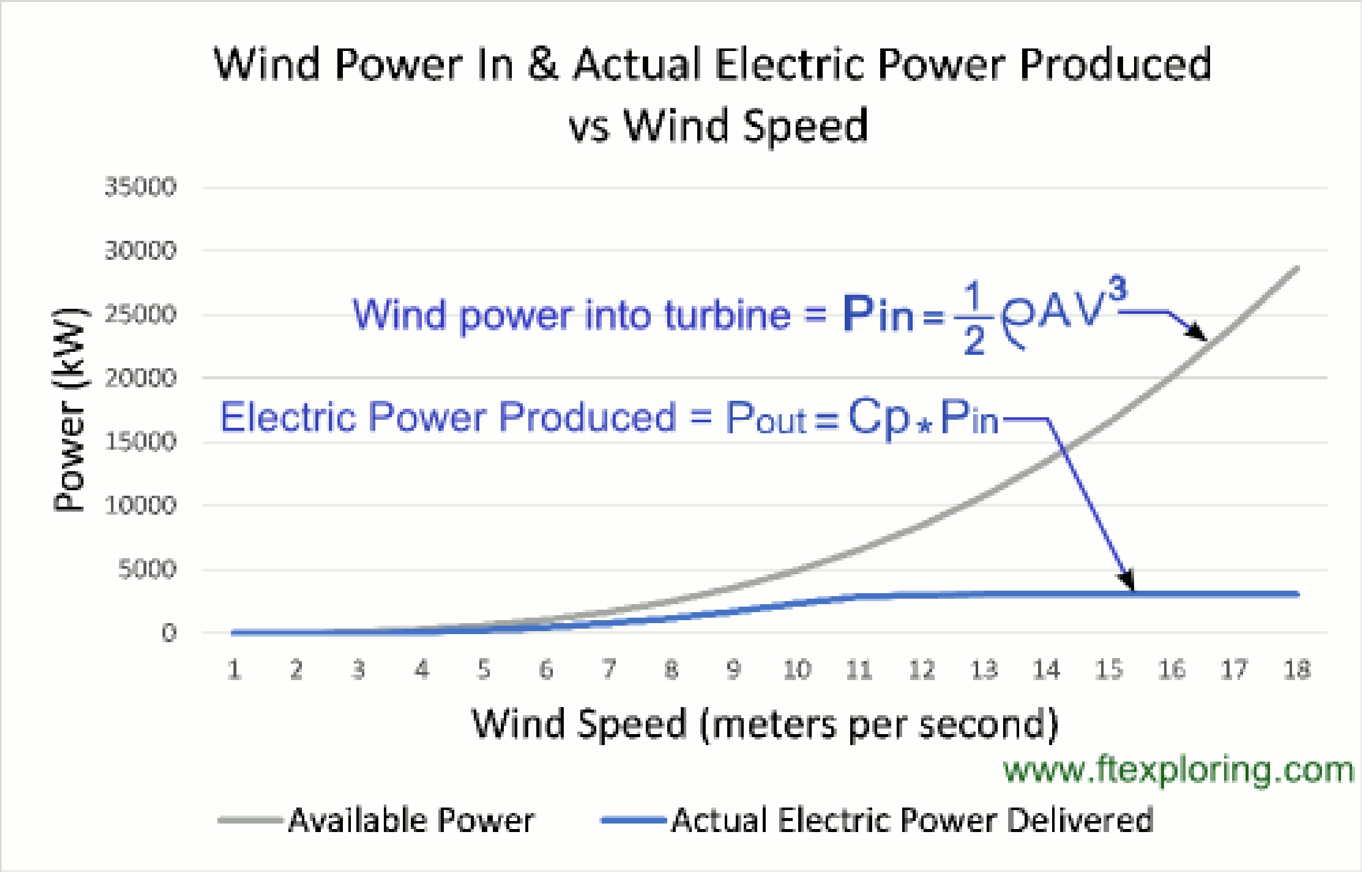
1

A significant increase in the average wind speed for both the inland and coastal wind farms and the surrounding areas.

2

Inland and coastal wind farms are showing different numbers of significant differences

Conclusion


Wind Power In & Actual Electric Power Produced vs Wind Speed
35000
30000
25000
20000
15000
10000
5000
0
Power (kW)
Wind power into turbine = Pin = 1/2 ρAV3
Electric Power Produced = Pout = Cp * Pin
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Wind Speed (meters per second)
www.ftexploring.com
Available Power
Actual Electric Power Delivered

Future Research

1. **Investigate other factors could influence wind speed**

Future Research

1. Investigate other factors could influence wind speed
2. Examine terrain for possible impediments

Future Research

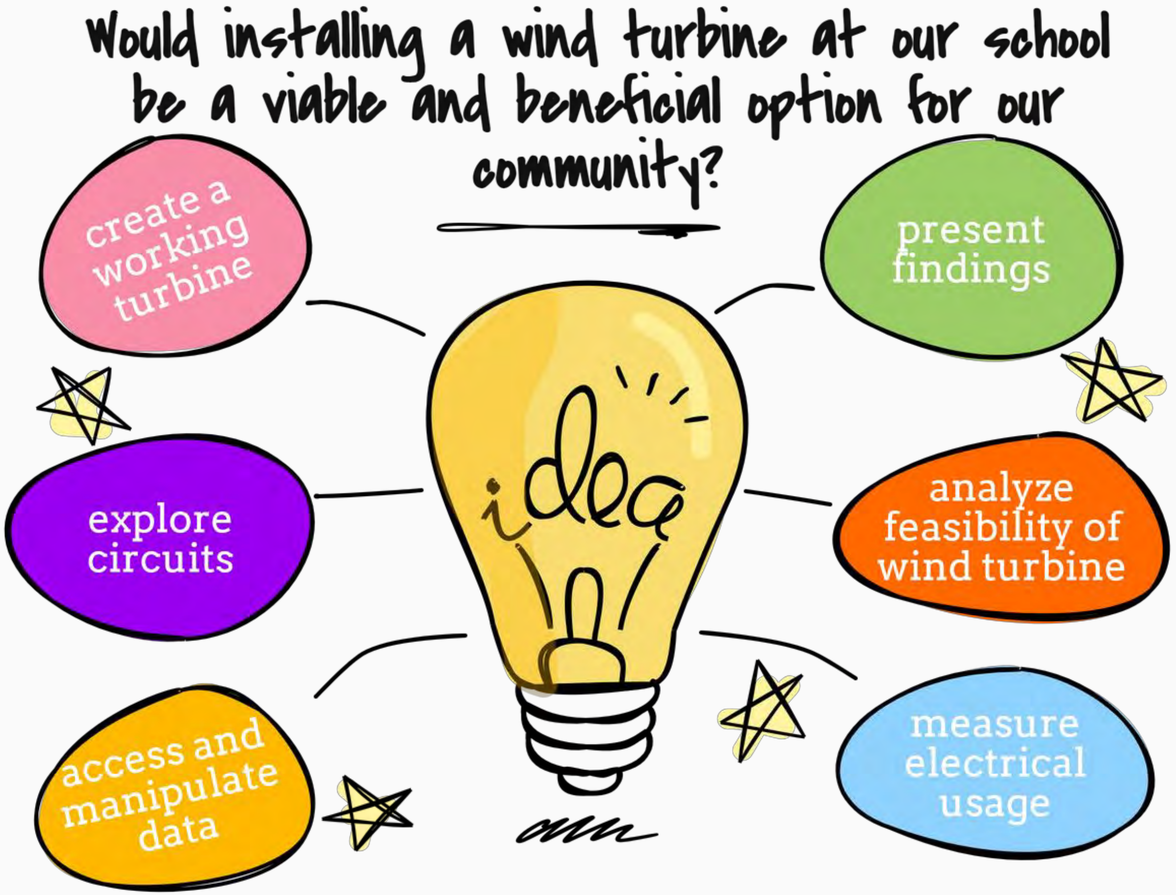
1. Investigate other factors could influence wind speed
2. Examine terrain for possible impediments
3. Explore how location differences affect wind speed

Curriculum Modules:

Physics and Chemistry

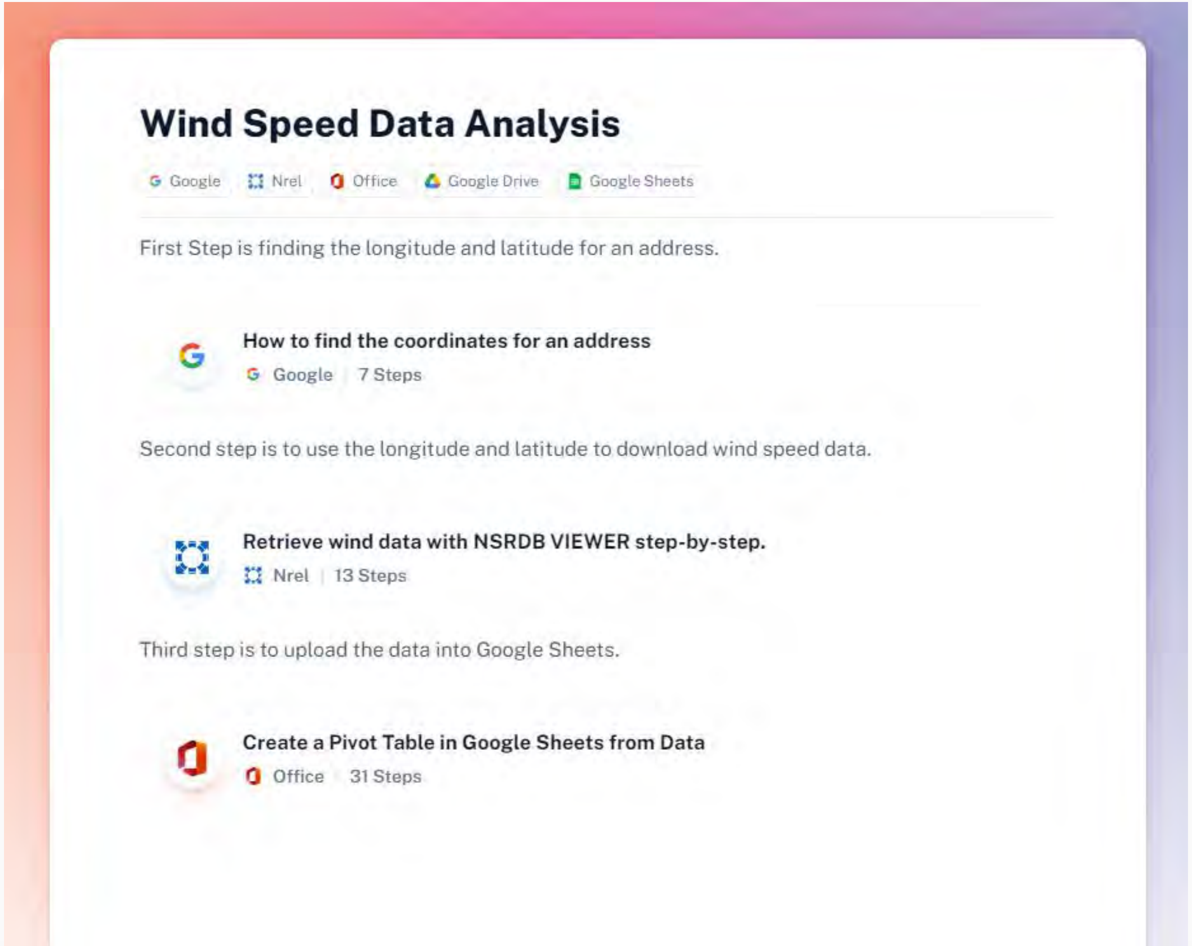
Both modules will be utilizing the Tempest Weather System with Built-in Wind Meter, Rain Gauge, and Accurate Weather Forecasts

Physics Modules:

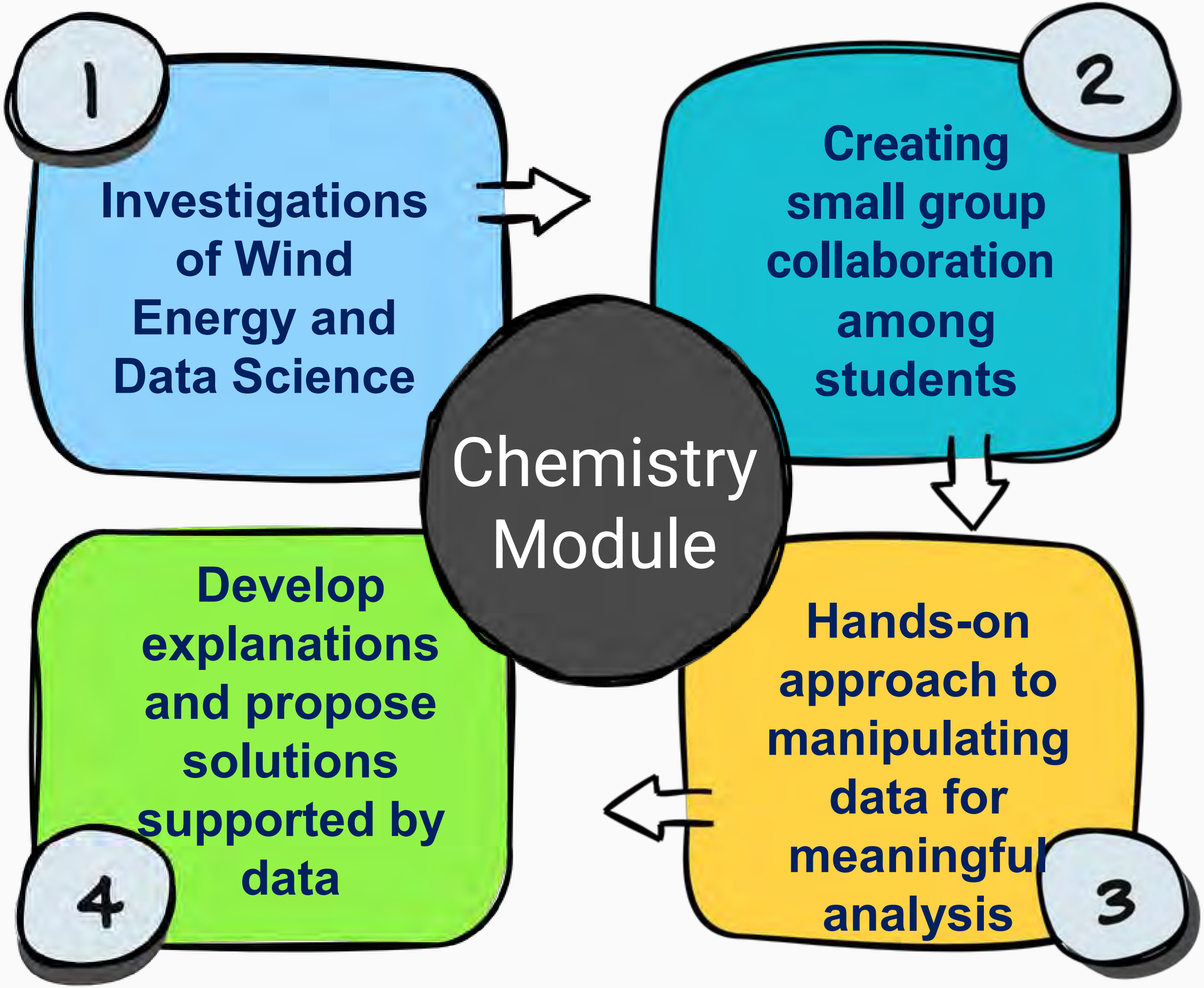


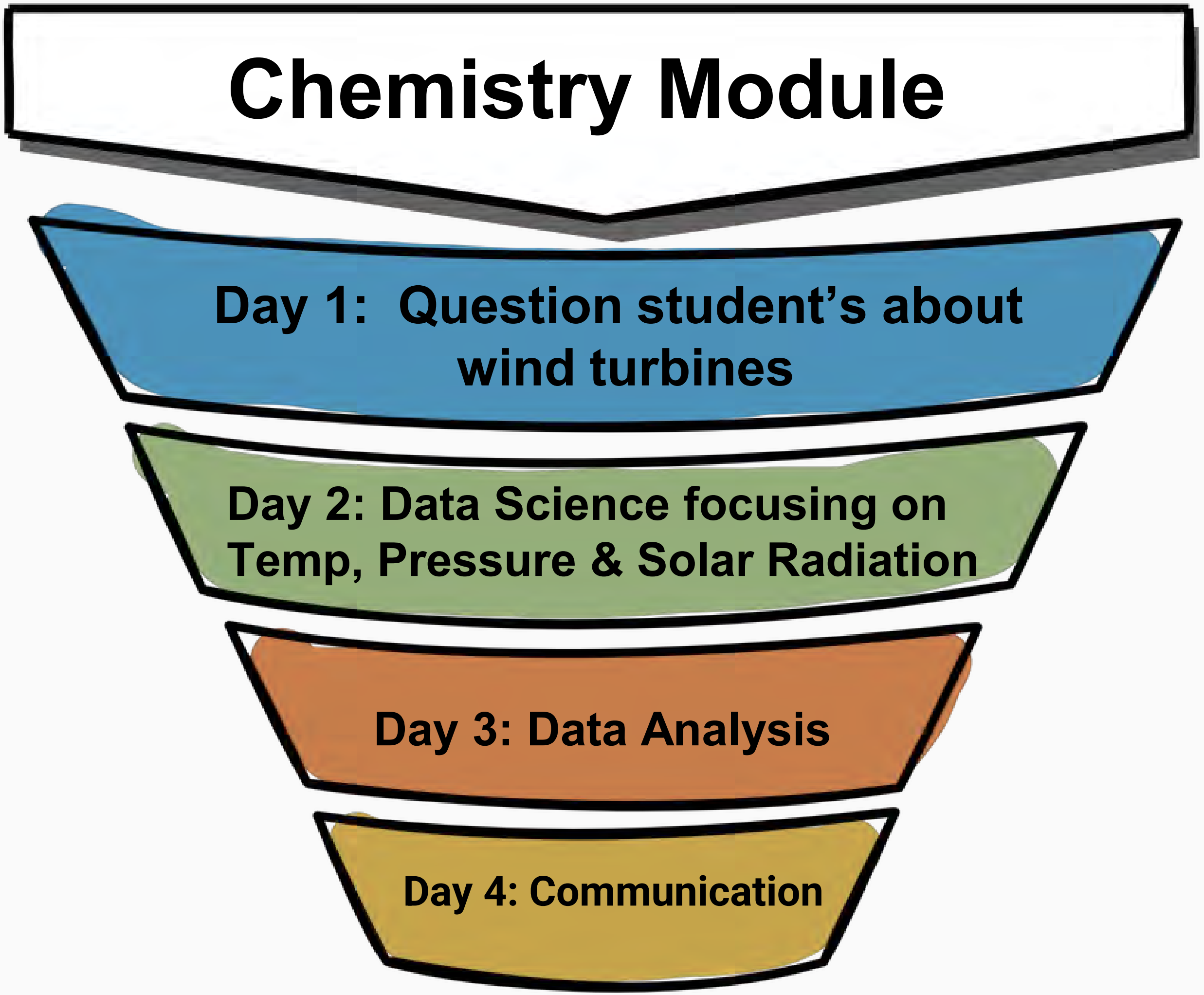
- 3-to-4-week project
- Incorporating electrical, energy, and power
- Science content AND science & engineering practices

NEED
National Energy Education Development



Scribe to create directions on how to access data


1
Investigations of Wind Energy and Data Science
2
Creating small group collaboration among students
Chemistry Module
3
Hands-on approach to manipulating data for meaningful analysis
4
Develop explanations and propose solutions supported by data


Chemistry Module
Day 1: Question student's about wind turbines
Day 2: Data Science focusing on Temp, Pressure & Solar Radiation
Day 3: Data Analysis
Day 4: Communication

Acknowledgements

Principle Investigator: Dr. Mohammad Hossain
Faculty Mentor: Dr. Hua Li
Educational Mentor: Dr. Marsha Sowell
Graduate Mentor: Yahya Al Bustanji

Industry Mentor: Rene Ramirez

Superintendent: Dr. Veronica Alfaro
SGA Principal: Charles Odom

Superintendent: Dr. Cissy Reynolds-Perez
Asst. Superintendent: Dr. Ada Besinaiz
Director of C & I: Dr. Olivia Ballesteros
HMK Principal: Dana Moore

Questions or Comments

Effect of Daylighting on Students' Learning and Classroom Electricity Consumption

Texas A&M University – Kingsville

Teacher Participants:
Kelsey Correa- Sinton ISD
Teresa Cherry- CCISD

Faculty Mentors:
Dr. Hui Shen
Dr. Marsha Sowell

Student Mentor:
Curtis Davenport

Industrial Advisor:
Ralph Pitzer, P.E

Illuminating Learning: The Impact of Daylight on Student Performance and Energy Efficiency

Our project:

Little scientific data exists on students' learning efficiency under different daylighting levels to enhance learning experience.

Research question:

How and to what extent daylighting affect students' learning efficiency and how much electricity can be saved via daylighting in the classrooms?

Background:

What is daylighting?

Daylighting refers to the practice of using natural light from the sun to illuminate the interior spaces of buildings.

Why daylighting?

This design strategy not only reduces the need for electric lighting (energy saving), but also has been linked to various benefits, including improved student performance in educational settings.

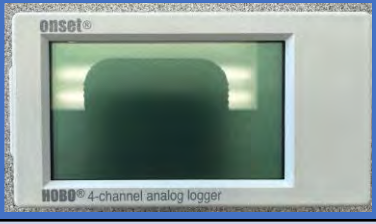
Background: Key Terms

- **Daylighting-**the practice of using natural light from the sun to illuminate the interior spaces of buildings
- **Pyranometer-**device that measures global solar radiation
- **Photometric Sensor-**device that measures light as seen by the human eye in lux or lumens
- **Lux-**the SI unit of illuminance, equal to one lumen per square meter. (500 lux is the ideal level for workspaces)
- **Daylight Autonomy (DA)-** represents the percentage of the occupied time during which a space receives enough daylight to meet the required lighting level (500 lux), without the need for artificial lighting.
- **Useful daylight illuminance (UDI)-**a metric used to assess the quality of natural light in a building. The UDI range is usually defined between 100 and 2,000 lux.

Background: Case Studies

Case 1:	Case 2:	Case 3:	Case 4:
Daylighting Impacts on Human Performance in School [1]	**The Impact of Classroom Design on Pupils' Learning: Final Results of a Holistic, Multi-Level Analysis. [2]**	**Analysis of The Performance of Students in Daylit Schools [3]**	**Strategic Daylighting in Schools: More is not always better [4]**
Improved Student Performance • Faster progress in math and reading tests **Higher Attendance Rates** • More daylight leads to better attendance **Energy Savings** • Less reliance on artificial lighting	**Impact on Learning** • Light levels affect student learning **Window Orientation** • Orientation matters more than size; glare risk **Artificial Light Quality** • Positive correlation with student performance **Temperature Control** • Controlled temperature improves performance	**Health and Attendance** • Full spectrum lighting: healthier students, better attendance **Reduced Noise** • Daylit libraries: lower noise levels **Positive Moods** • Full spectrum lighting improves student moods **Performance Correlation** • Studies show positive impact on student performance with full spectrum lighting	**Glare vs. Window Position** • Glare impacts tech use more than window position **Mitigating Glare** • Sun shades can reduce glare **Window Size** • Size ≠ amount of useful daylight

Research Materials: Human and Non-Human Data Collection



LI-COR LI-210R Photometric Sensor	LI-COR LI-200R Pyranometer	EME Systems UCLC Amplifier	HOBO 4-Channel Data Logger
Measures Light • Measures amount of light in an environment **Human Perception** • Similar to how the eye perceives brightness (photometric measurements) **Error %** • Has an absolute error of 3%.	**Measures Solar Radiation** • measures the amount of solar radiation (sunlight) reaching a surface. **Error %** • Has an absolute error of 3%.	**Boosts Signals** • Strengthens weak electrical signals **Enhances Sensitivity** • Improves sensor sensitivity	**Data Collection** • Collects and stores data from up to four sensors **Simultaneous Measurements** • Supports four different measurements at once **Ease of Use** • Simple setup and data retrieval with software for analysis

Research Materials: Human Data Collection

Solar Light PMA2100 Radiometer

- **Functions**: Light meter, photometer, UV meter (UVA, UVB, UVC), Visible, and IR light.
- **Measures**: LUX
- **Setup**: One sensor worn on the head, the other on the desk

ReadWorks Abstract Expressionism

Abstract Expressionism

This text is provided courtesy of The Museum of Modern Art

ReadWorks Harlem Hospital

Harlem Hospital

This text and image are provided courtesy of the Schomburg Center for Research in Black Culture

ReadWorks Solving New York City's Hurricane Problem With Representations

Solving New York City's Hurricane Problem With Representations

by Alissa Fleck

Activities and Quizzes

- **Source**: ReadWorks website
- **Grade Level**: 11th-12th
- **Lexile Level**: ~1300
- **Length**: ~500-700 words per passage
- **Passages**: 3 (one per room)
- **Questions**: 5 multiple choice per passage

On a scale of 1 to 5, with *1 being the least comfortable* and *5 being the most comfortable*, rate the **comfortability of the light intensity** in room **220**. *

Artificial + Natural Light

	1	2	3	4	5	
Not Comfortable	○	○	○	○	○	Very Comfortable

Questionnaire

Comfort Rating Scale (1-5):

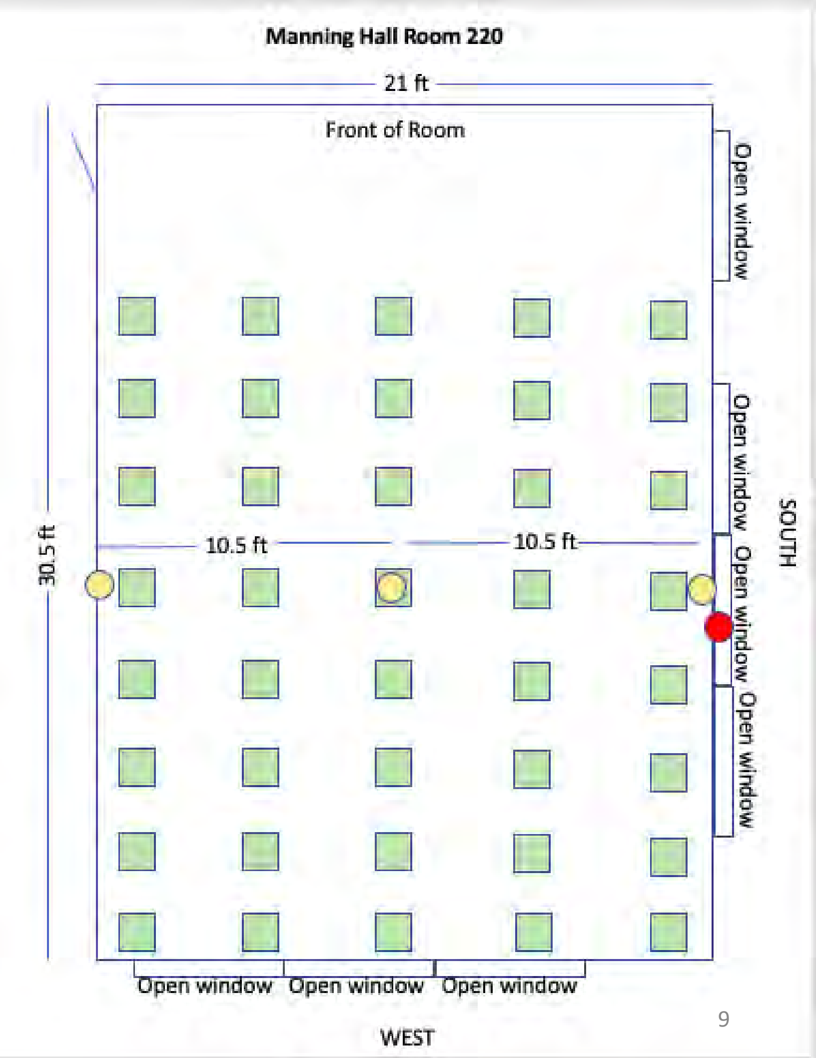
- 1: Not Comfortable
- 2: Semi-Comfortable
- 3: Neutral
- 4: Comfortable
- 5: Very Comfortable

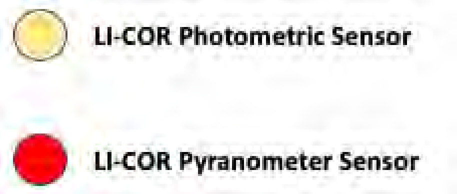
Methodology: Non-Human Data Collection

- **Conditions**: Windows open, electric lights off
- **Data Collection Period**: 72 hours (Friday 7/5 12:00 PM to Monday 7/8 12:00 PM)
- **Locations**: Manning Hall Rooms 220 and 224
- **Data Collection**: Every 5 minutes, undisturbed
- **Sensor Placement**: Refer to the figure on the next slides

Methodology: Non-Human Data Collection

Sensor	Distance from Window (feet)
1.Pyranometer	0 (on window)
2.Photometric	0 (on windowsill)
3.Photometric	10.5
4.Photometric	21





Methodology: Non-Human Data Collection

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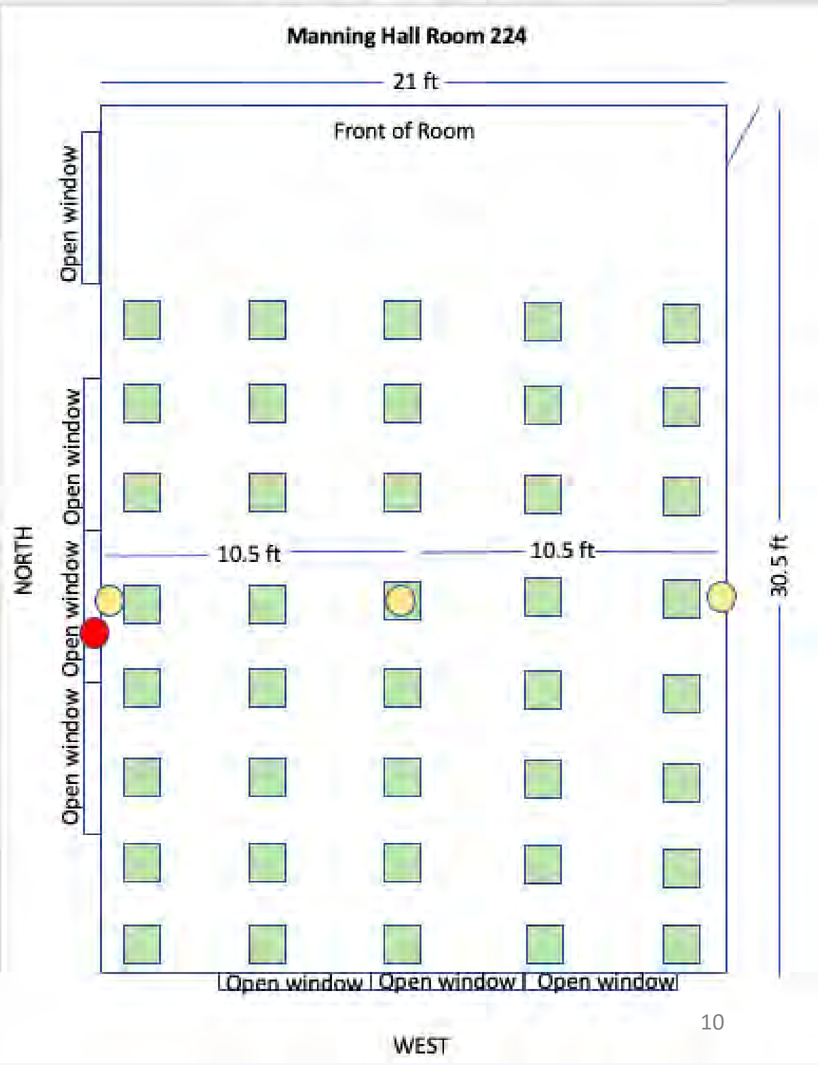
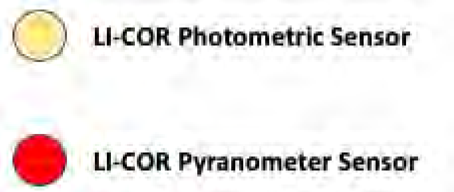
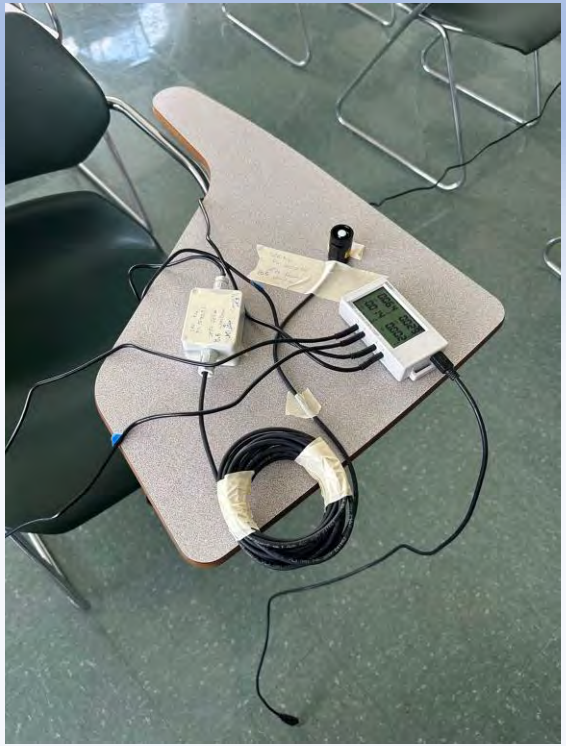
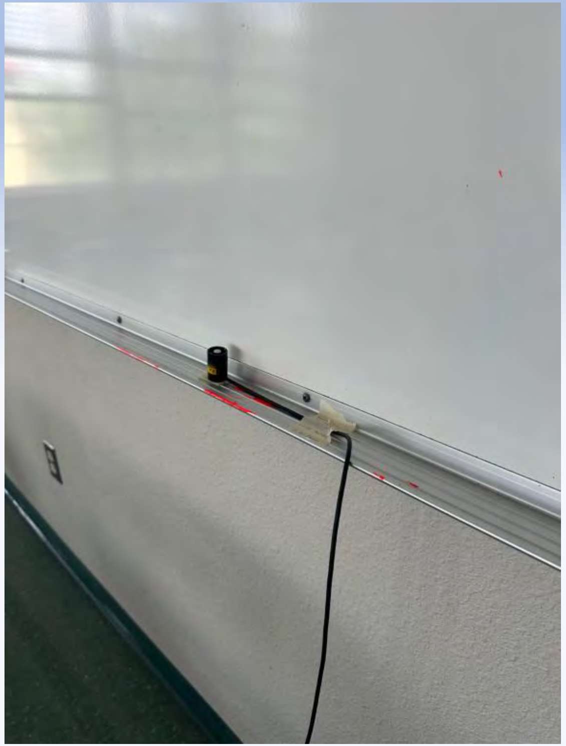


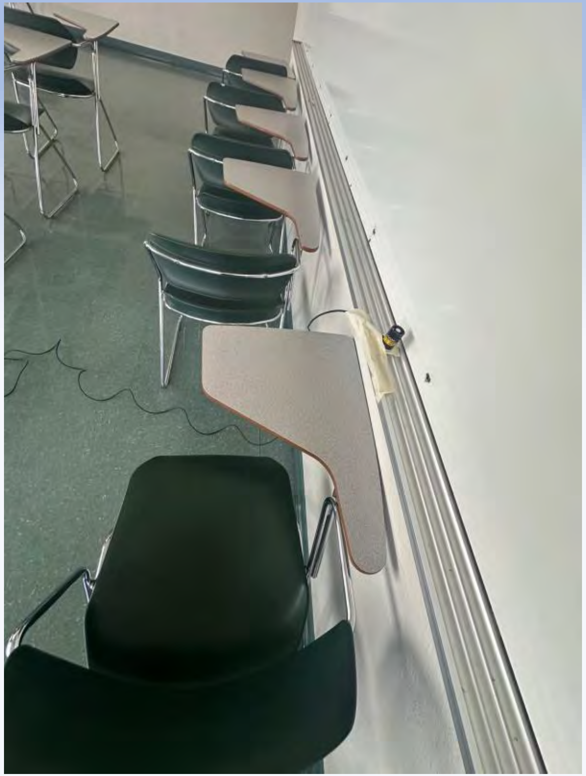


Methodology: Non-Human Data Collection





Methodology: Non-Human Data Collection



Data Analysis: Non-Human Data Collection

Analysis:

- Calculated DA (Daylight Autonomy) and UDI (Useful Daylight Illuminance) for each sensor in each room
- Assessed energy savings for each room over the collection period
- Data used: 8:00 AM - 5:00 PM (typical working/school hours)

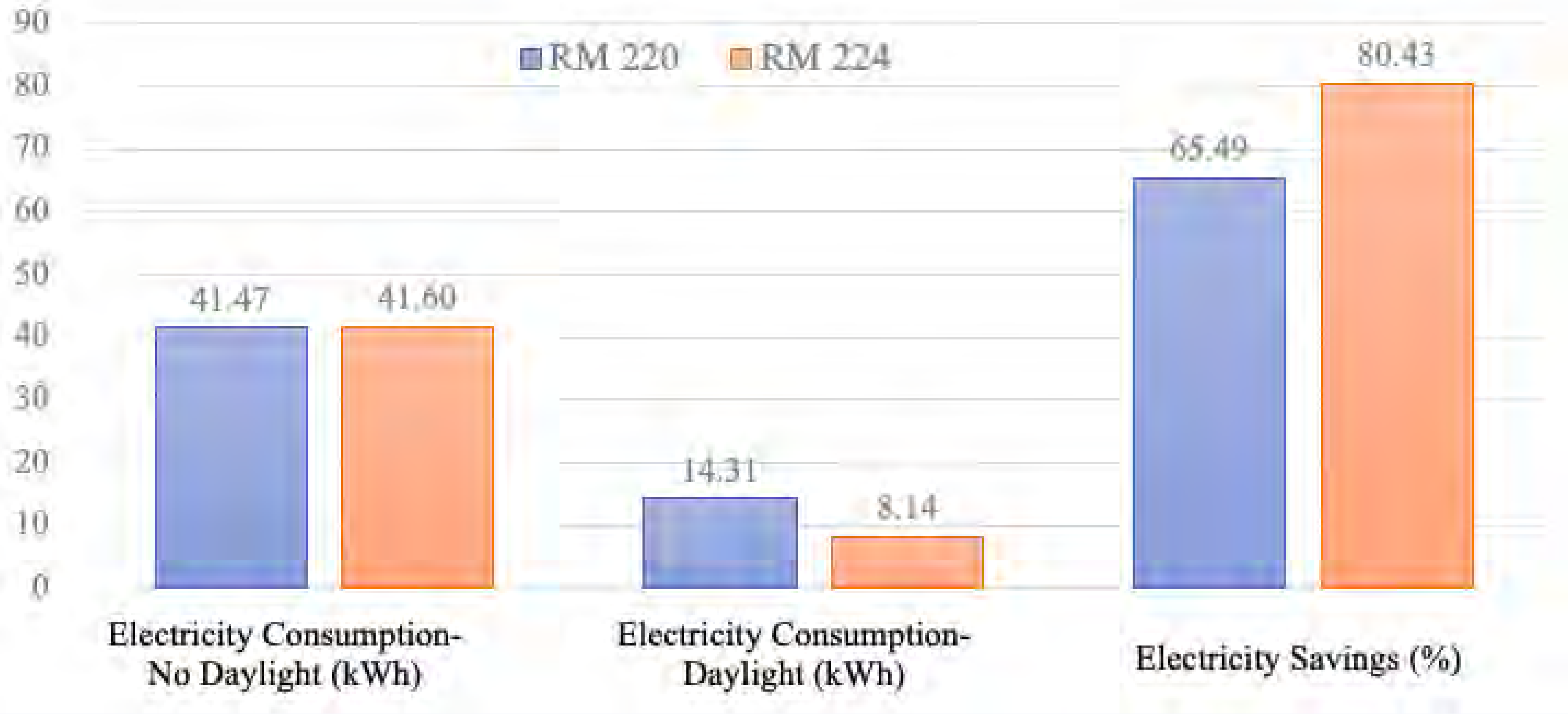
Data Analysis: DA and UDI Room 220

Manning RM 220 South and West Windows 8am-5pm			
LUX	**Windowsill**	**10.5 ft from Window**	**21ft from Window**
DA >500	98.77%	39.51%	0.00%
UDI (>=100,<500)	1.23%	60.49%	2.16%
UDI (>=500,<1000)	15.74%	39.51%	0.00%
UDI (>=1000,<2000)	39.51%	0.00%	0.00%
UDI (>3000)	15.74%	0.00%	0.00%

Data Analysis: DA and UDI Room 224

Manning RM 224 North and West Windows 8am-5pm			
LUX	**Windowsill**	**10.5 ft from Window**	**21ft from Window**
DA >500	100.00%	39.69%	7.69%
UDI (>=100,<500)	0.00%	60.31%	89.54%
UDI (>=500,<1000)	6.77%	39.69%	7.69%
UDI (>=1000,<2000)	61.54%	0.00%	0.00%
UDI (>3000)	5.85%	0.00%	0.00%

Data Analysis: Energy Savings



Methodology: Human Data Collection

Setup:

- Participants placed one Solar Light PMA2100 sensor on their head and one on the desk.

Task:

- Read a passage (~1300 Lexile Level, 500-700 words) and complete a 5-question quiz.

Comfort Rating:

- After each quiz, participants rated light comfort on a scale of 1-5 (1 = Not Comfortable, 5 = Very Comfortable).

LUX Measurement:

- Recorded LUX level after each passage before moving to the next room.

Lighting Scenarios:

- Mixed Lighting: Manning Hall Room 220
- Only Electric Lighting: Manning Hall Room 222
- Only Natural Lighting: Manning Hall Room 224

Methodology: Human Data Collection

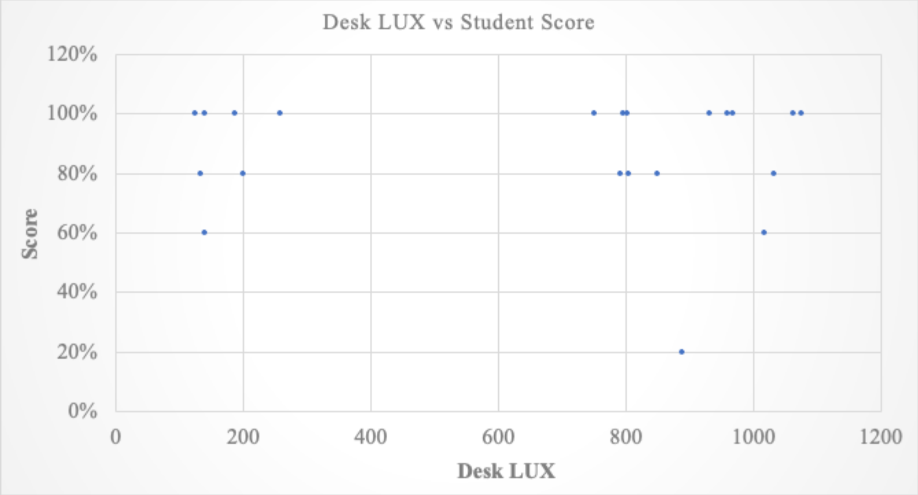
Manning Hall Room 220
Mixed Lighting

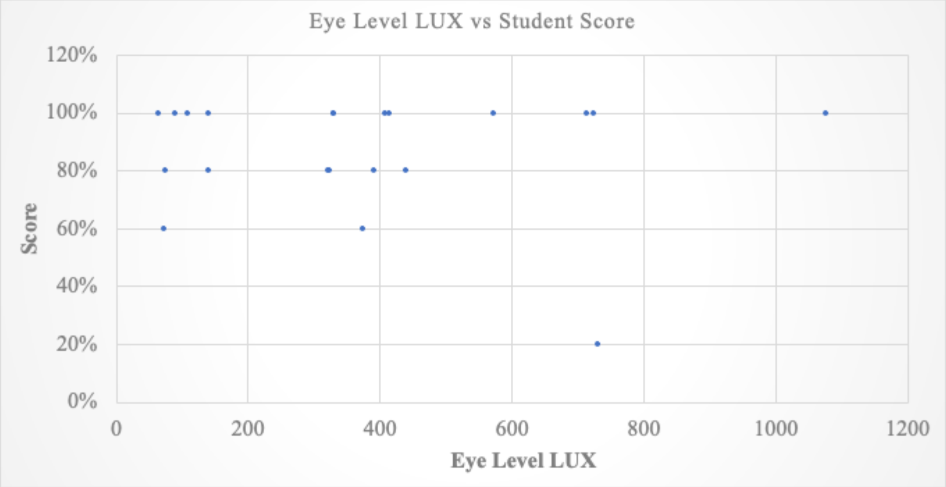
Manning Hall Room 222
Electric Lighting

Manning Hall Room 224
Natural Lighting

Data Analysis: Human Data Collection

- Our plan was to investigate whether there is a correlation between LUX levels and student scores. However, due to the small sample size, the data is inconclusive.





Data Analysis: Human Data Collection

- Participant feedback on the comfortability of the light in each room is shown below.

Participant	Mixed Light RM 220	Electric Light RM 222	Natural Light RM 224
1	2	4	5
2	2	4	5
3	2	2	5
4	3	5	1
5	3	5	4
6	3	4	5
7	4	3	5
Average Rating:	2.71	3.86	4.29

KEY				
1	2	3	4	5
Not Comfortable	Semi-Comfortable	Neutral	Comfortable	Very Comfortable

Conclusion:

UDI Range: Ideal UDI (500-1000 lux) achieved ~40% of the time in the center of each classroom.

Energy Savings:

- Room 220: 65.49% savings with daylighting
- Room 224: 80.43% savings with daylighting

Participant Preference: Room 224 (natural lighting) was favored.

Lux vs. Student Score: No significant correlation found.

Analyzing the Effects of Daylight on Student Performance

Objective:

Students will investigate the relationship between daylighting and student performance.

TEKS:

●calculate, using technology, the correlation coefficient between two quantitative variables and interpret this quantity as a measure of the strength of the linear association **A.4(A)**

●compare and contrast association and causation in real-world problems **A.4(B)**

●write, with and without technology, linear functions that provide a reasonable fit to data to estimate solutions and make predictions for real-world problems **A.4(C)**

Materials:

- Photometric sensors
- Cumulative worksheets
- Graph paper and graphing software
- Calculators

Curriculum Module: Algebra 1

1 — 2 — 3 — 4 — 5 — 6

1. Data Collection

Students will complete a cumulative worksheet in a room using natural light, and record LUX level using photometric sensor.

2. Data Collection

Students will complete a similar cumulative worksheet in a room using electric light and record LUX level using photometric sensor.

3. Linear Regression

Students will create a scatter plot of the data collected (LUX and Student Score), then determine the linear regression equation that best fits the data.

4. Correlation Coefficient

Students will calculate the correlation coefficient using technology and determine the strength of the relationship.

5. Correlation vs. Causation

Students will reflect on their findings and discuss whether the correlation they found suggests a causal relationship, and consider other variables and potential confounding factors.

6. Assessment

Students will complete a reflective activity.

Extension: Challenge students to explore non-linear relationships between daylighting and student performance using different types of regression models.

Curriculum Module: Biology

Types of Lighting Influence The Growth of Plants

Objective:

Students will investigate how different types of lighting influence plant growth. They will identify and analyze factors affecting growth and energy conservation in plants, and understand the role of light in photosynthesis and plant development.

TEKS Alignment:

- **§112.34. Biology, Grade 9-12:**
  - **(1) Scientific and engineering practices:** Plan and carry out investigations, analyze data, and communicate findings.
  - **(9)(A):** Compare structures and functions of different cell types.
  - **(10)(B):** Investigate interactions in an ecosystem and effects on the environment.
  - **(11)(B):** Investigate and analyze conditions necessary for plant growth, including light.

Types of Lighting Influence The Growth of Plants

Materials:

- Potted plants (same species, same size)
- Different types of light sources (e.g., natural sunlight, incandescent bulbs, fluorescent bulbs, LED lights, solar lamps)
- Light meters (possible phone app)
- Rulers or measuring tapes
- Data recording sheets or notebooks
- Graph paper or software for data visualization
- Watering can and water
- Soil
- Timer or clock

Curriculum Module: Biology

Day 1

Set up Plants

Determine watering schedule,

Identify variables

Initial measurements

2-3 Weeks

Measure plant growth for different lighting types

Record data in a notebook

2 Days

Analyze Data

Graph the data and interpret

Compare with other groups with different lighting

Final day

Determine the conclusion and assessment

Form conclusion based on the data of their group and other groups.

Take Quiz

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.

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Questions?

Assessing Heat Generation in Anaerobic Composting of Yard and Food Waste for Backyard Renewable Energy Potential

Teacher
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Faculty Advisors
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Dr. Marsha Sowell - Curriculum Development Faculty Mentor (TAMUK)

Student Mentor
Ravi Chandra Madasani (TAMUK)

Industrial Advisor
Enrique Molina

TEXAS A&M UNIVERSITY KINGSVILLE

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

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OVERVIEW

- Composting and Facts on Yard and Food Waste
- Research and Results
- Curriculum Modules and Classroom Implementation

Composting

Types

Aerobic Composting

- Relies on oxygen and moisture
- Promotes heat generation
- Generate energy from heat
- Faster - 6 weeks

Anaerobic Composting

- Fueled by bacteria and moisture
- Produces end products like biogas
- Generate energy from combustion
- Slower - 6 months


In Vessel


Open Pile


In Vessel

Composting

Types

Aerobic Composting
- Open Pile
- Windrow
- Static Pile
- In-Vessel
- Vermicomposting

Anaerobic Composting
- Covered static compost heap or bin
- Submersion or underwater composting
- Pits or trenches (Landfill)

YARD WASTE

The 3 Classifications Yard waste include:

1. Grass clippings
2. Small Yard Waste
   - Brush
   - Leaves
3. Heavy Brush
   - Tree trimmings greater than 3"in
   - Tree trunks
   - Root balls

FOOD WASTE

- Food waste is the single most common material landfilled and incinerated in the U.S.
  - One-third of the food produced in the US is never eaten
  - 66 million tons of wasted food (2019-EPA)
  - 60% to landfills

FOOD WASTE

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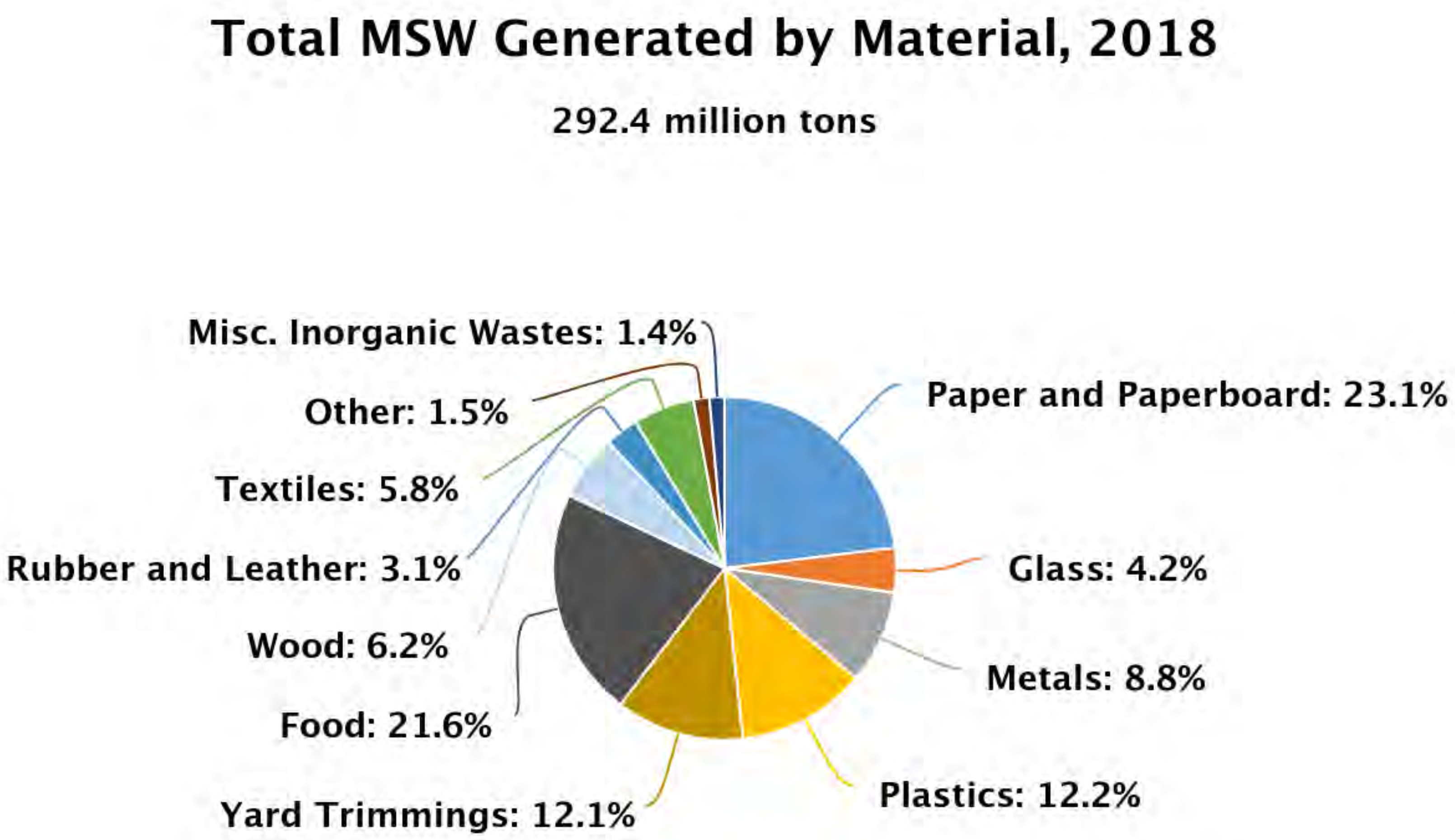
So, What is the Bottom Line?

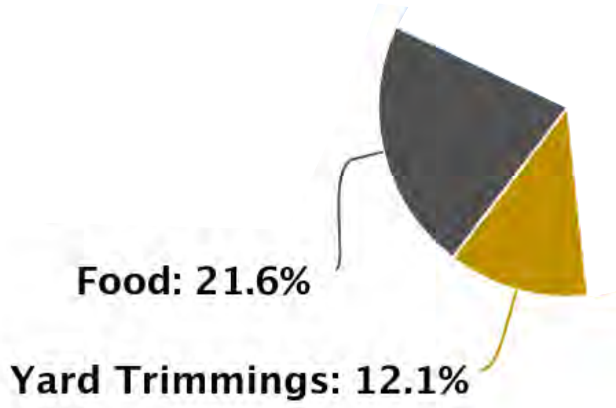


So, What is the Bottom Line?

Total MSW Generated by Material, 2018

292.4 million tons

33.7%



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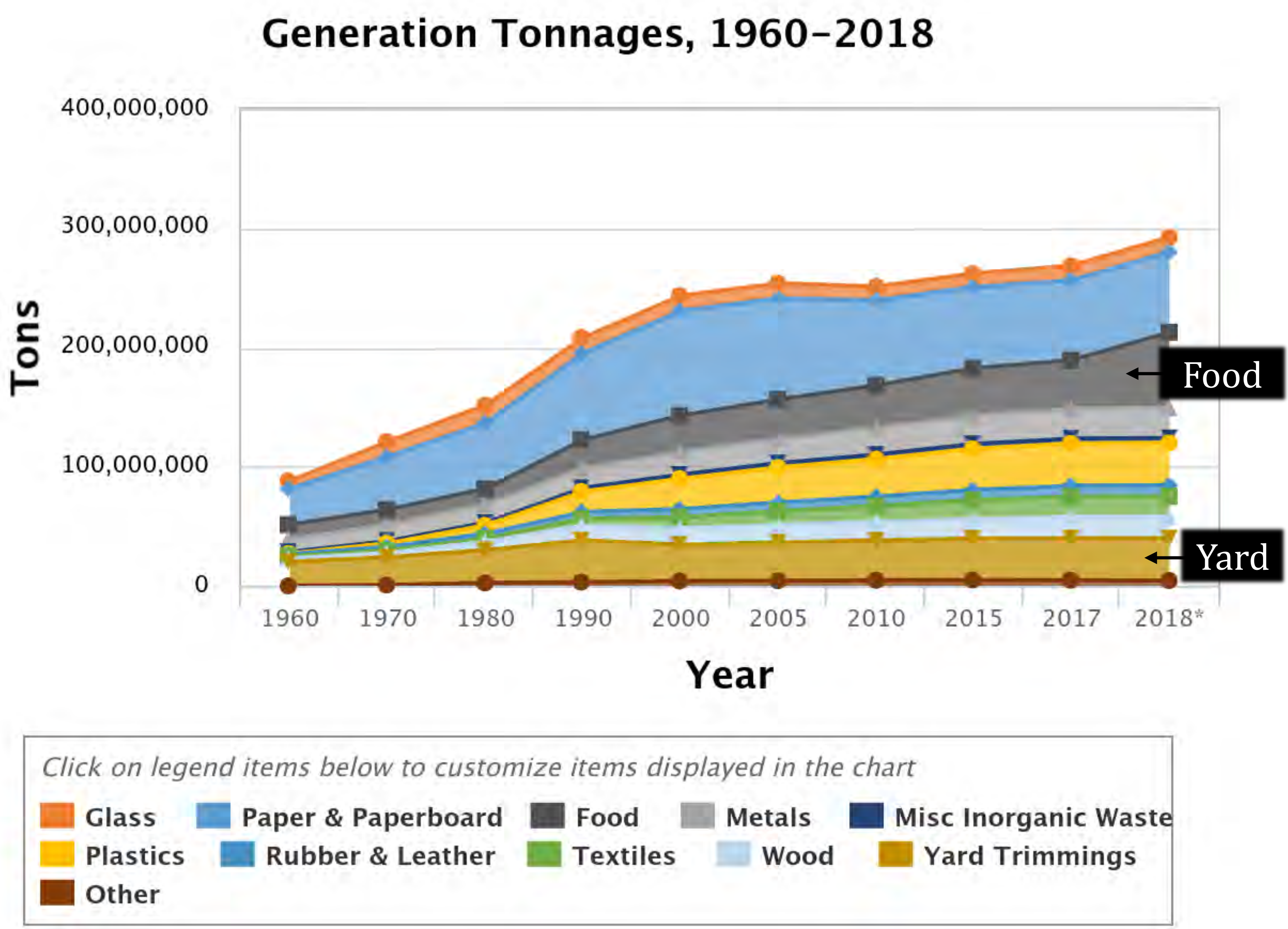
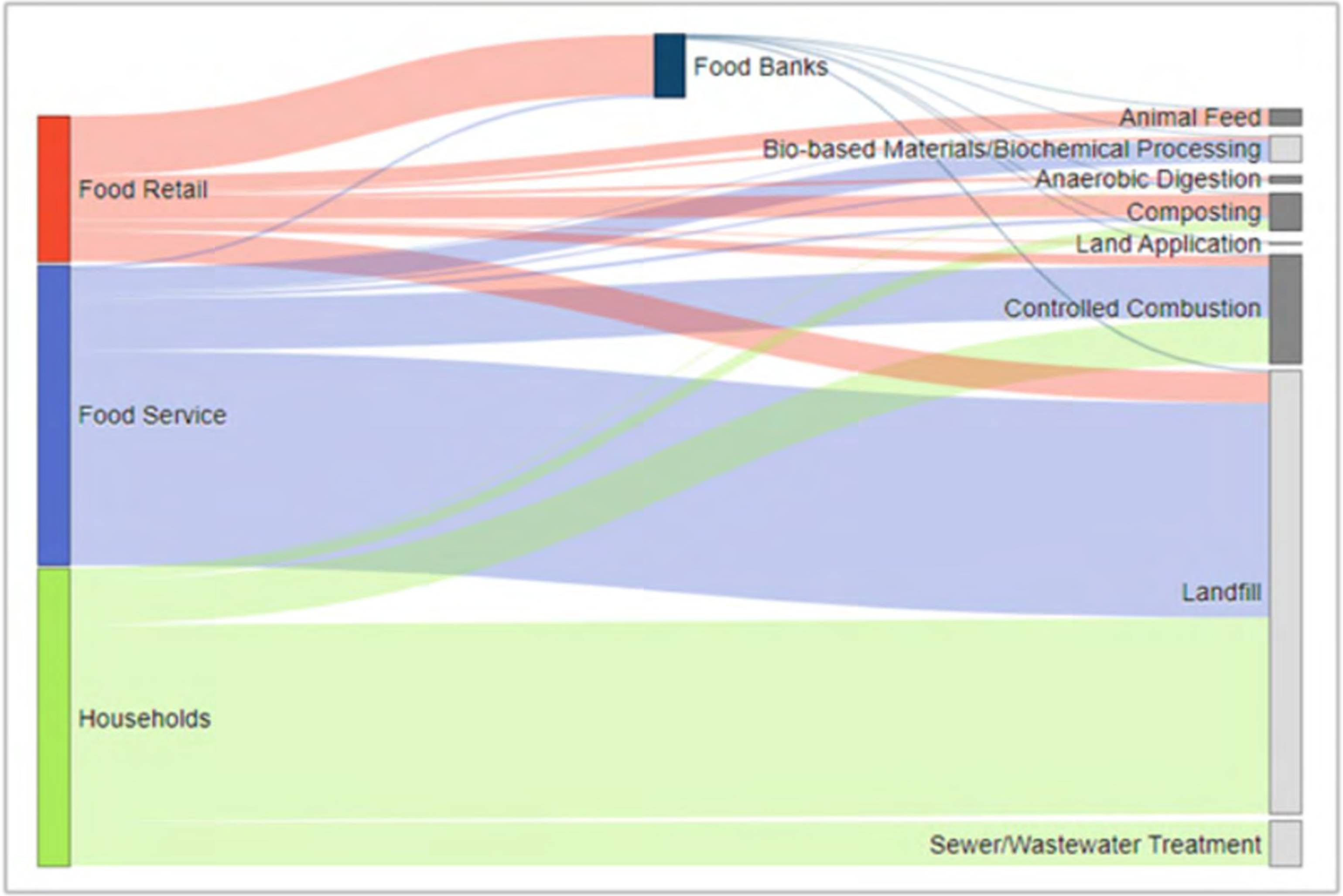


So, What is the Bottom Line?



Assessing Heat Generation in Anaerobic Composting of Yard and Food Waste for Backyard Renewable Energy Potential

Present Focus

Future Focus

Generation

Capture

Utilization

Research Objectives

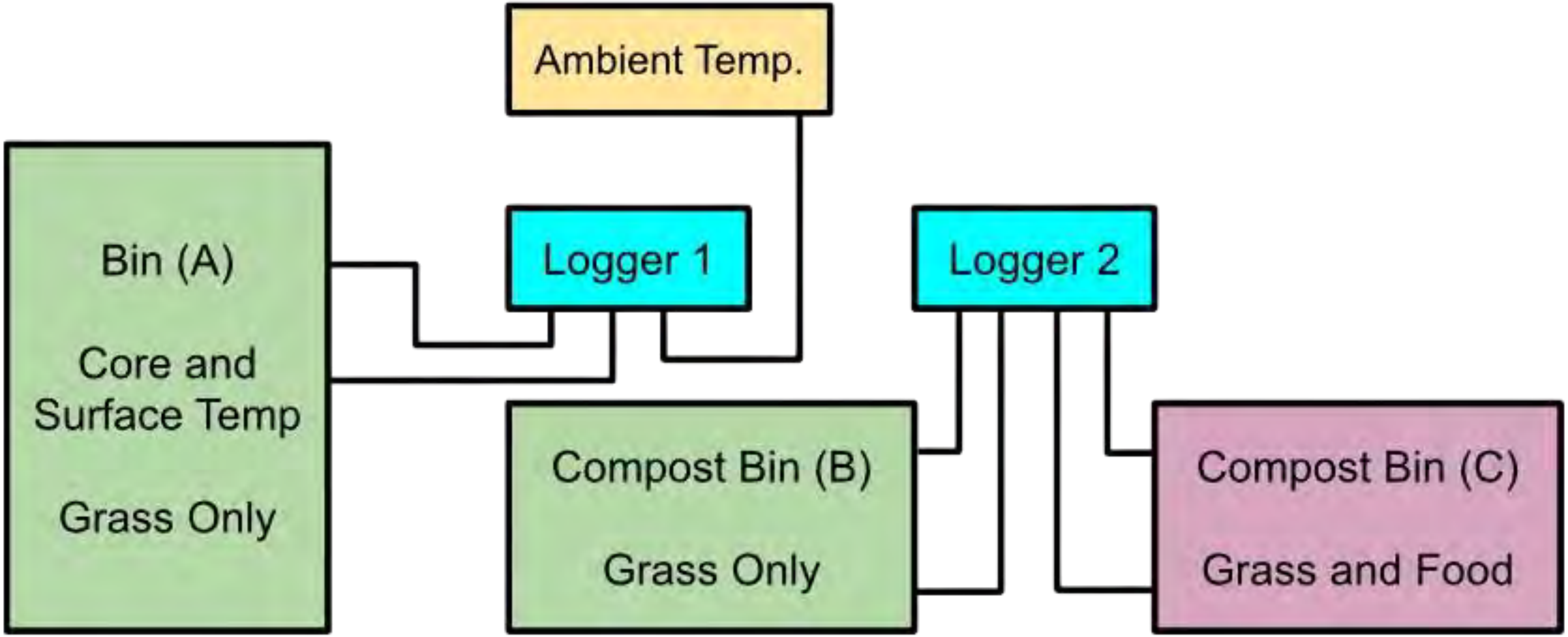
1. **Investigate heat generation from anaerobic composting of yard and food waste.**

2. **Compare large bin core and surface level temperatures.**

3. **Compare core temperatures between large and small bins.**

4. **Compare core temperatures of small bins with grass-only versus grass/food.**

Methodology



Methodology

Trash Can (A) (mass in lbs)		
Load 1	Grass	14
Load 2	Grass	21.4
Load 3	Grass	25
Load 4	Grass	24.2
Load 5	Grass	26.2
Total		110.8

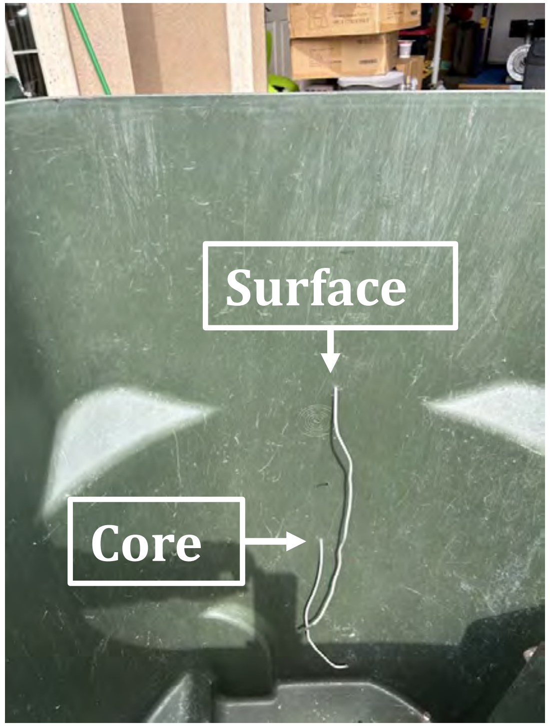
Bin (A)

Core and Surface Temp

Grass Only

Approx. 115 gallons
Depth 108 cm

Surface Depth 13 cm
Core Depth 54 cm



Sealed shut to keep heat inside

Methodology

Compost Bin B (mass in lbs)		
Load 1	Grass	25.2
Load 2	Grass	17
Total		42.2

Approx. 43 gallons

Tested / Sealed

Compost Bin (B)

Grass Only

Sensors Location (2)

Compost Bin C (mass in lbs)		
Load 1	Grass	4.2
Load 2	Food	13.8
Load 3	Grass	5
Load 4	Food	12.6
Load 5	Grass	6.8
Total		42.4

Methodology

Approx. 43 gallons

Sensors Location (2)

Tested / Sealed

Compost Bin (C)

Grass and Food

Methodology

Ambient Temp.

Suspended in Air

Logger Settings
Start Date: July 14, 2024 8:00pm
End Date: July 21, 2024 8:00pm
Data Point Intervals: Every 30 minutes

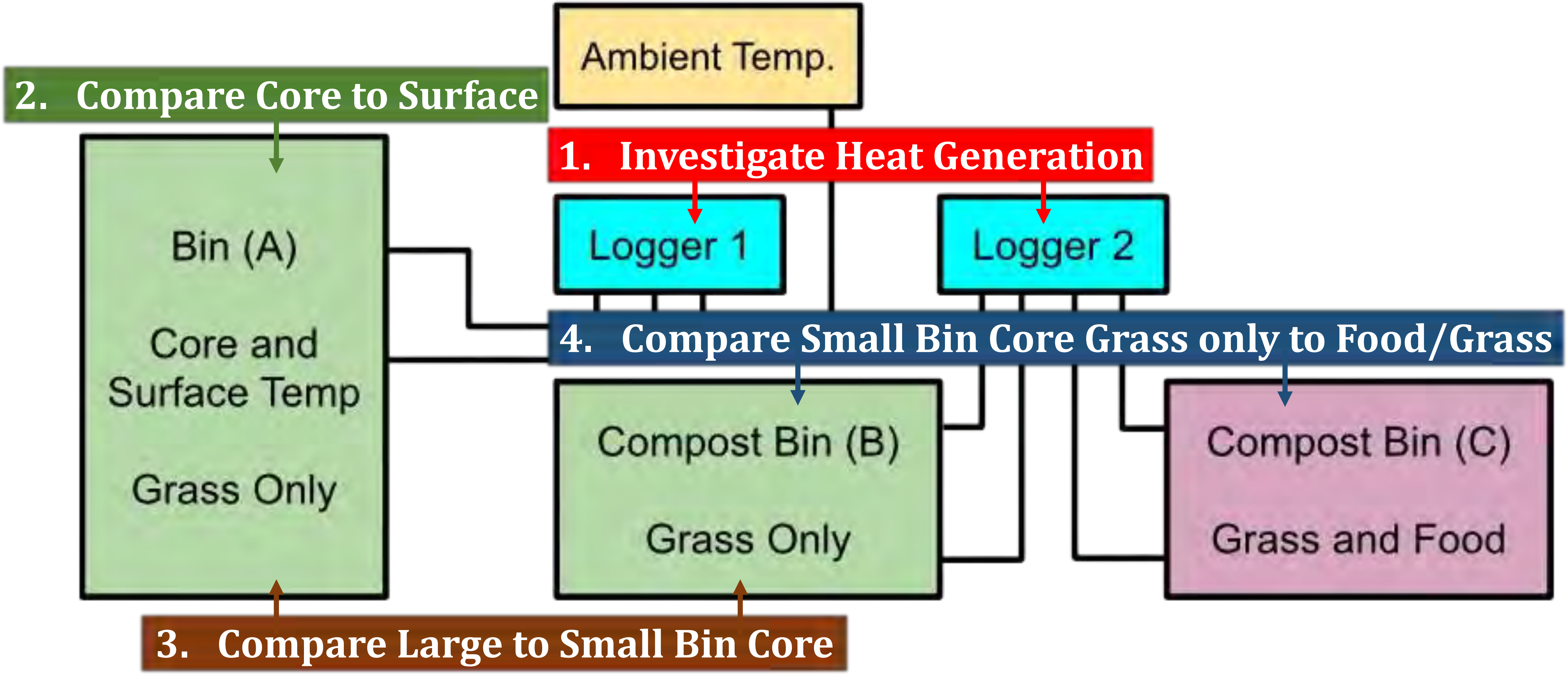
Logger 1

3 Sensor Ports use:
1. Bin A – Core
2. Bin A – Surface
3. Ambient Temp.

Logger 2

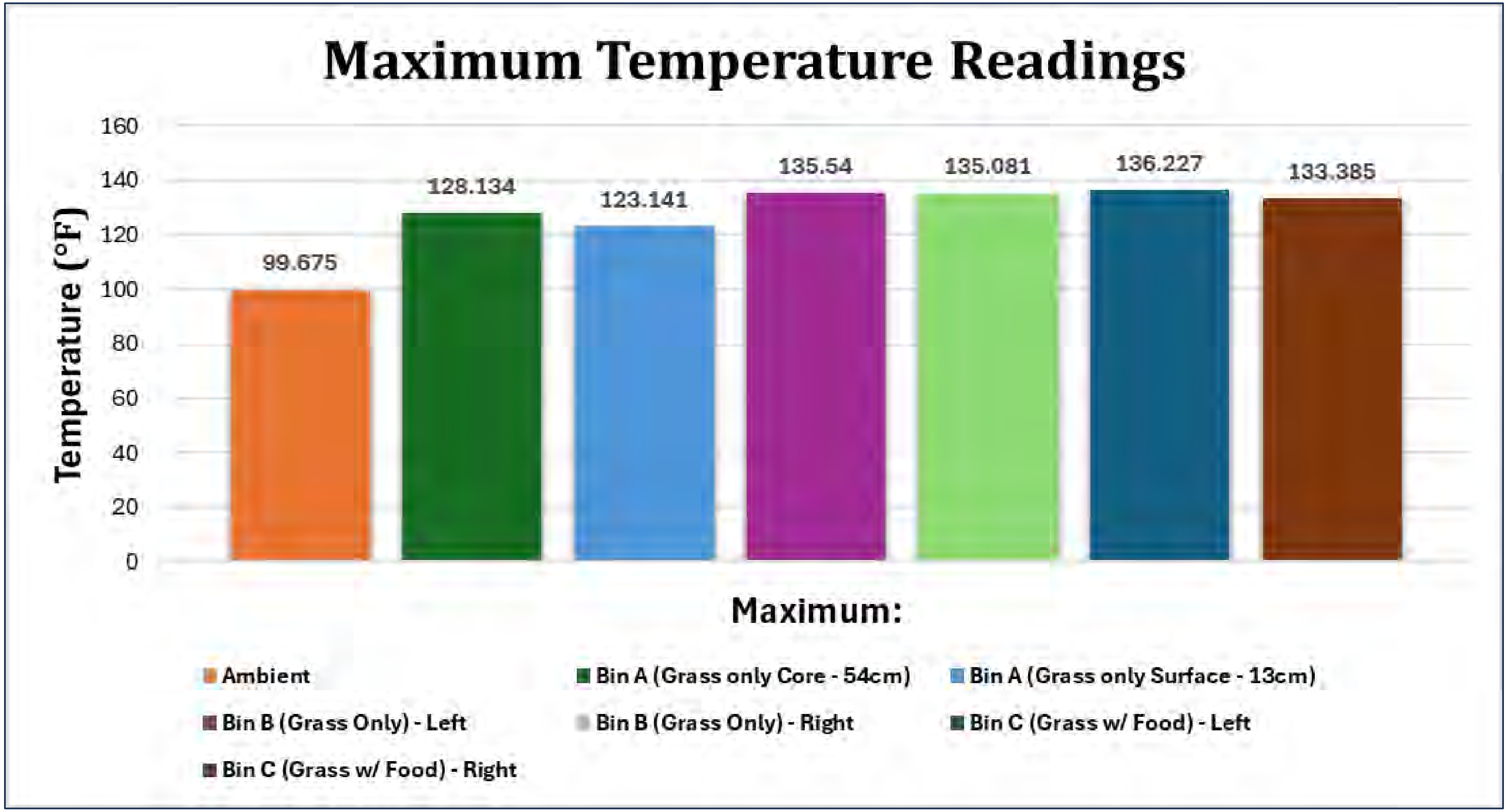
4 Sensor Ports use:
1. Bin B – Left
2. Bin B – Right
3. Bin C – Left
4. Bin C – Right

Methodology



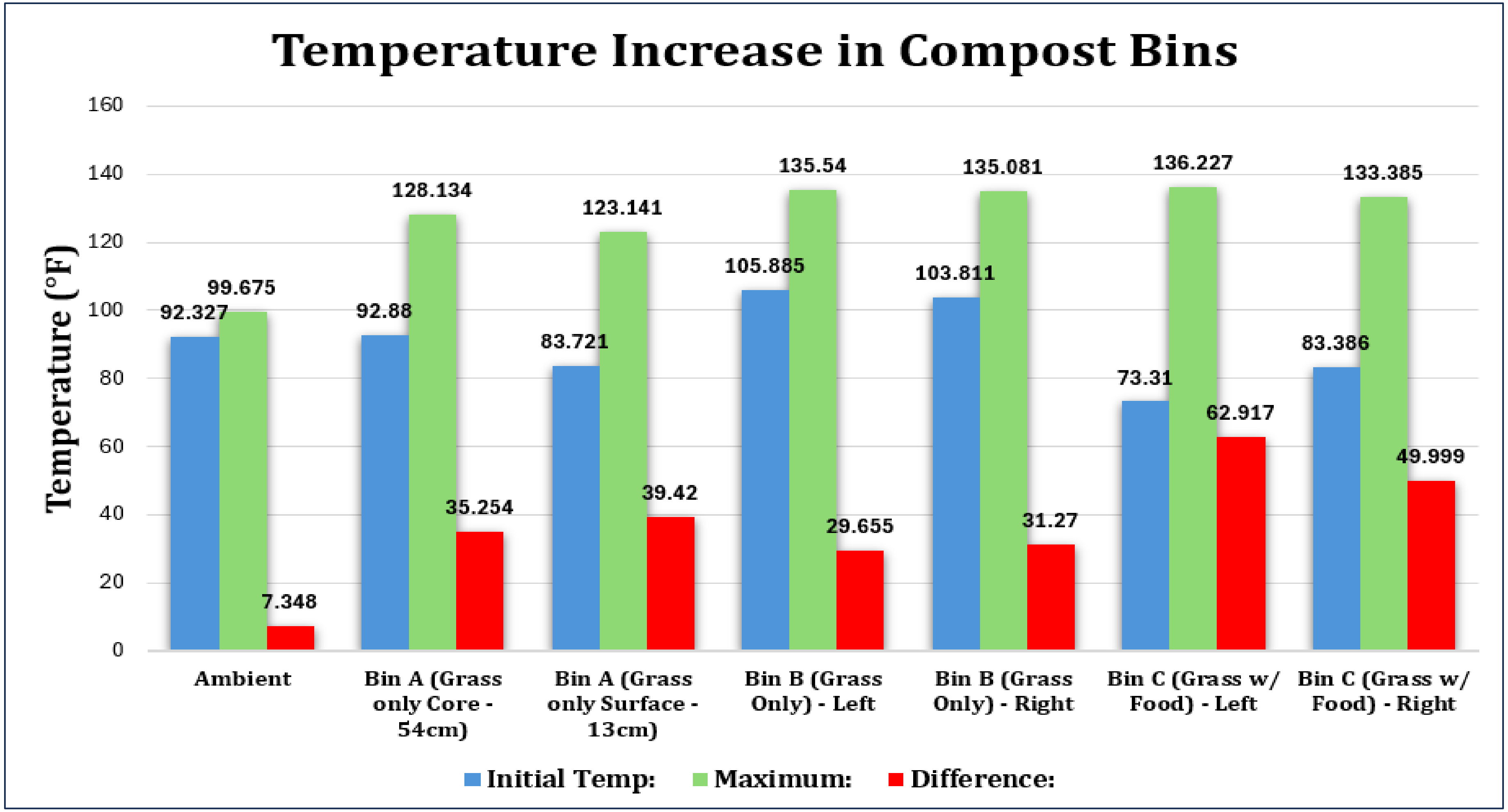
Results

Investigate Heat Generation



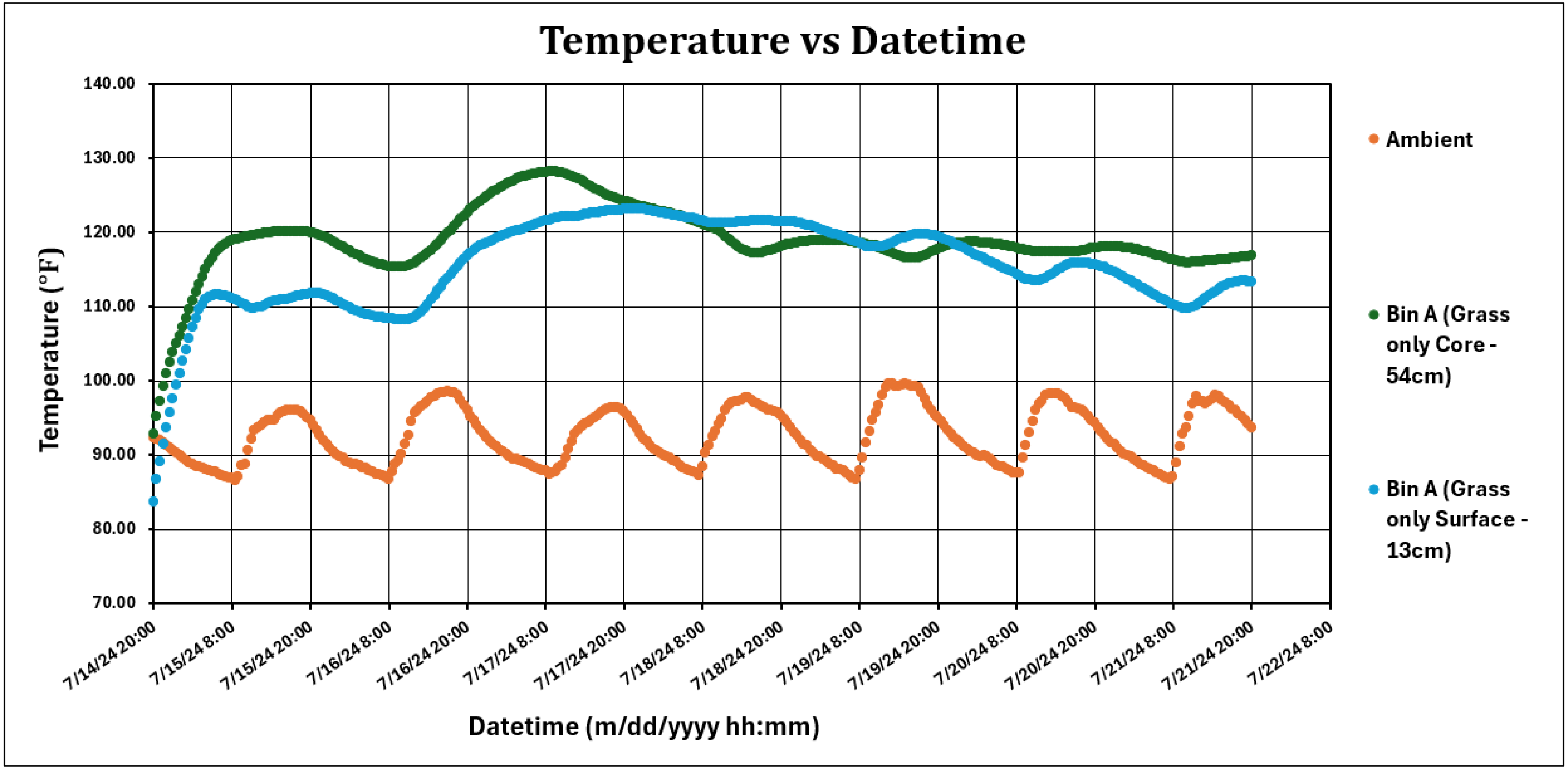
Results

Investigate Heat Generation



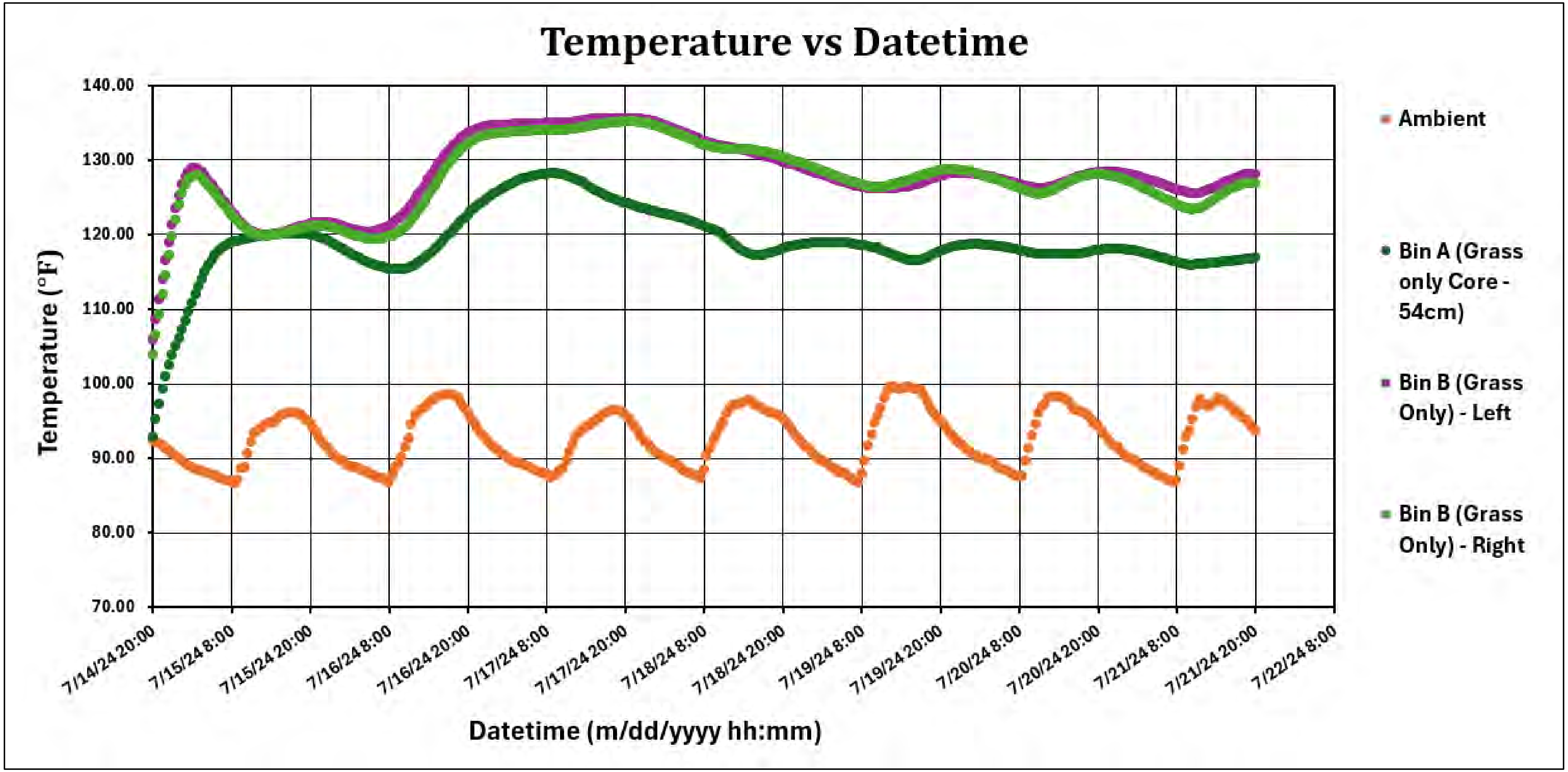
Results

Comparing Core to Surface Temperatures in Bin A



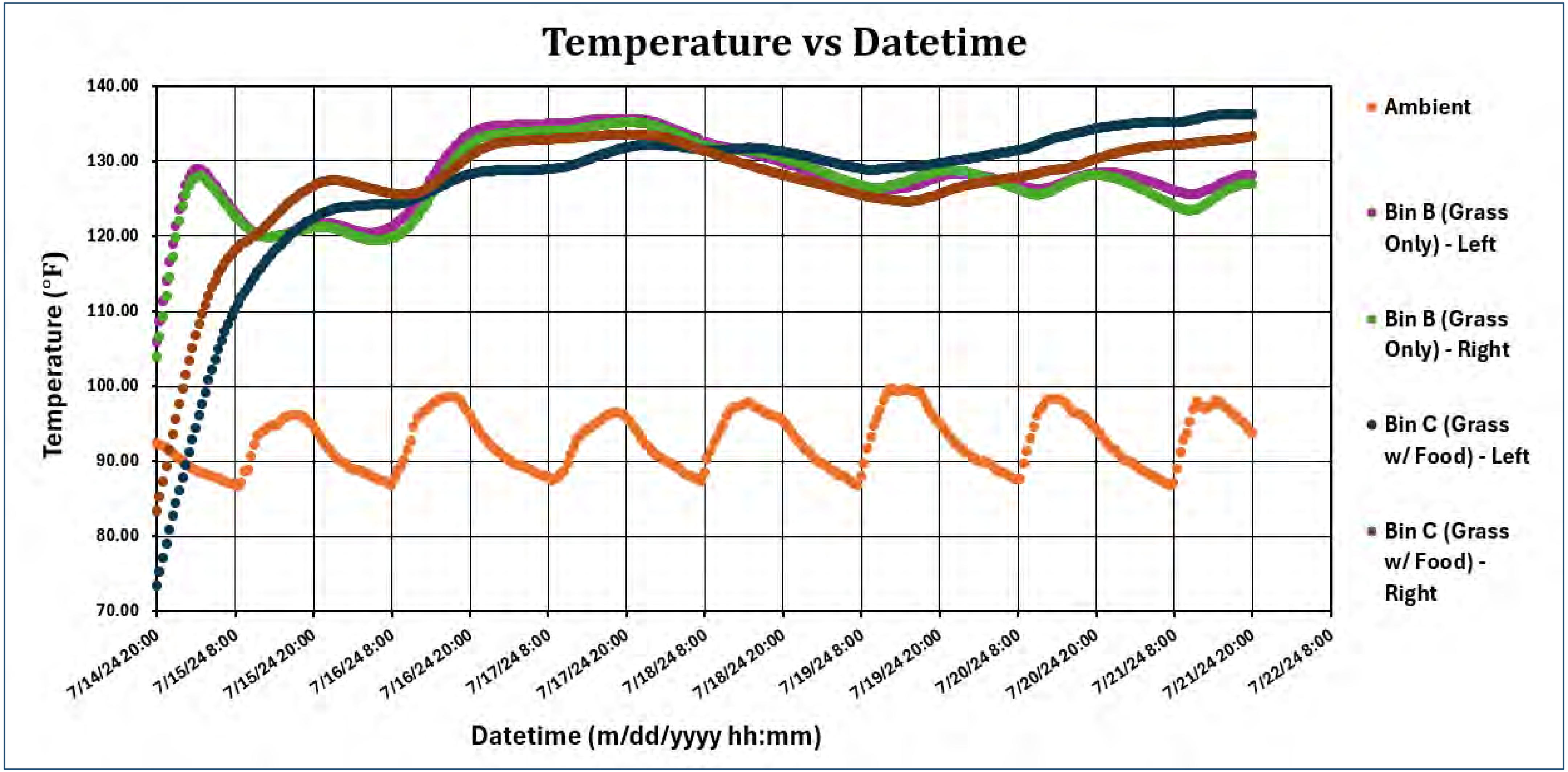
Results

Comparing Large (A) to Small (B) Bin Core Temperatures

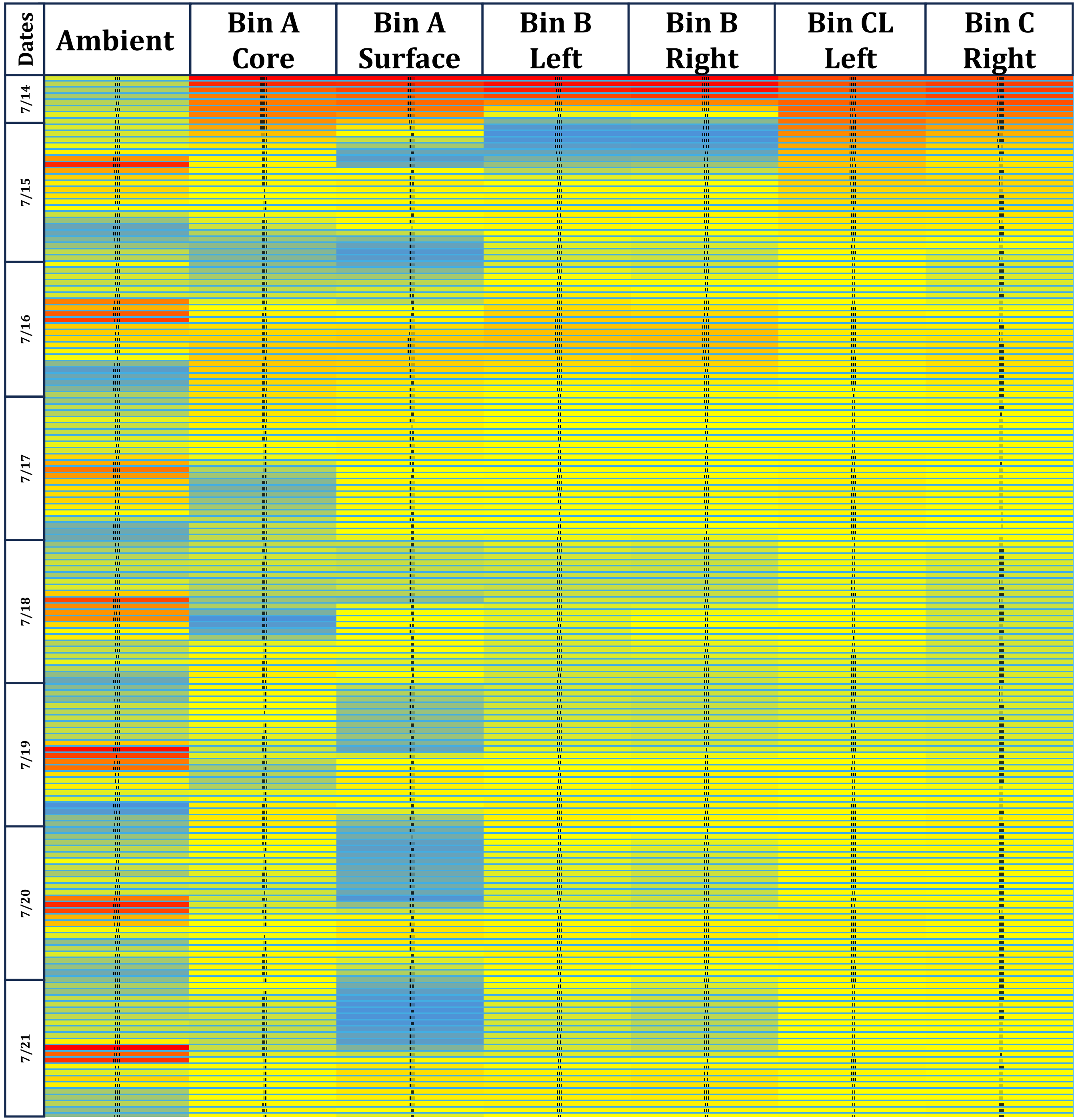


Results

Comparing Small Bin (Grass Only to Food/Grass) Temperatures



Rate of Change of Temperature



Conclusions

- Investigate Heat Generation
  - Heat can be produced through the anaerobic composting
  - Evidenced by maximum temperatures in each bin exceeding the ambient temperature by 23°F to 36°F

- Comparing Core to Surface Temperatures in Bin A
  - Similar rates of change
  - Core reached a higher max temperature
  - Core maintained a higher average temperature

- Comparing Large (A) to Small (B) Bin Core Temperatures
  - Bin B had higher initial rate of change
  - Bin B reached a higher max temperature
  - Bin B maintained a higher average temperature

- Comparing Small Bin (Grass Only to Food/Grass) Temperatures
  - Bin C had higher / longer sustained initial rate of change
  - Bin C reached a higher max temperature by the week's end
  - Bin B maintained a slightly higher average temperature (0.679 °F)

Conclusions

- Investigate Heat Generation
  - Heat can be produced through the ana
  - Evi each tem

- Comparing Core to Surface Temperatures in Bin A
  - rature

- Compar Temper
  - Bin
  - Bin
  - Bin B maintained a higher average temperature

- ed
- erature by the week's end
- Bin B maintained a slightly higher average temperature (0.679 °F)

Based on results from this experiment:

A smaller bin containing food and grass with temperature sensors located within the core will produce the most heat within a week's timeframe.

Curriculum Modules

Environmental Systems and Physics

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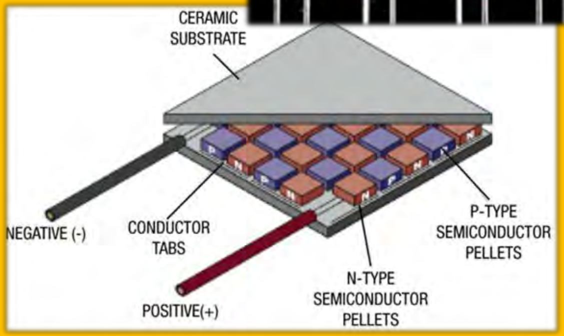
Environmental Systems

Composting in the Classroom

- **Background Information and Vocabulary Exploration**
  - Students will be given the opportunity to research and explore the science behind composting.

- **Composting Project (Weeks 1 through 6)**
  - Activities over several weeks will include:
    - Setting Up Composting Bins
    - Daily Monitoring and Rotation
    - Data Collection
    - Week-by-Week assessment the decomposition progress of each bin
    - Final Report and Presentation

Physics



Thermoelectric Generator Investigation Activity

Four Day Activity

- **Day 1: In-depth Background**
  - Students will gain a comprehensive understanding of thermoelectric generators, the Seebeck effect, and related principles.
- **Day 2: LED Module**
  - Students will use a thermoelectric generator to power an LED and understand the conversion of heat energy to electrical energy.
- **Day 3: EMF Module**
  - Students will measure the EMF produced by the TEG and calculate the current using a known resistance.
- **Day 4: Heat vs EMF Module**
  - Students will measure and graph the voltage output of the TEG as the heat input is varied.

Thank You!

Acknowledgement:
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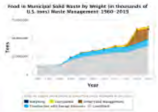
References



https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/food-material-specific-data


Yard trim graph
https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/yard-trimmings-material-specific-data

Yard waste facts
https://www.cctexas.com/services/utilities/storm-water-pollution-prevention/disposing-yard-waste
https://www.nctcog.org/envir/watershed-management/stormwater/yard-waste


https://www.epa.gov/land-research/farm-kitchen-environmental-impacts-us-food-waste

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MODELING IMPACTS OF WAKE STEERING ON WIND FARM DEVELOPMENT

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CURRICULUM MENTOR: DR. MARSHA SOWELL
INDUSTRIAL ADVISOR: RICHARD MARTINEZ

INT

INNOVATIVE SOLUTIONS:

- Wake Steering Techniques:
- Potential to increase energy output by up to 13%.
- Builds on previous research to optimize performance.

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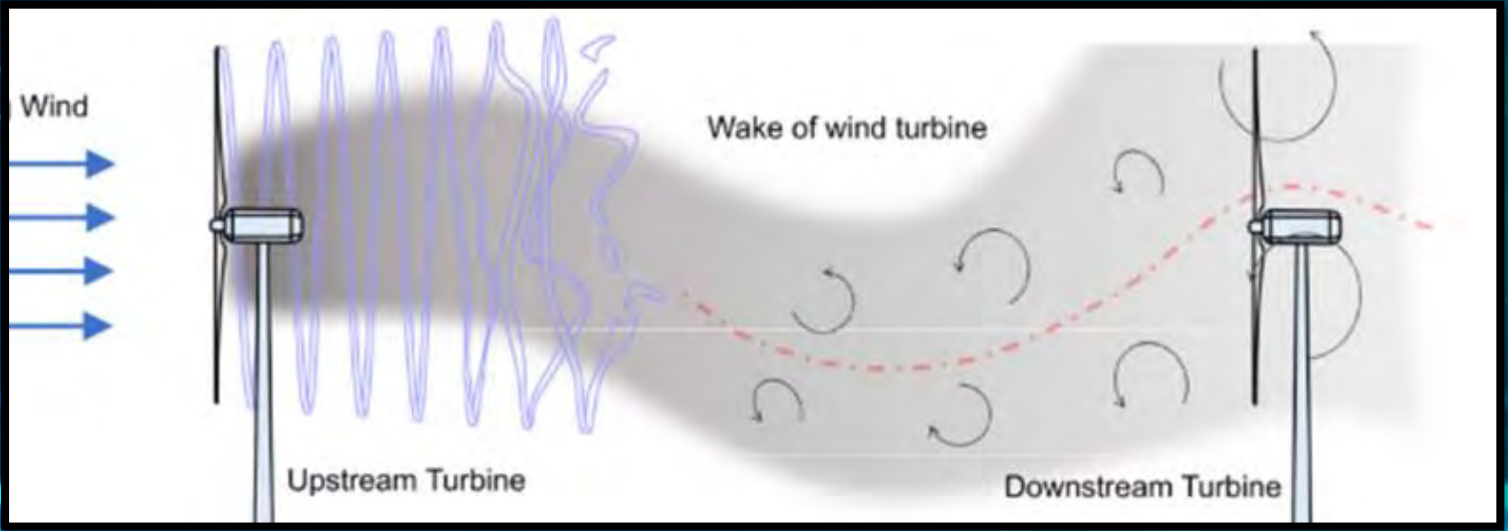
WIND TURBINE WAKE EFFECT

Definition:

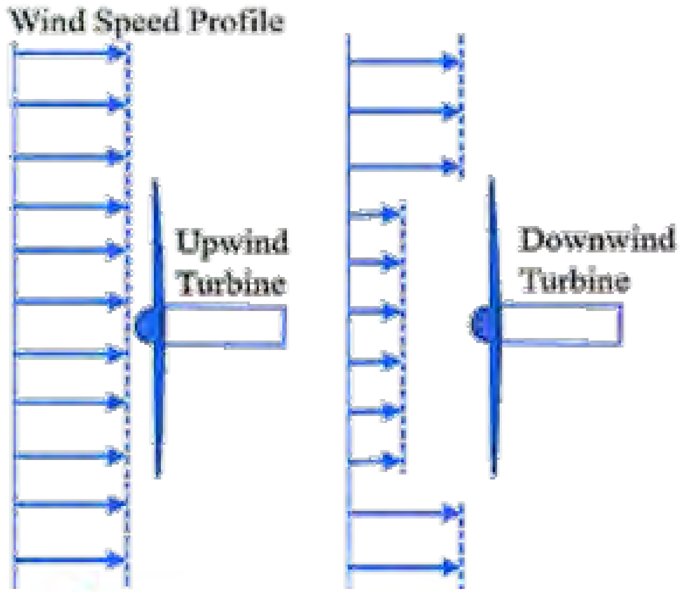
- Disturbance in airflow caused by a wind turbine.
- Creates a downstream area with reduced wind speed and increased turbulence.

Impacts:

- Reduces efficiency and power output of downstream turbines.
- Similar to how a boat leaves a wake in the water behind it.



WIND TURBINE WAKE LOSSES



Definition:

- Reduction in energy production caused by the wake effect.

Mechanism:

- Wind turbines create a wake of slower, turbulent air behind them.
- This wake affects downstream turbines, reducing their efficiency and power output.

Impact:

- Downstream turbines generate less power in disturbed wind conditions.
- Significant reduction in overall energy output of the wind farm.

Mitigation Strategies:

- Strategic turbine spacing and alignment with prevailing winds.
- Proper turbine placement to ensure optimal wind conditions for each turbine.

Importance:

- Maximizes power production.
- Enhances economic viability of the wind farm.

Wake Steering

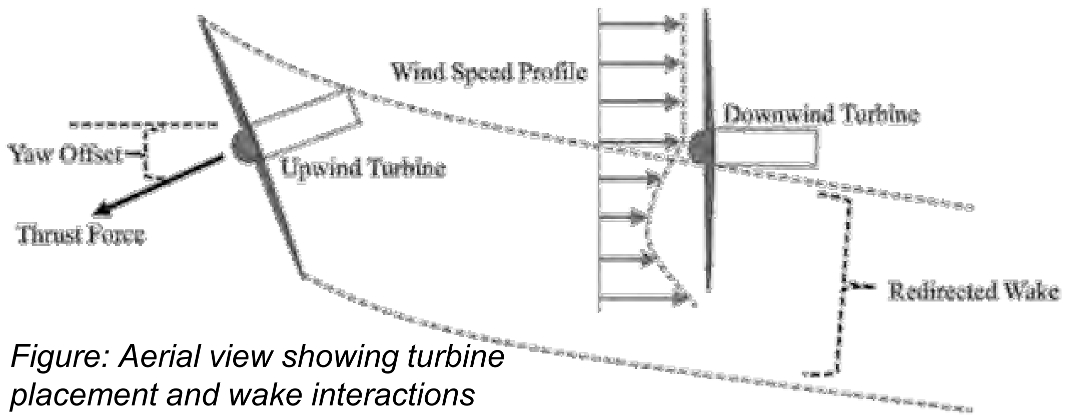


Figure: Aerial view showing turbine placement and wake interactions

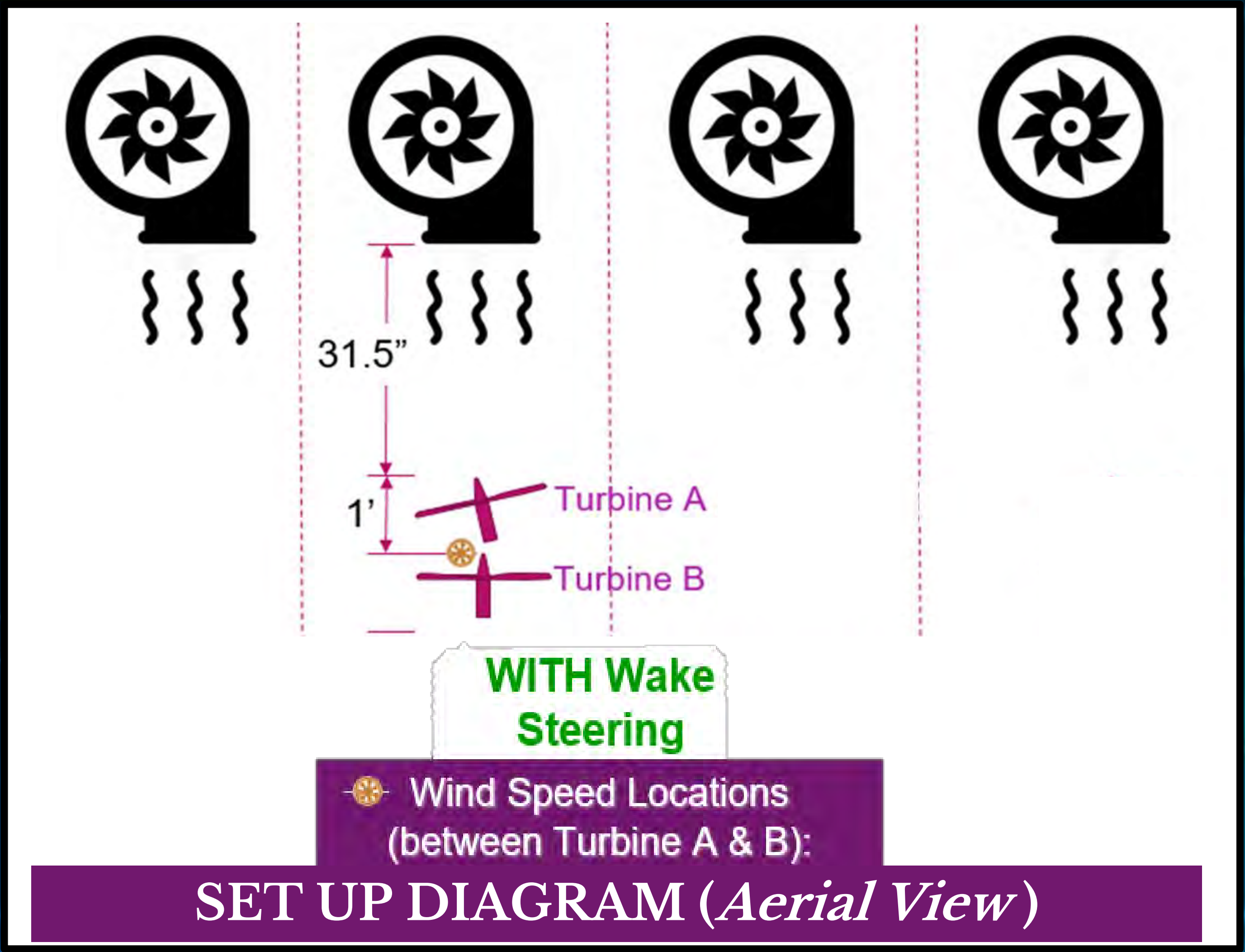
Objective:
- Optimize wind farm layout and increase power production

Key Strategy:
- Redirect wakes of upstream turbines away from downstream turbines using yaw angle adjustment.

Benefits:
- Increases power production for downstream turbines.
- Enhances overall wind farm efficiency and economic potential.
- Provides design flexibility, especially in land-constrained locations.

Evidence:
- Proven success through field trials and simulation studies.

Experiment Set Up



SET UP DIAGRAM (*Aerial View*)

Baseline Measurements:

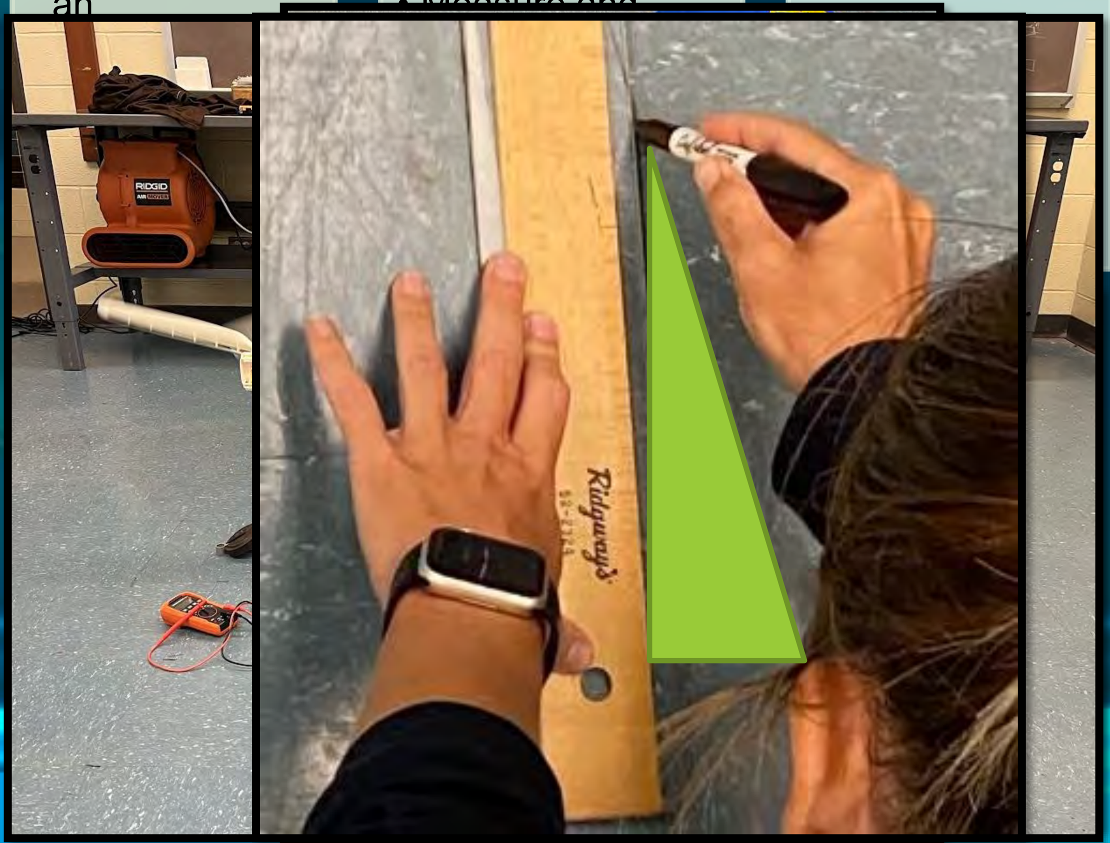
- Set up four industrial blowers.
- Model is in a controlled environment.
- Measure initial wind speeds at various distances using an

Single Turbine Measurements:

- Place the first turbine 31.5 inches from a blower.
- Position a second turbine at incremental distances of 1 ft. behind the first, up to 10 feet.
- Measure and

Wake Steering Tests:

- Set first turbine to wake steering.
- Repeat measurements for the second turbine.



WAKE STEERING Model In Action

Mitigation Strategies:

- Strategic turbine positioning.
- Optimal wind farm design to reduce wake interference.

Importance:

- Reduces costs.
- Advances sustainable wind energy solutions.

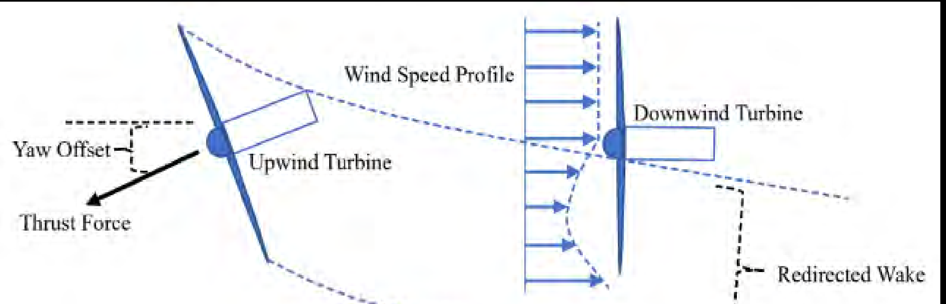


Figure: Aerial view of turbine placement and wake interactions

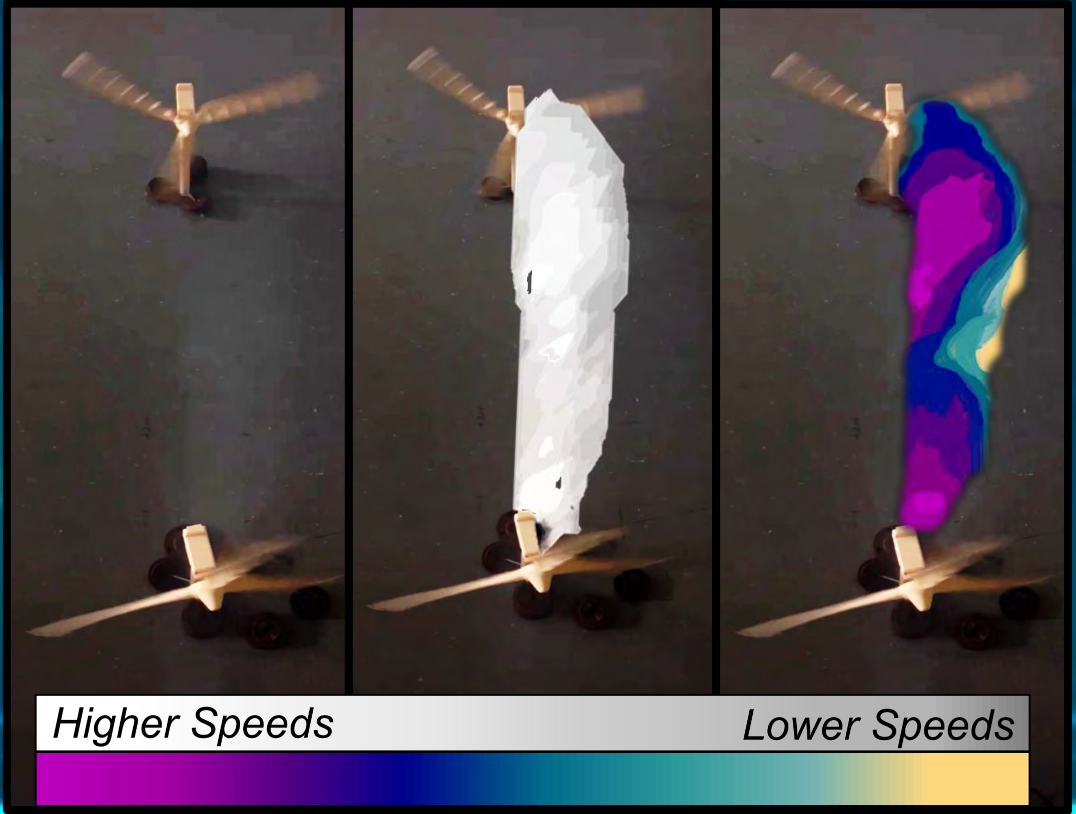
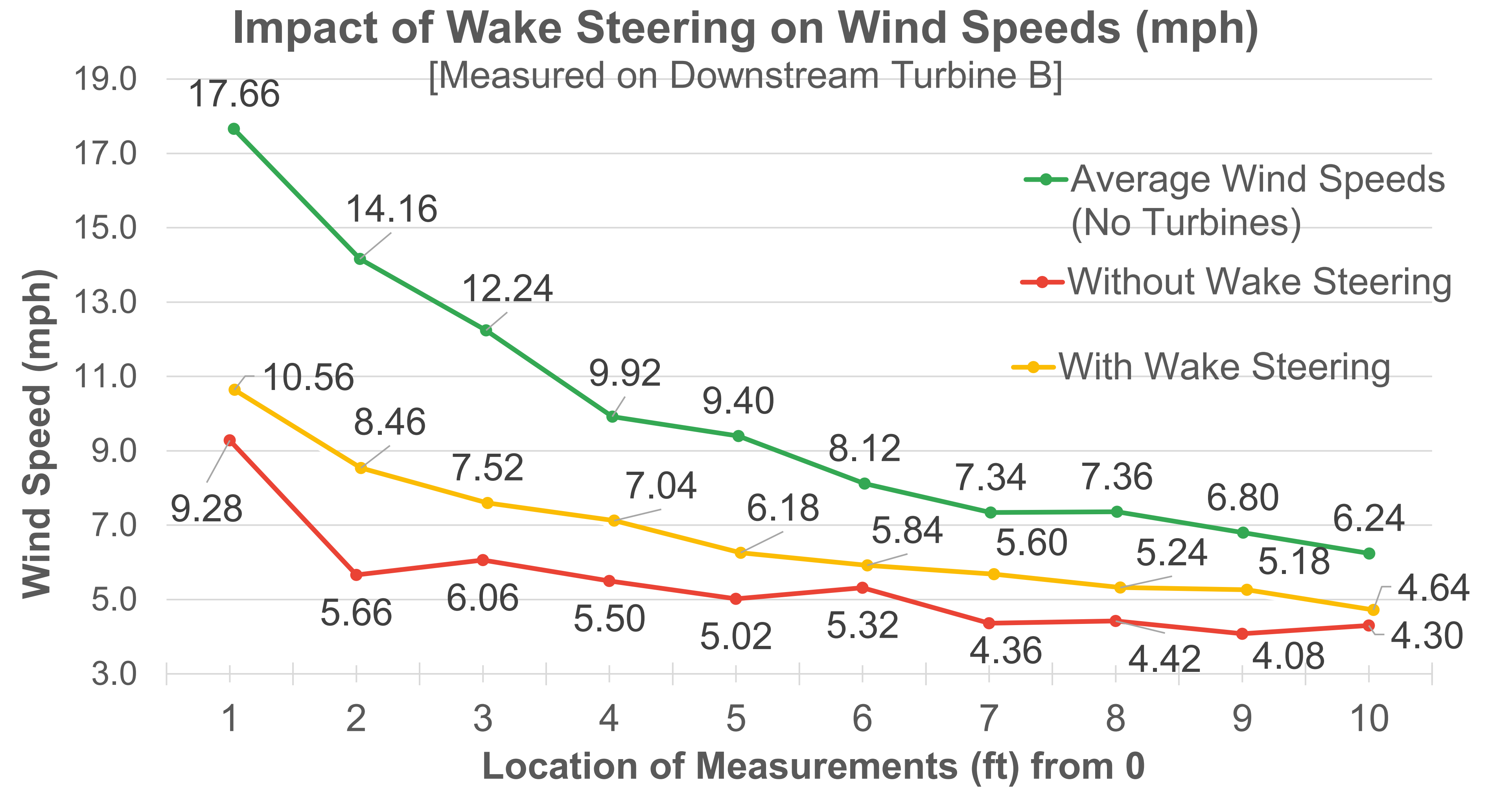


Figure: Aerial view of wake steering on Turbine A and Turbine B downwind with no wake steering.

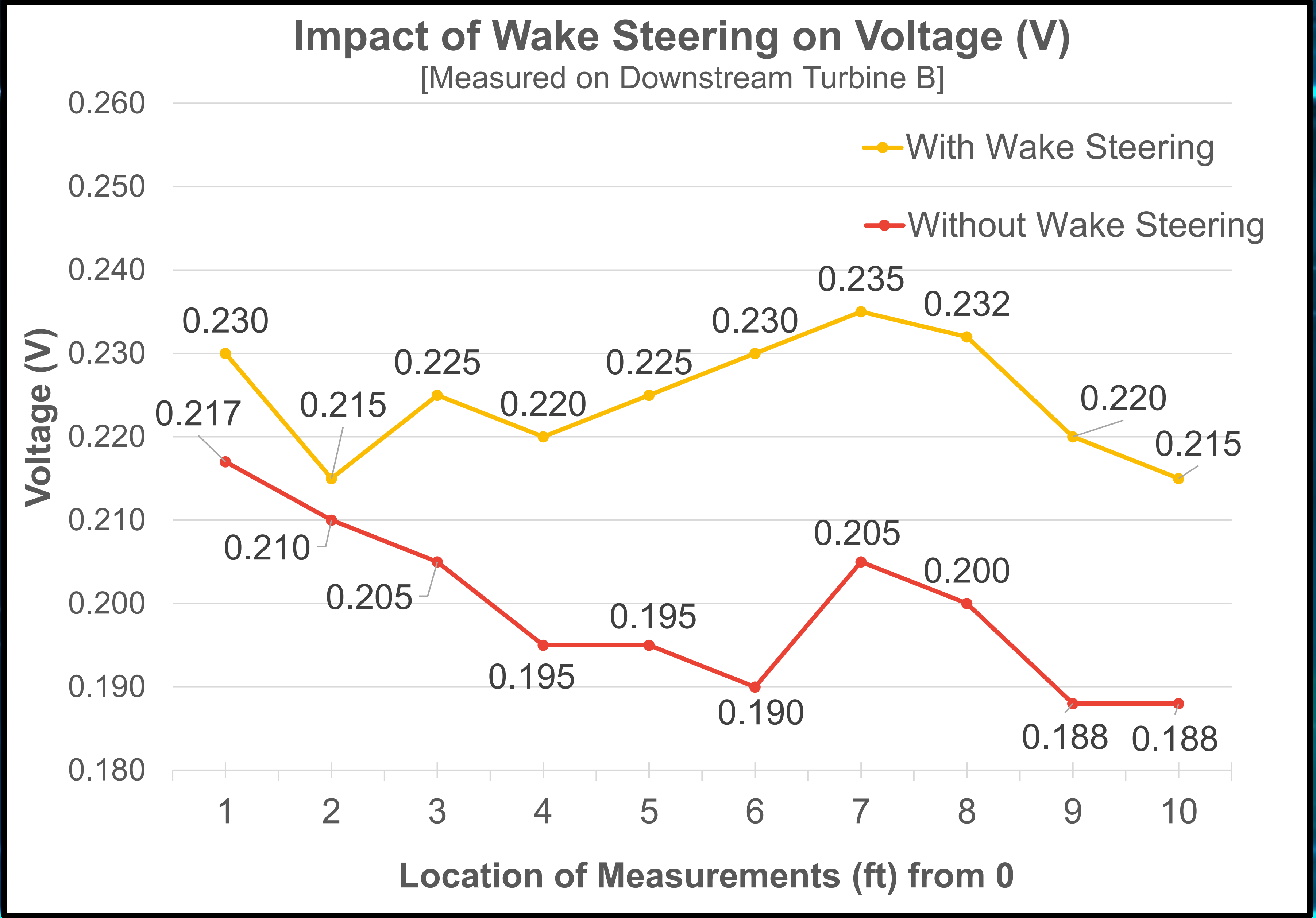
WIND SPEEDS



Green line represents the baseline wind speed without any turbines present. (No wind Interference)

Red line represents the wind speeds downstream from turbine A without wake steering efforts.

Yellow line represents the wind speeds downstream from turbine A with wake steering efforts.
There is a clear increase in wind speeds downstream from turbine A with wake steering.

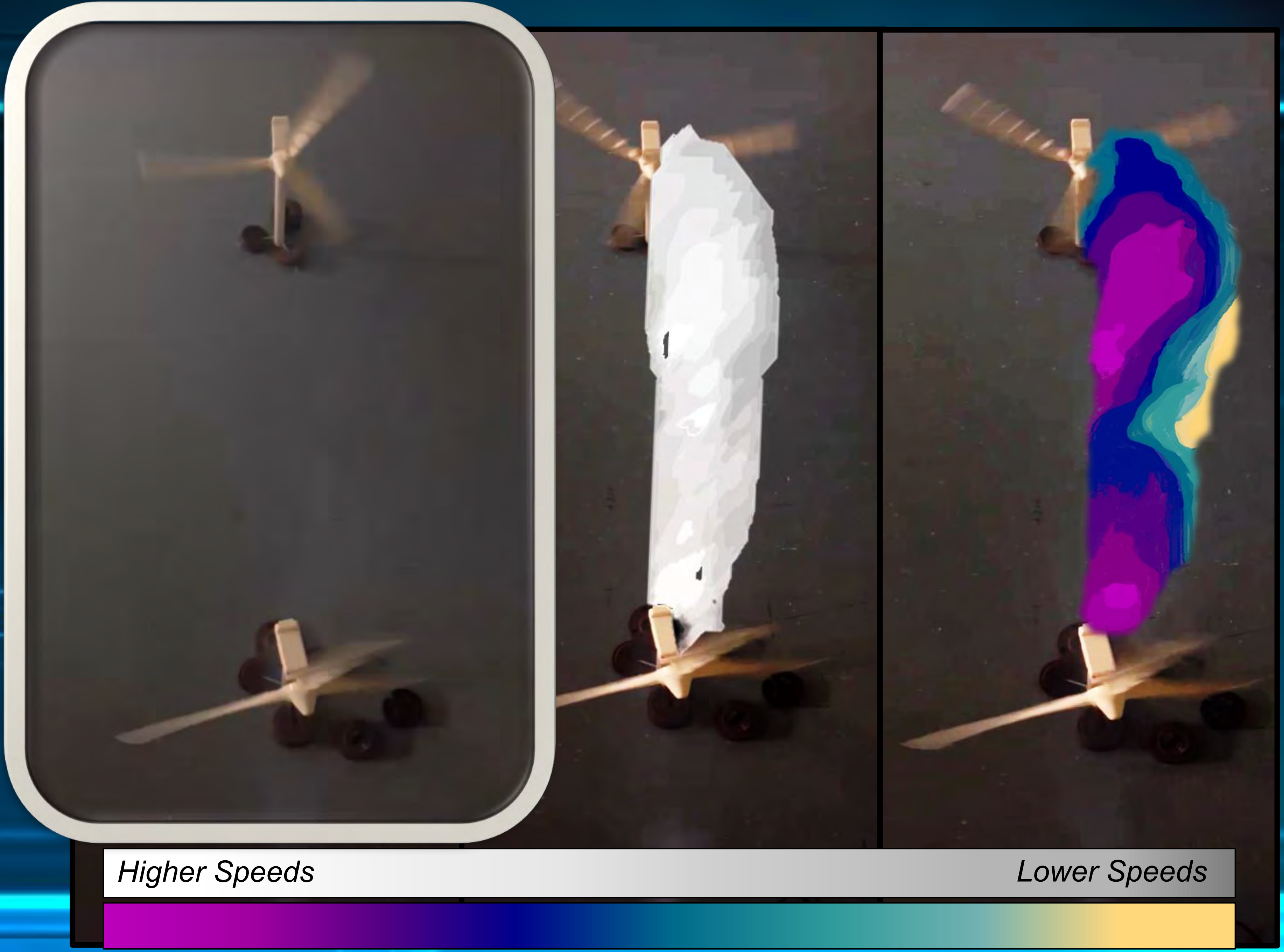


Voltage Data

		A --- B ---	A / B ---	Difference (%)
Turbine Layout:		A --- B ---	A / B ---	Difference (%)
Wake Steering:		No	Yes	
Location of Measurements (ft from X_0)	X_0	0.250	0.210	-16.00%
	1	0.217	0.230	5.99%
	2	0.210	0.215	2.38%
	3	0.205	0.225	9.76%
	4	0.195	0.220	12.82%
	5	0.195	0.225	15.38%
	6	0.190	0.230	21.05%
	7	0.205	0.235	14.63%
	8	0.200	0.232	16.00%
	9	0.188	0.220	17.02%
	10	0.188	0.215	14.36%
			Increase %:	5%

X_0 - includes Turbine A only. All other measurements are taken

Video Data



Curriculum Modules

- Observe wake steering effects on turbine models and analyze physics properties to optimize wind farm layouts, explaining how wind speed and generated energy vary by turbine location.

PB1: Physics in Wind Turbine Analysis

- Identify problems and apply solutions using proper tools and models.

B4B: AP Biology - Engineering Practices

A2B: Statistics - Analyzing Functions in Wind Turbine Data

- Identify and interpret relationships in wind speed and turbine output data, record and analyze data.

G10A: Geometry - Trigonometric Ratios in Right Triangles

- Use trigonometric ratios to calculate yaw offset angles, at which wind strikes turbines and analyze resulting wake effects.

Wake Steering: Conclusions and Results

Achieved:

- Optimized wind farm layout, increased power production.

Effective Strategy:

- Redirecting wakes with yaw angle adjustment.

Key Results :

- Higher power output for downstream turbines.
- Improved overall wind farm efficiency and economic potential.
- Enhanced design flexibility for land-constrained locations.

Validation:

- Success demonstrated in field trials and simulations.

FUTURE STUDIES

Determining the effects of wake steering on column C and column D.

Graphing the effects of wind steering on plant growth.

Investigating the long-term impacts of wake steering on turbine longevity and maintenance.

Exploring the economic implications of large-scale implementation of wake steering in wind farms.

ACKNOWLEDGEMENTS

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Questions?