2025

DAYLIGHTING PERFORMANCE AND ENERGY CONSUMPTION IN CLASSROOMS

TEACHER PARTICIPANTS

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FACULTY MENTORS

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INDUSTRIAL MENTOR

RALPH PITZER

STUDENT MENTOR

LOVEKESH SINGH

Scan to access full Research Project Material

Scan to access full Presentation

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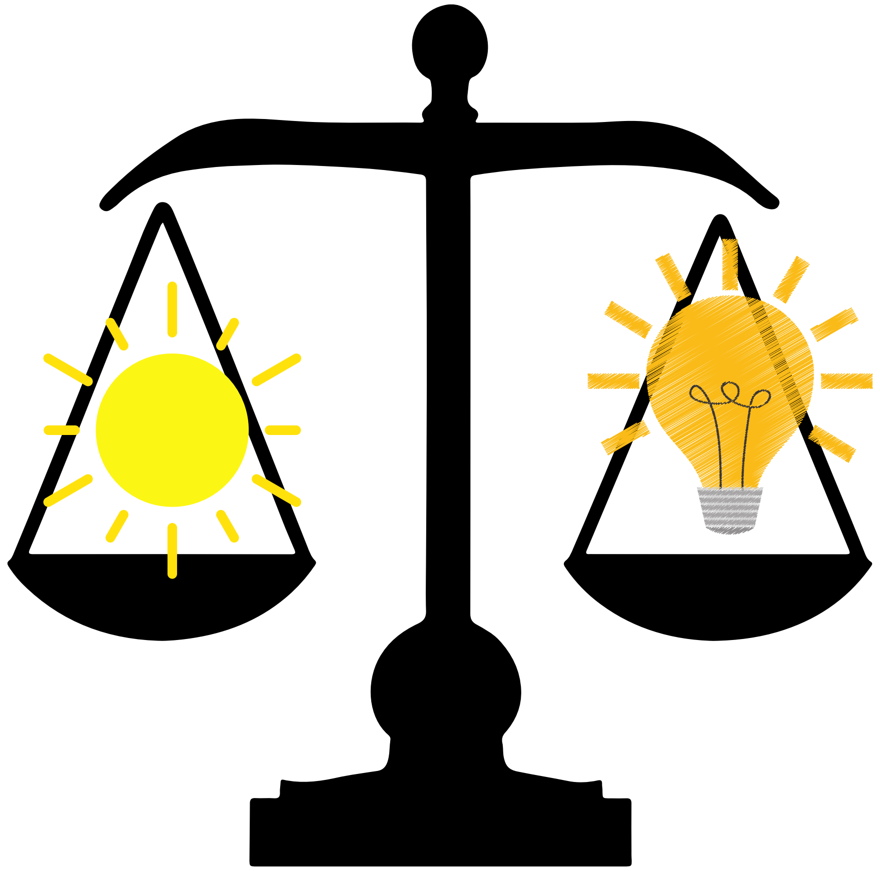
OUR OBJECTIVE

Find a balance between natural and artificial lighting within a classroom to conserve the most energy.



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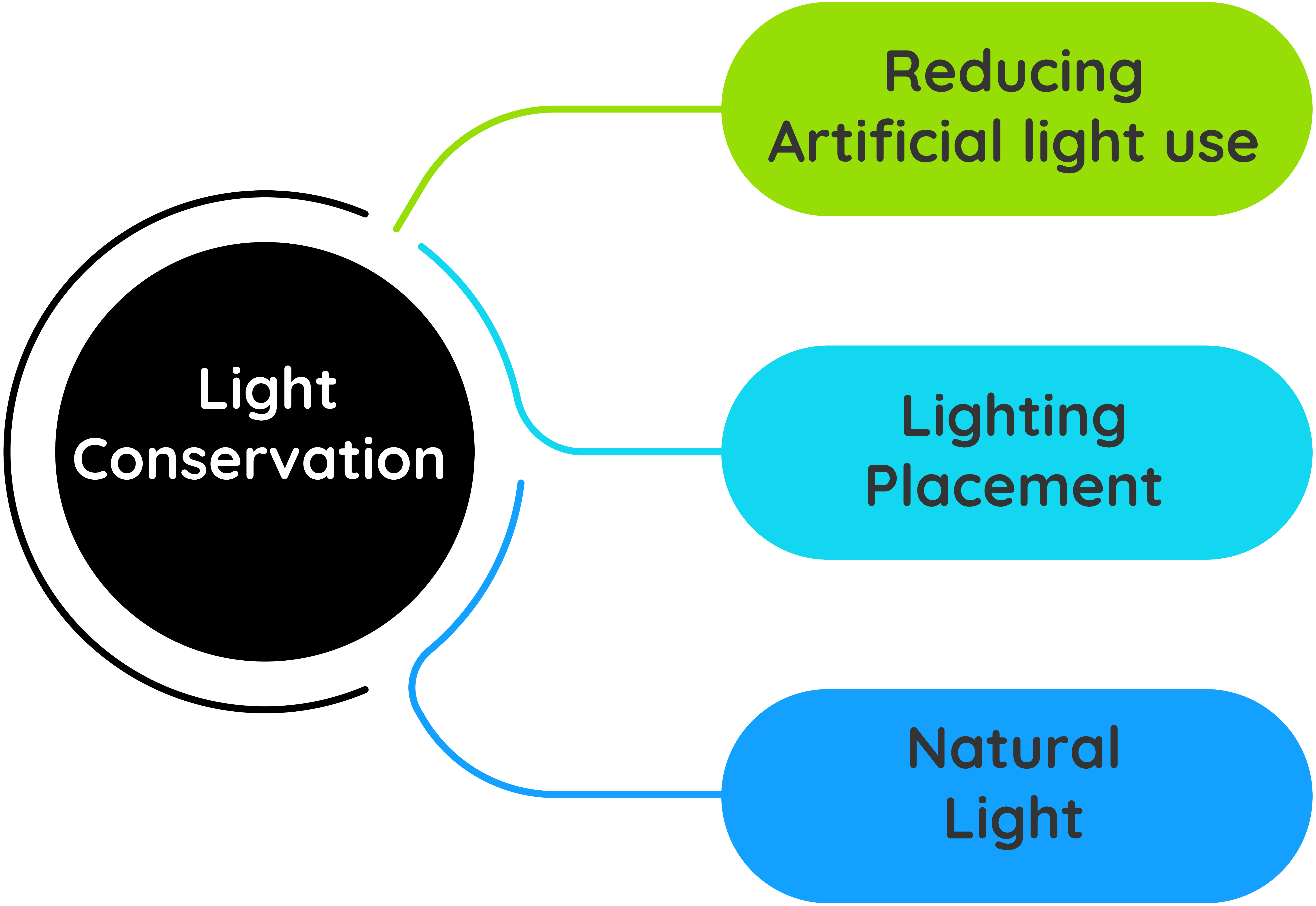
LIGHT

ARTIFICAL LIGHT

DAY LIGHTING


Light Conservation
Reducing Artificial light use
Lighting Placement
Natural Light

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HISTORY OF SCHOOL BUILDING DESIGN

Designed initiatlly to maximize light

MID-1960'S SHIFT

- Air Conditioning
- Promotion of Open Classrooms
- Cost saving construction

Daylight reconsidered:
- reduce energy cost
- Improve student performance and health

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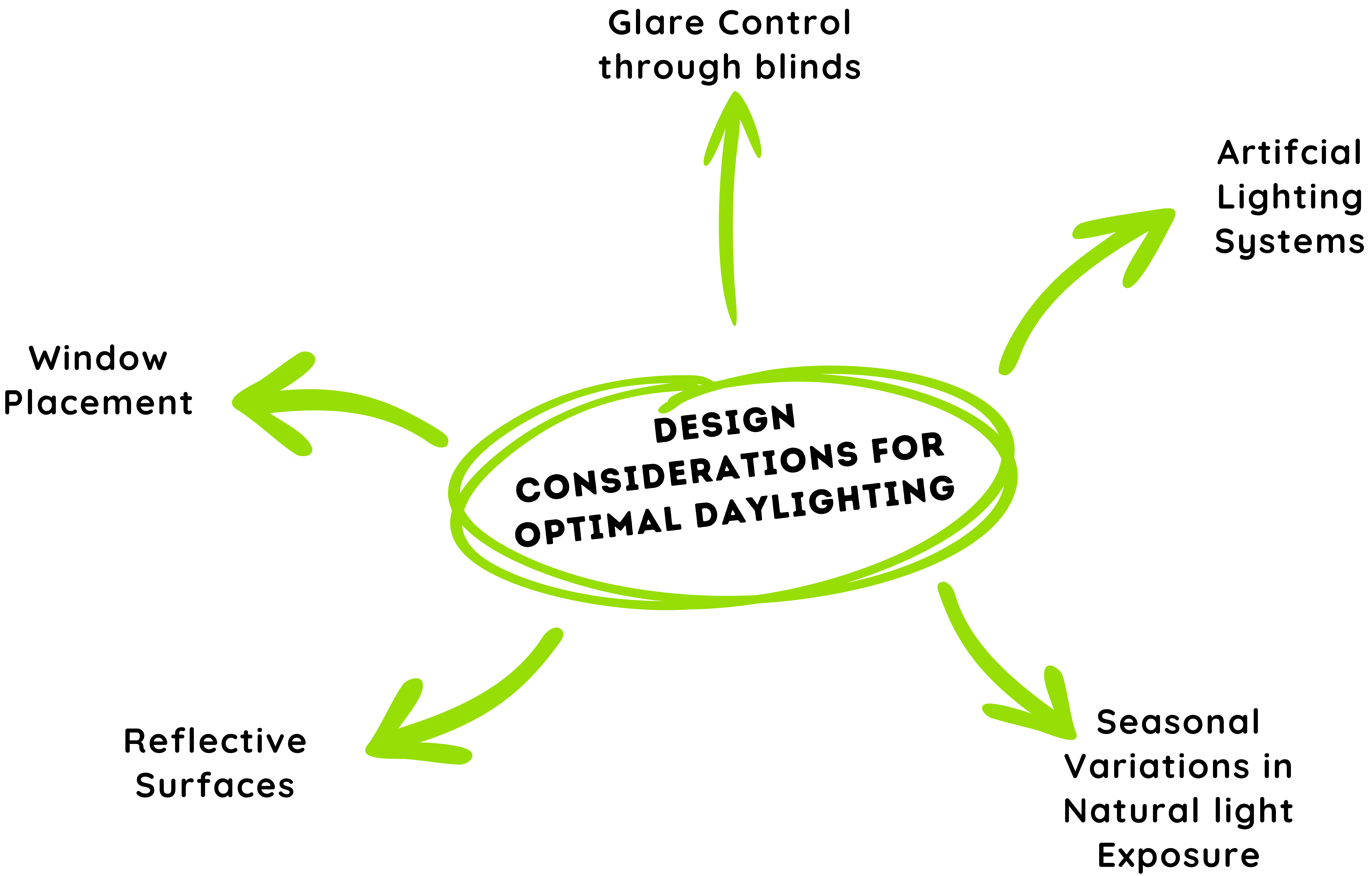
DESIGN CONSIDERATIONS FOR OPTIMAL DAYLIGHTING
Glare Control through blinds
Artifcial Lighting Systems
Window Placement
Reflective Surfaces
Seasonal Variations in Natural light Exposure

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IMPACTS OF ARTIFICIAL LIGHTING

BENEFITS OF DAYLIGHTING

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Experiment Overview

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- Find rooms to fit parameters of experiment. Rooms that are same in size and have windows facing different directions.
- Ensure weather is conducive to the needs of the experiment.
- Determine setup of light and solar sensors
- Set up measuring tools within the classroom to measure the light and solar within the room at different points within the day.
- Each room had 2 full business days (8am-4pm) of data collected.
- Repeat the process for remaining two rooms.

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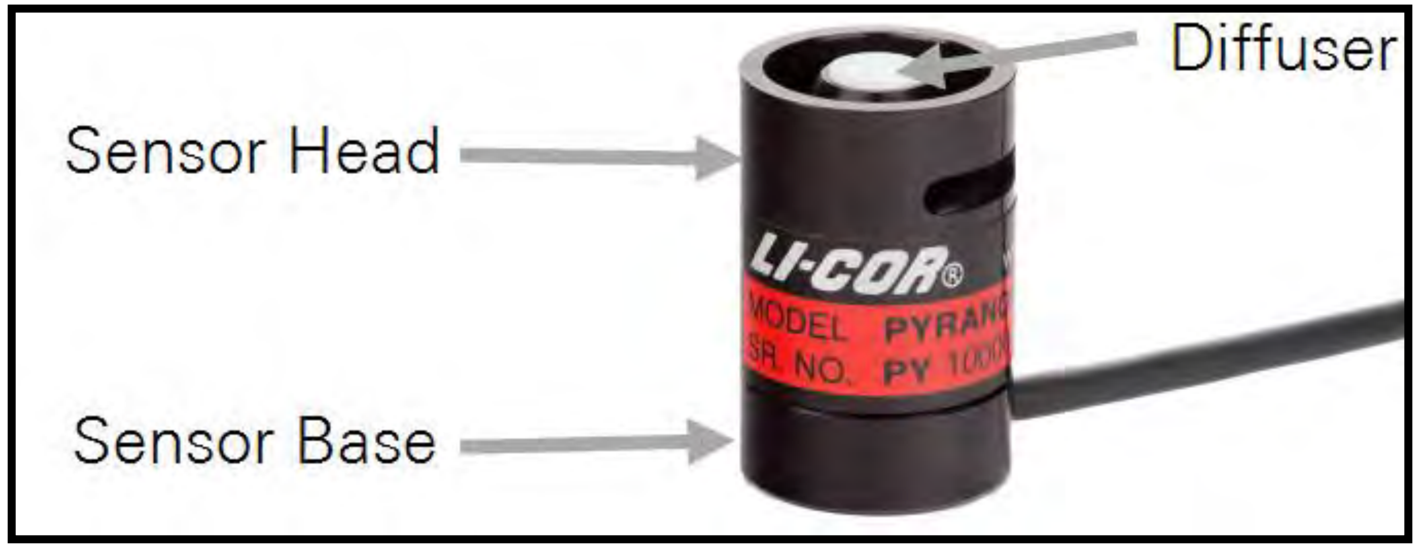
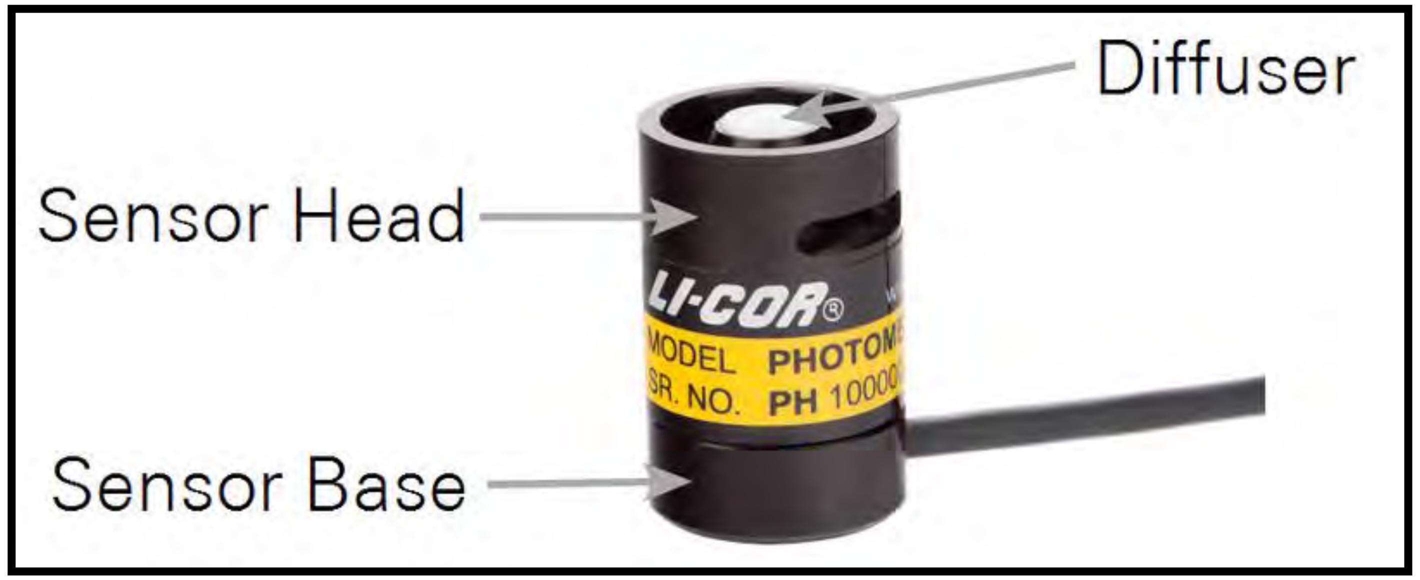
TOOLS

DATA LOGGER UX90-006
12 METER RANGE
HOBO DATA LOGGER
MEASUREMENTS ARE IN KLUX
REQUIRES:HOBOWARE SOFTWARE



PYRANOMETER-SOLAR
LI-200R
MEASURES GLOBAL SOLARE RADIATION
MEASURES ARE IN W/M^2



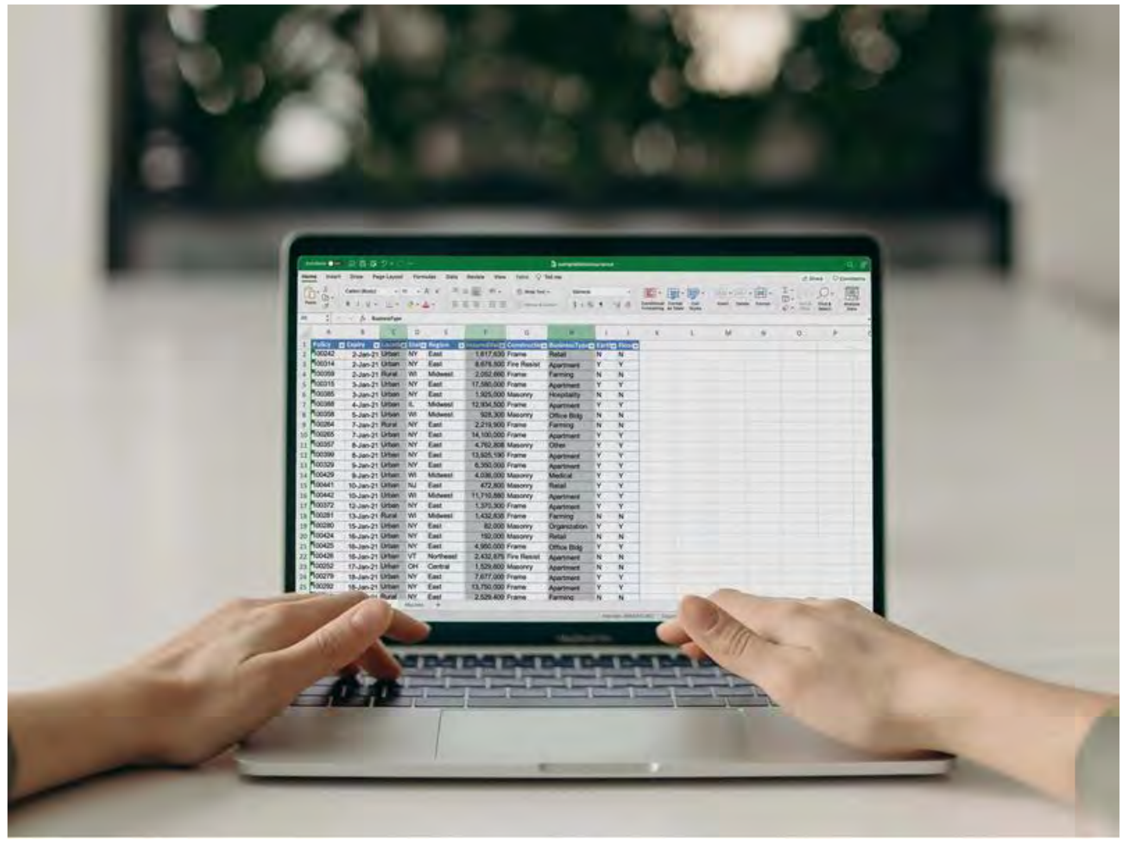
PYRANOMETER-LIGHT
LI-210R
MEASURES LIGHT
MEASUREMENTS ARE IN LUX OR KLUX

SOFTWARE

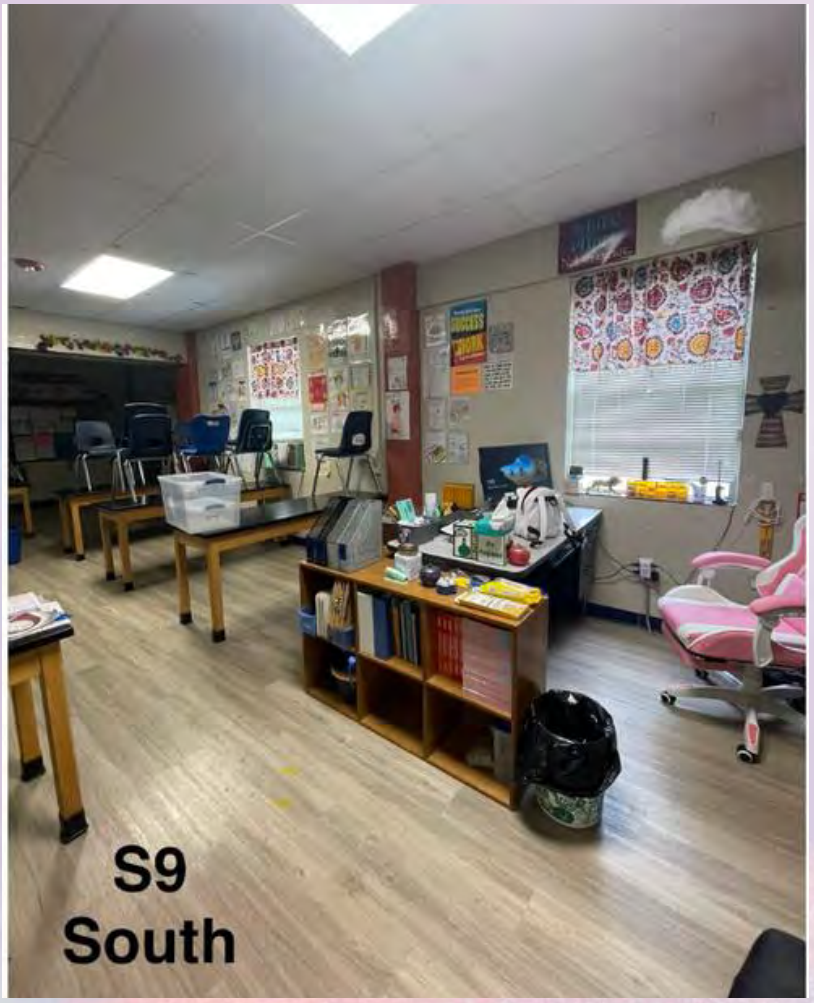
Both were used throughout the experiment

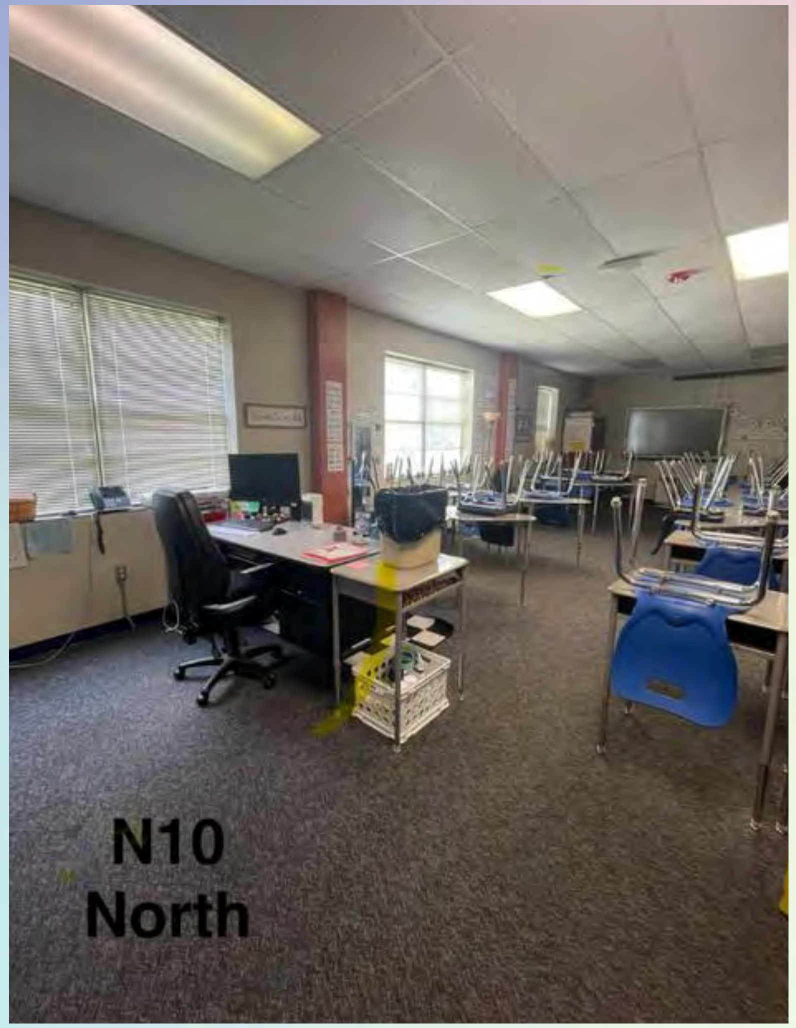
HOBOWARE

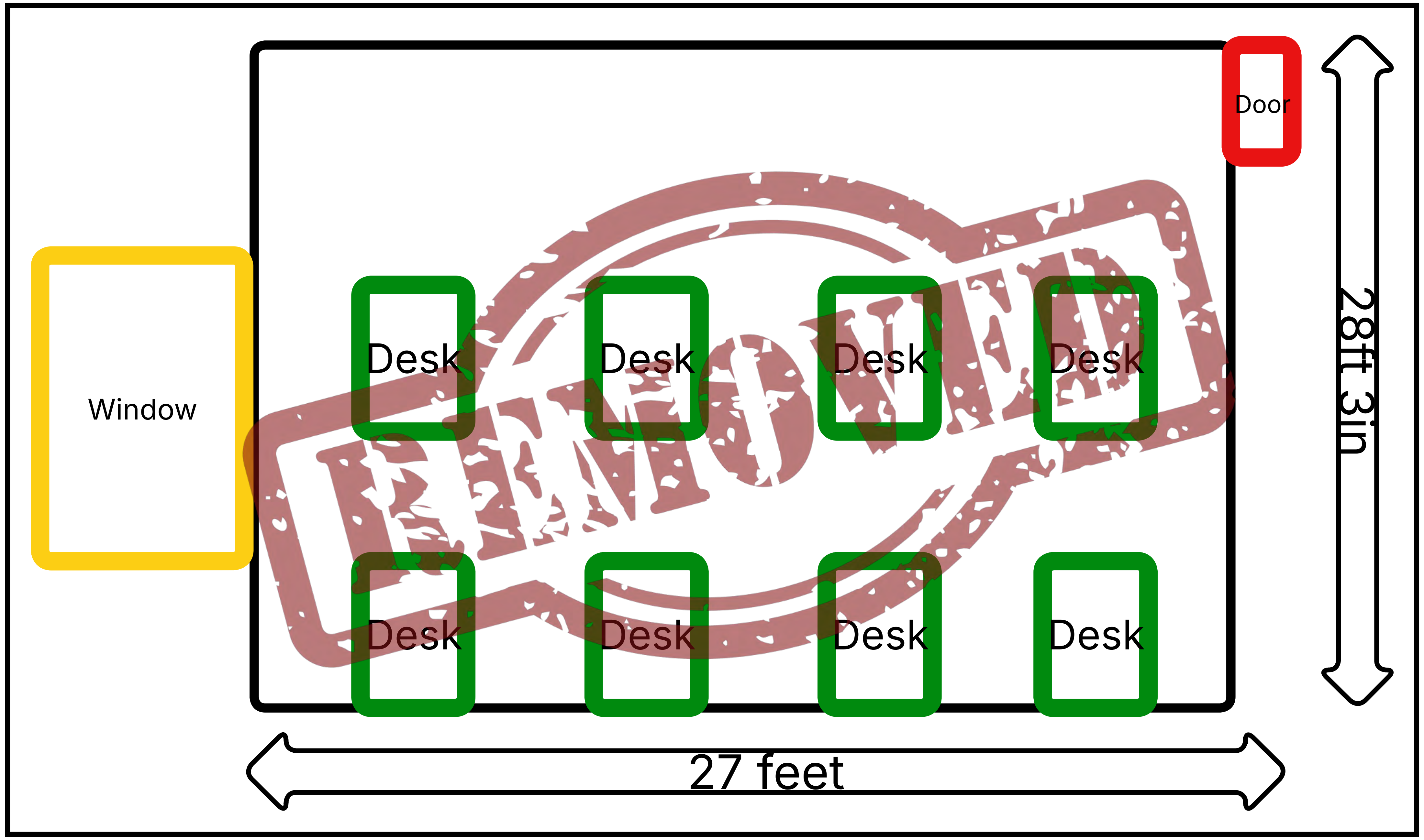
EXCEL



ROOMS USED TO COLLECT DATA: SANTA GERTRUDIS ACADEMY HIGH SCHOOL



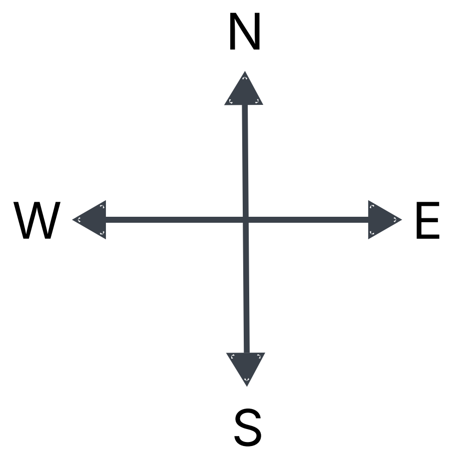




Room W1

<u>Window Dimensions</u>

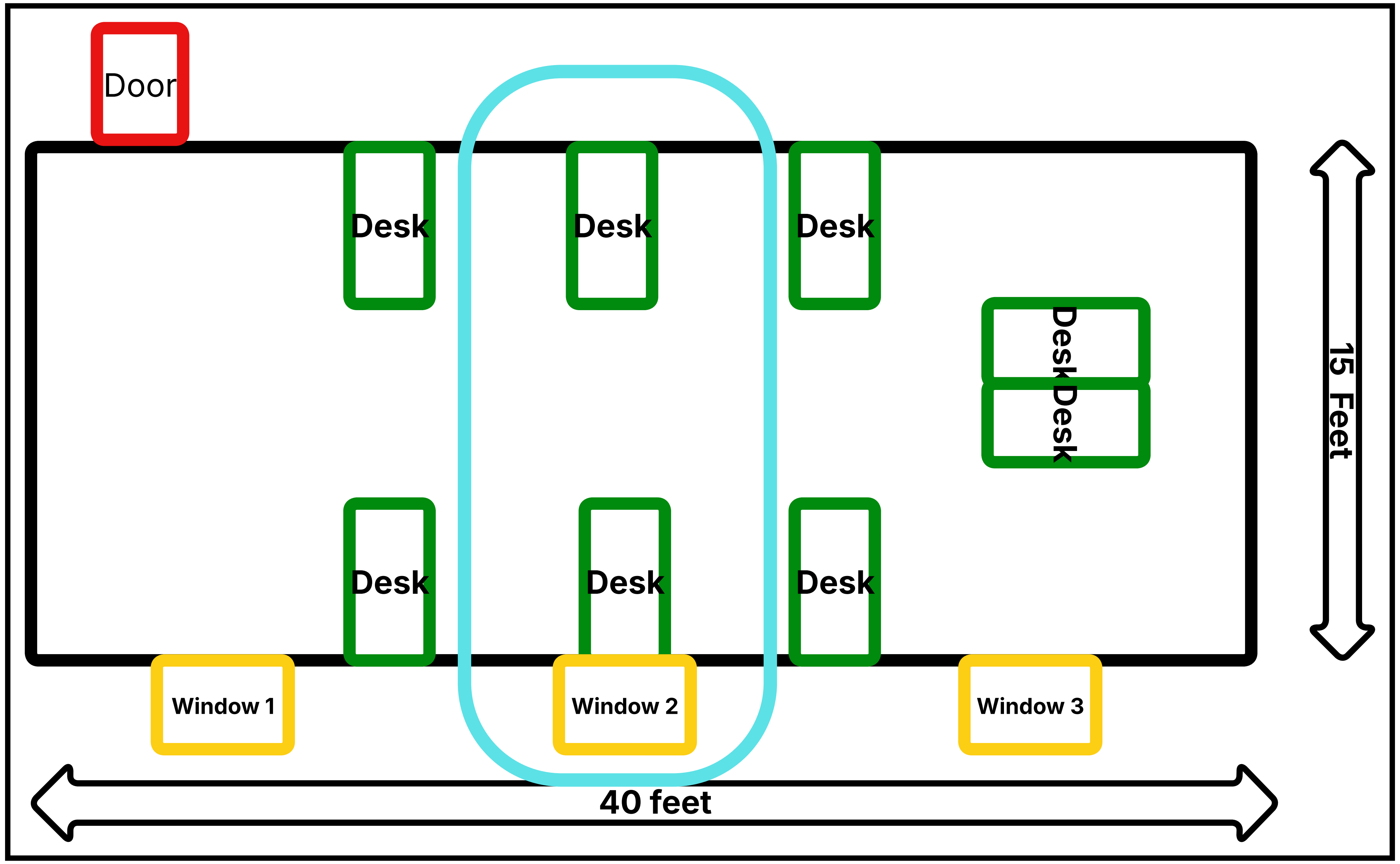
8ft X 11ft 5in



Reasoning:

Due to the size of the window being to different from the other classes inside, this one will not be included.

Sun rises in the east and sets in the west. Data will be similar to the west classroom.



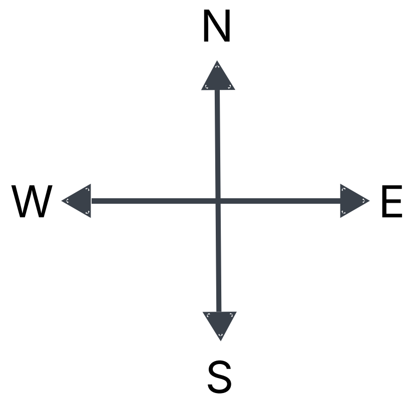
Room S9

Window Dimensions

Window 1: 5ft X 3ft

Window 2: 3ft 10in X 3ft 5in

Window 3: 3ft 10 in X 3ft 5 in



HOBO Data Logger 1

(1) PH54 = on window

(2) PH471= on window

(3) PH52 =3ft from window

(4) PH56 =6ft from window

HOBO Data Logger 2

(5) PH435 = 7.5ft from window

(6) PH53 =9ft from window

(7)PH55= 12ft from window

(8)PH469=15ft from window

FORMULAS USED:

Light Conversion

Klux=volts*multiplier/0.12*1000

2.5 volts

Depends on sensor

Solar Conversion

w/m^2=volts*multiplier/0.02

output data

Depends on sensor

Window to Wall Ratio (WWR) = $\frac{(39)(41)}{(110)(480)} = \frac{1599}{52800} = \frac{533}{17600}$

Window to Floor Ratio (WFR) = $\frac{(39)(41)}{(480)(180)} = \frac{1599}{86400} = \frac{9}{28800}$

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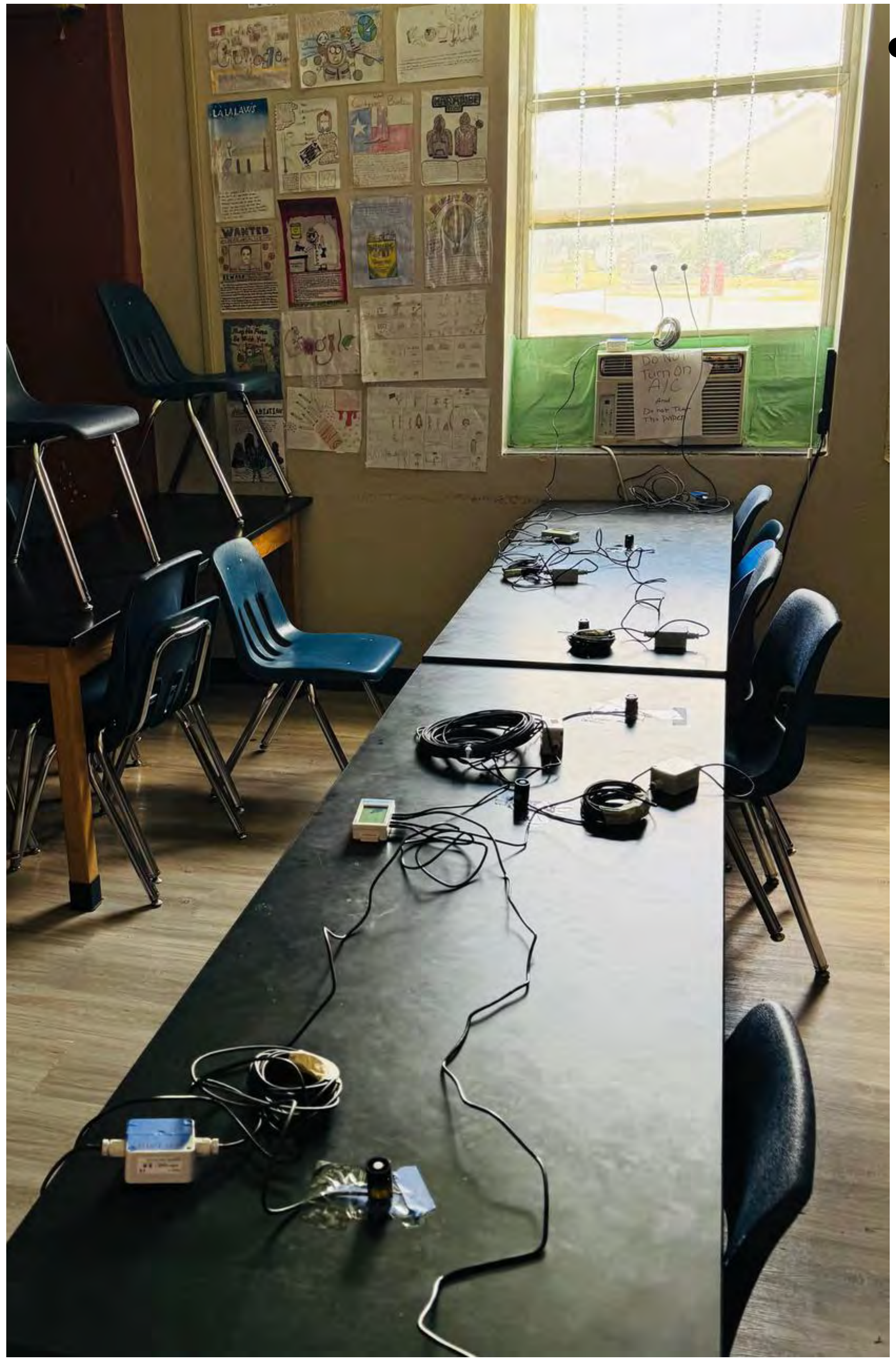
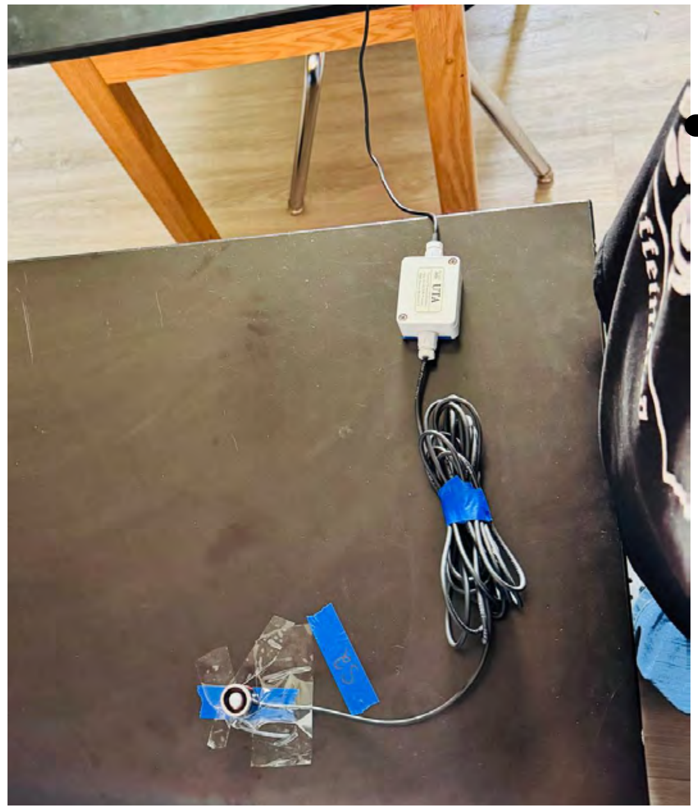
ROOM S9 (SOUTH FACING)

A solar and light senosr attached directly to the window.



A light sensor is placed 3ft, 6ft and 9ft from the window.



The last sensor, solar, 15 ft away from the window, first one is 7.5ft away.

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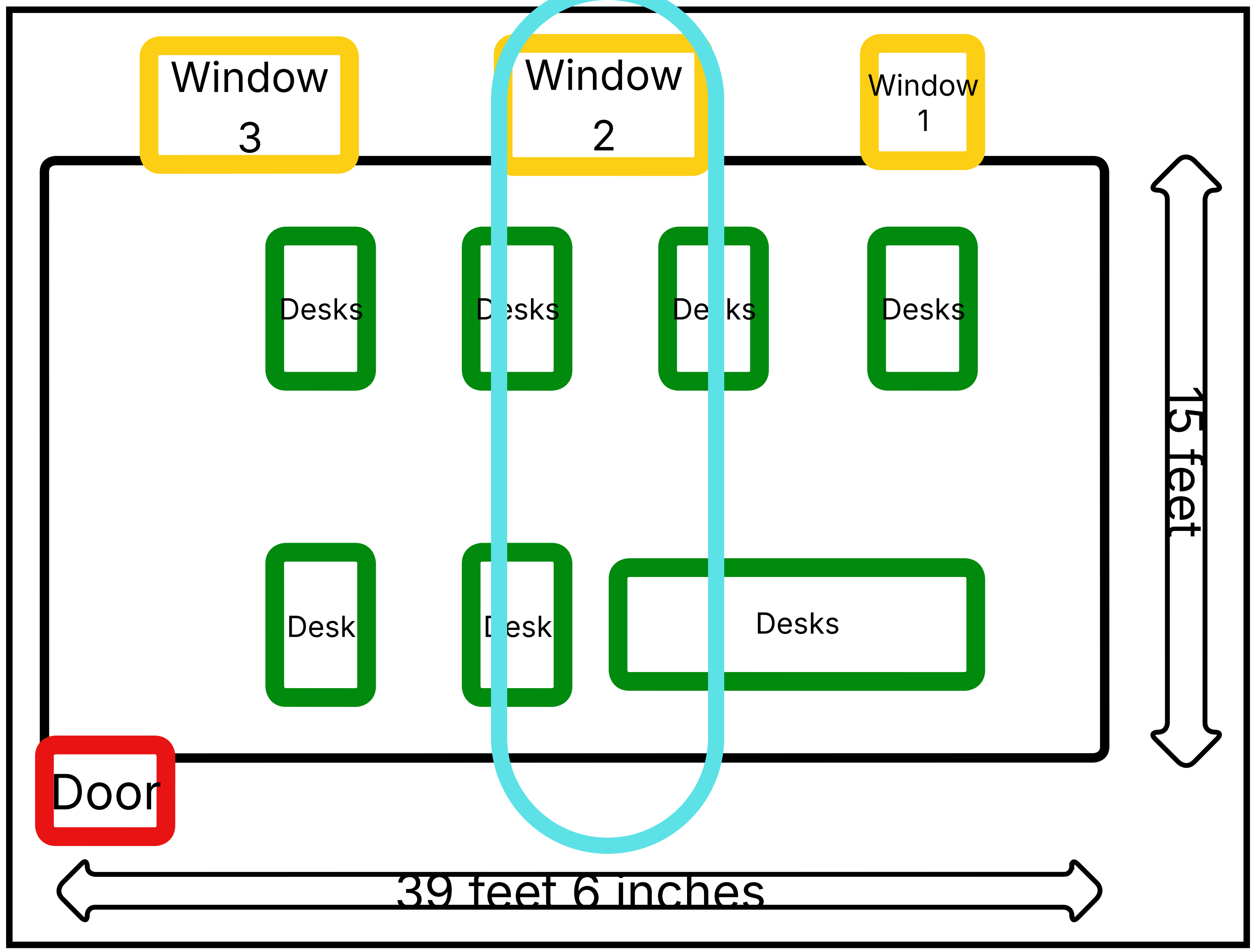

HOBO Data Logger 1

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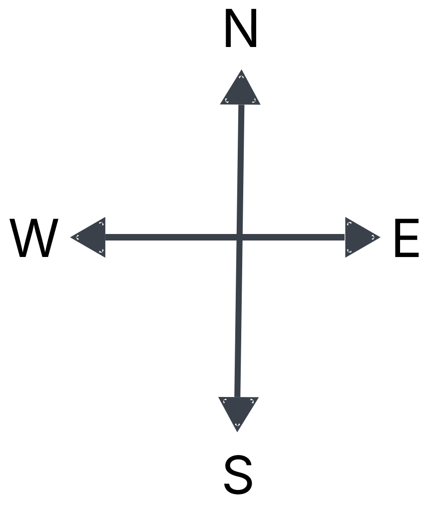
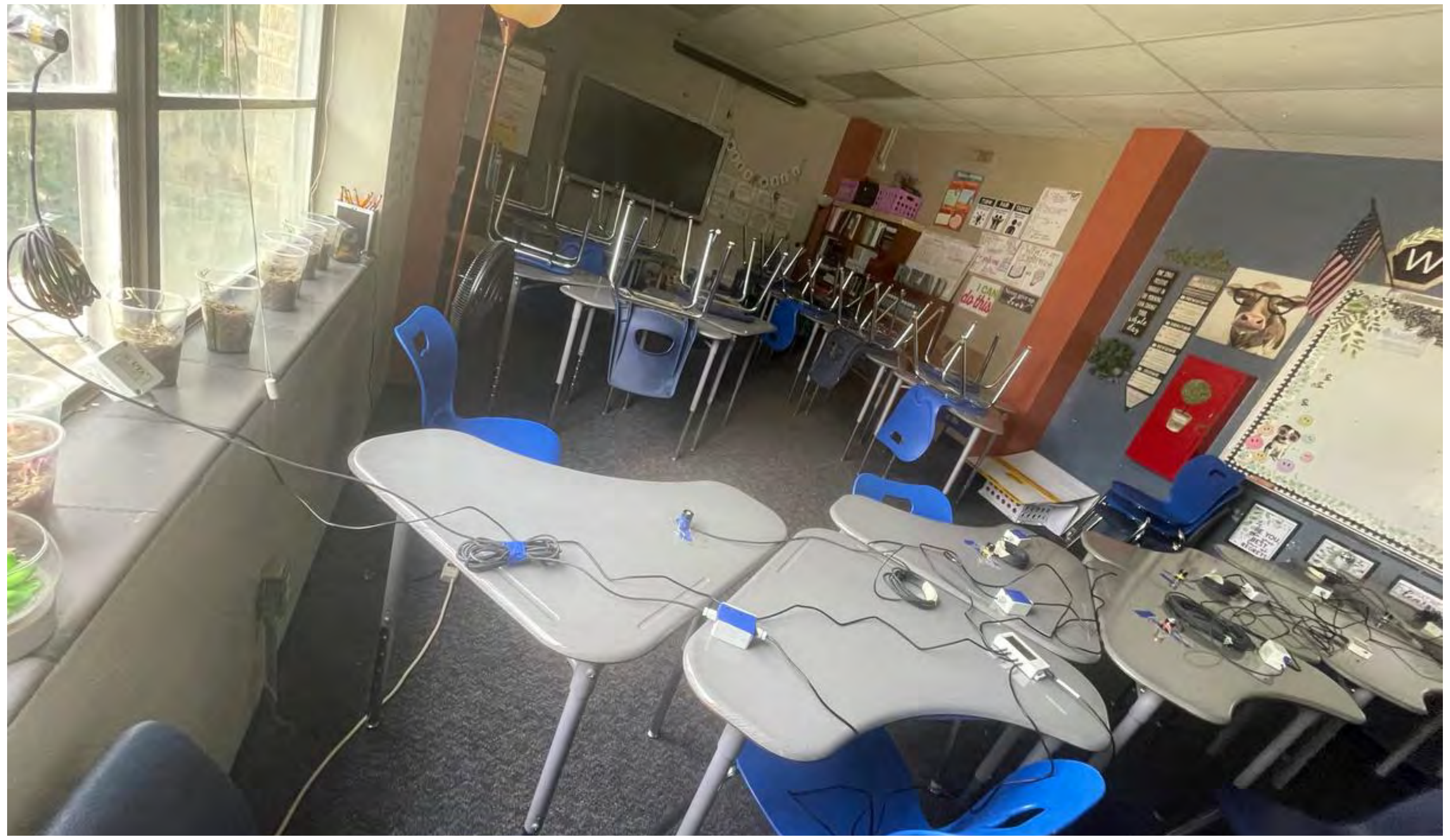


N10

Window Dimensons

Window 1: 5ft X 3ft 5in
Window 2: 5ft X 6ft 9in
Window 3: 5ft X 6ft 9in



FORMULAS USED:

Light Conversion

Klux=volts*multiplier/0.12*1000

2.5 volts

Depends on sensor

Solar Conversion

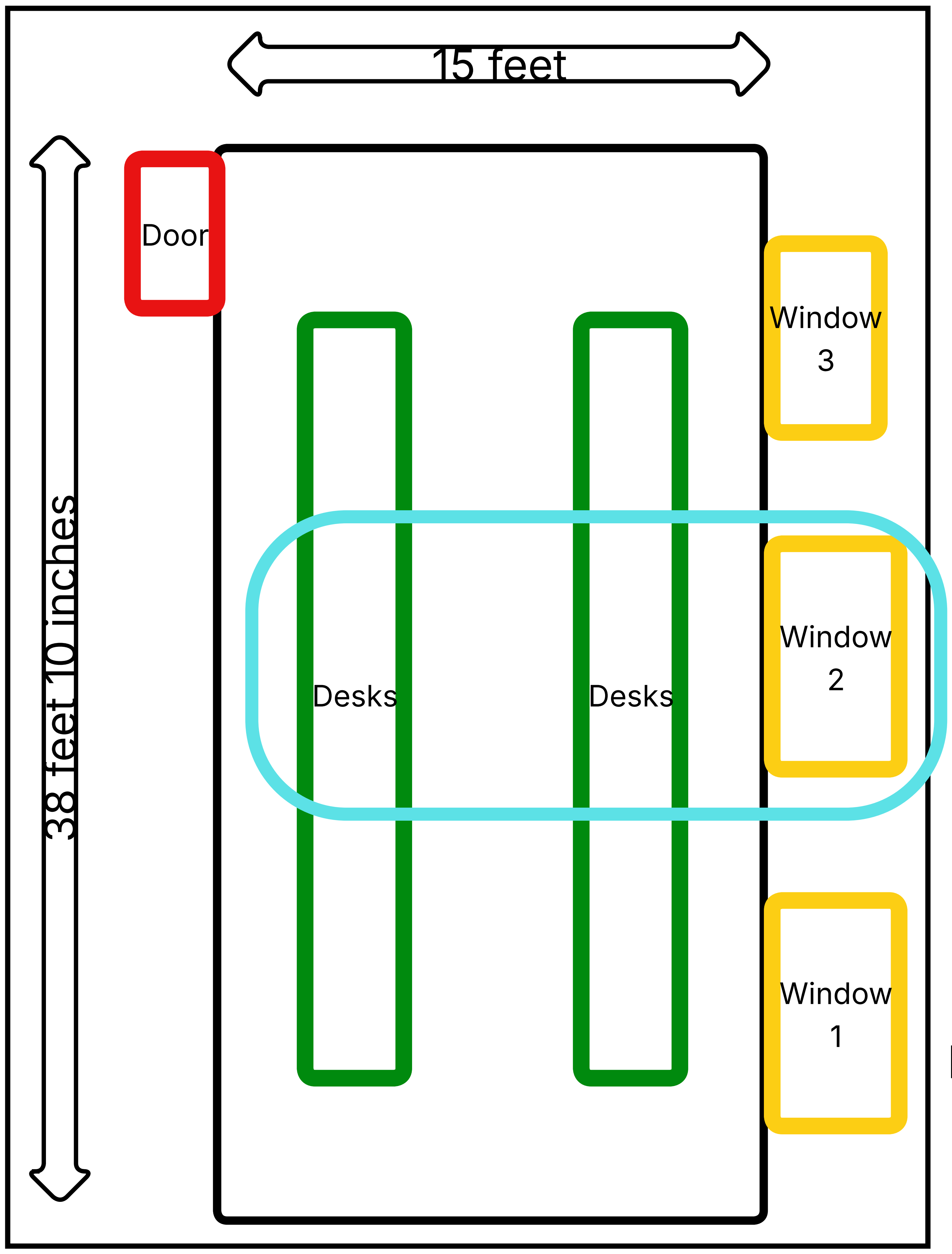
w/m^2=volts*multiplier/0.02

output data

Depends on sensor

Window to Wall Ratio (WWR) $= \frac{(60)(81)}{(110)(474)} = \frac{4860}{52140} = \frac{81}{869}$

Window to Floor Ratio (WFR) $= \frac{(60)(81)}{(474)(180)} = \frac{4860}{85320} = \frac{9}{151}$



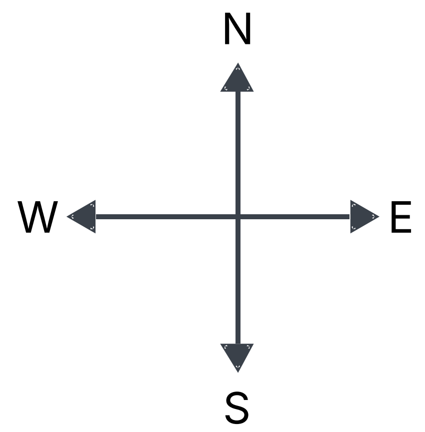
Room E2

<u>Window Dimensions</u>

Window 1: 5ft X 3ft 5in

Window 2: 5ft X 3ft 5in

Window 3: 3ft 10 in X 3ft 5in



HOBO Data Logger 1

(1) PH54 = on window

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HOBO Data Logger 2

(5) PH435 = 7.5ft from window

(6) PH53 =9ft from window

(7)PH55= 12ft from window

(8)PH469=15ft from window

Window to Wall Ratio (WWR) $= \frac{(60)(41)}{(110)(466)} = \frac{2460}{51260} = \frac{123}{2563}$

Window to Floor Ratio (WFR) $= \frac{(60)(41)}{(466)(180)} = \frac{2460}{83880} = \frac{41}{1398}$

FORMULAS USED:

Light Conversion

Klux=volts*multiplier/0.12*1000

2.5 volts

Depends on sensor

Solar Conversion

w/m^2=volts*multiplier/0.02

output data

Depends on sensor

2025

MEASURED DATA Raw Data collected

#	Date Time, GMT-05:00	Date Time, GMT-05:00	Hour	Business hours	L1 (window) (volts)	L2 (3 feet) (volts)	L3 (6 feet) (volts)	L1 (window) (Lux) m=3.66, g=0.06	L2 (3ft) (Lux) m=3.77 g=0.12	L3 (6ft) (Lux) m=3.64 g=0.6	DA (500lux) (Window)	DA (500lux) (3ft)	DA (500lux) (6ft)	UDI 100-500 (Window)	UDI 500-1000 (window)	UDI 1000-2000 (window)	Illuminance Needed from artifical lights (window)	Illuminance Needed from artifical lights (3 ft)	Illuminance Needed from artifical lights (6 ft)
1	6/27/2025	2:15 PM	14	1	0.18387	0.02121	0.00626	11216.07	666.3475	189.8866667	1	1	0	0	0	0	0	0	310.1133333
2	6/27/2025	2:20 PM	14	1	0.17868	0.02125	0.00614	10899.48	667.6041667	186.2466667	1	1	0	0	0	0	0	0	313.7533333
3	6/27/2025	2:25 PM	14	1	0.17941	0.02045	0.00614	10944.01	642.4708333	186.2466667	1	1	0	0	0	0	0	0	313.7533333
4	6/27/2025	2:30 PM	14	1	0.18074	0.0206	0.0061	11025.14	647.1833333	185.0333333	1	1	0	0	0	0	0	0	314.9666667
5	6/27/2025	2:35 PM	14	1	0.18116	0.02079	0.01129	11050.76	653.1525	342.4633333	1	1	0	0	0	0	0	0	157.5366667
6	6/27/2025	2:40 PM	14	1	0.18437	0.02098	0.01144	11246.57	659.1216667	347.0133333	1	1	0	0	0	0	0	0	152.9866667
7	6/27/2025	2:45 PM	14	1	0.17823	0.02018	0.01076	10872.03	633.9883333	326.3866667	1	1	0	0	0	0	0	0	173.6133333
8	6/27/2025	2:50 PM	14	1	0.17342	0.01957	0.0103	10578.62	614.8241667	312.4333333	1	1	0	0	0	0	0	0	187.5666667
9	6/27/2025	2:55 PM	14	1	0.16869	0.01961	0.01022	10290.09	616.0808333	310.0066667	1	1	0	0	0	0	0	0	189.9933333
10	6/27/2025	3:00 PM	15	1	0.16911	0.01999	0.00965	10315.71	628.0191667	292.7166667	1	1	0	0	0	0	0	0	207.2833333
11	6/27/2025	3:05 PM	15	1	0.16655	0.02689	0.01286	10159.55	844.7941667	390.0866667	1	1	0	0	0	0	0	0	109.9133333
12	6/27/2025	3:10 PM	15	1	0.14817	0.01755	0.00912	9038.37	551.3625	276.64	1	1	0	0	0	0	0	0	223.36
13	6/27/2025	3:15 PM	15	1	0.14782	0.01717	0.00919	9017.02	539.4241667	278.7633333	1	1	0	0	0	0	0	0	221.2366667
14	6/27/2025	3:20 PM	15	1	0.15507	0.01694	0.00935	9459.27	532.1983333	283.6166667	1	1	0	0	0	0	0	0	216.3833333
15	6/27/2025	3:25 PM	15	1	0.1519	0.01728	0.00965	9265.9	542.88	292.7166667	1	1	0	0	0	0	0	0	207.2833333
16	6/27/2025	3:30 PM	15	1	0.14794	0.01667	0.00961	9024.34	523.7158333	291.5033333	1	1	0	0	0	0	0	0	208.4966667
17	6/27/2025	3:35 PM	15	1	0.1397	0.01663	0.00958	8521.7	522.4591667	290.5933333	1	1	0	0	0	0	0	0	209.4066667
18	6/27/2025	3:40 PM	15	1	0.13169	0.0164	0.0095	8033.09	515.2333333	288.1666667	1	1	0	0	0	0	0	0	211.8333333
19	6/27/2025	3:45 PM	15	1	0.12539	0.01663	0.00954	7648.79	522.4591667	289.38	1	1	0	0	0	0	0	0	210.62
20	6/27/2025	3:50 PM	15	1	0.1199	0.01709	0.00961	7313.9	536.9108333	291.5033333	1	1	0	0	0	0	0	0	208.4966667
21	6/27/2025	3:55 PM	15	1	0.11574	0.01801	0.00988	7060.14	565.8141667	299.6933333	1	1	0	0	0	0	0	0	200.3066667
22	6/27/2025	4:00 PM	16	0	0.10639	0.01732	0.00904	6489.79	544.1366667	274.2133333	1	1	0	0	0	0	0	0	225.7866667
23	6/27/2025	4:05 PM	16	0	0.11761	0.01904	0.00973	7174.21	598.1733333	295.1433333	1	1	0	0	0	0	0	0	204.8566667
24	6/27/2025	4:10 PM	16	0	0.13306	0.02529	0.01308	8116.66	794.5275	396.76	1	1	0	0	0	0	0	0	103.24
25	6/27/2025	4:15 PM	16	0	0.14199	0.02831	0.01156	8661.39	889.4058333	350.6533333	1	1	0	0	0	0	0	0	149.3466667
26	6/27/2025	4:20 PM	16	0	0.12871	0.02266	0.01122	7851.31	711.9016667	340.34	1	1	0	0	0	0	0	0	159.66
27	6/27/2025	4:25 PM	16	0	0.14164	0.02586	0.00984	8640.04	812.435	298.48	1	1	0	0	0	0	0	0	201.52
28	6/27/2025	4:30 PM	16	0	0.11784	0.02667	0.00816	7188.24	837.8825	247.52	1	1	0	0	0	0	0	0	252.48
29	6/27/2025	4:35 PM	16	0	0.14473	0.02663	0.01194	8828.53	836.6258333	362.18	1	1	0	0	0	0	0	0	137.82
30	6/27/2025	4:40 PM	16	0	0.13455	0.02136	0.01026	8207.55	671.06	311.22	1	1	0	0	0	0	0	0	188.78
31	6/27/2025	4:45 PM	16	0	0.11769	0.02918	0.01057	7179.09	916.7383333	320.6233333	1	1	0	0	0	0	0	0	179.3766667

Output Data

Converted Output

DA

UDI

Illuminanc

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Converted Output

Light Data

Multiplier is unique to each sensor.

Dividend unique to each sensor.

=F3*multiplier/0.6*1000

L4 (9 ft) (volts)	L5 (12 ft) (volts)	L4 (9 ft)(Lux) m=3.83 g=0.6	L5 (12 ft) (Lux) m=4.05 g=3.6
0.15976	0.74941	1019.801333	843.08625
0.04135	0.13439	263.9508333	151.18875
0.04303	0.14	274.6748333	157.5
0.04181	0.13344	266.8871667	150.12
0.04253	0.13485	271.4831667	151.70625

Solar Data

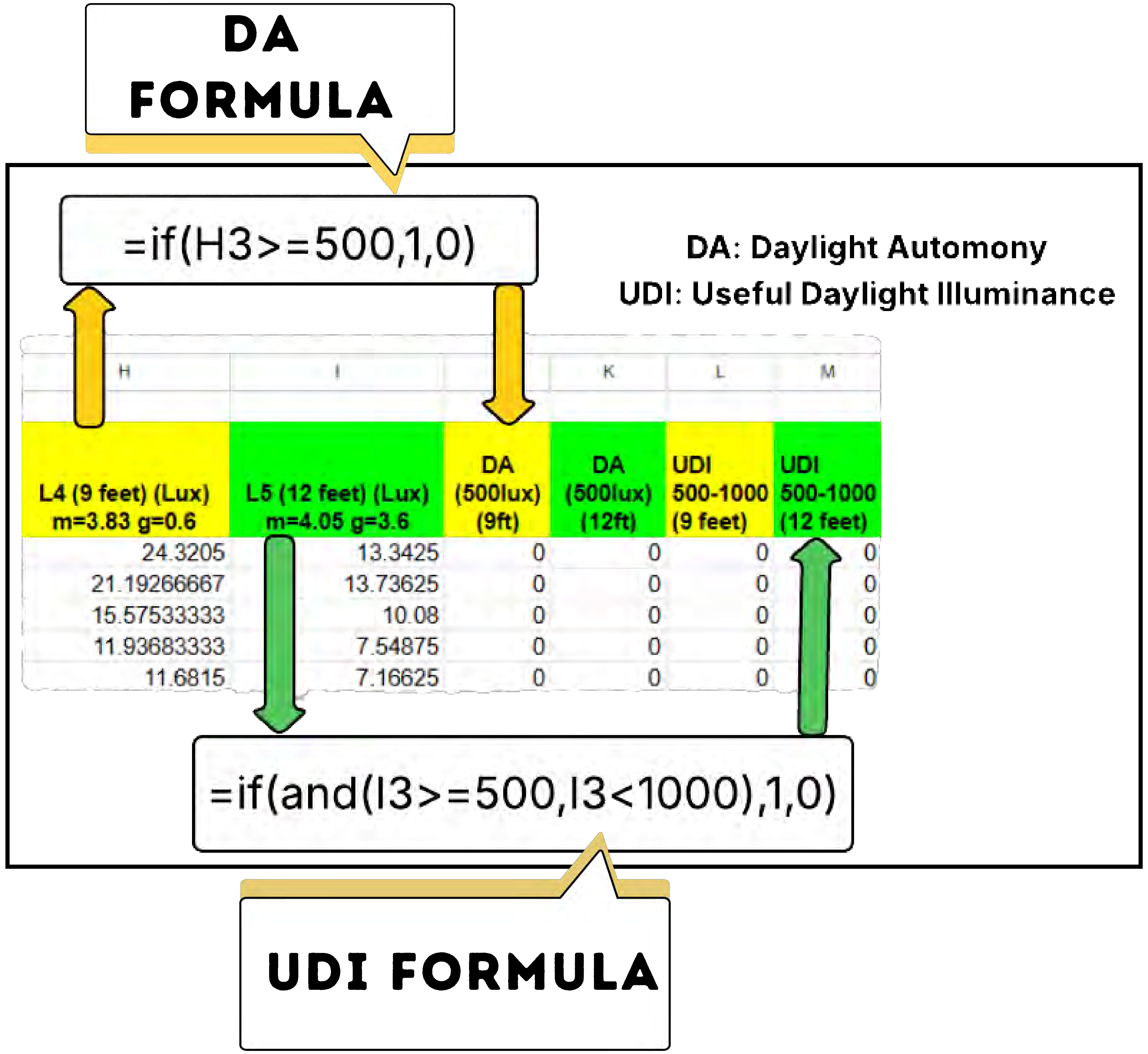
W/m² = (Volts)(Multiplier) /0.02

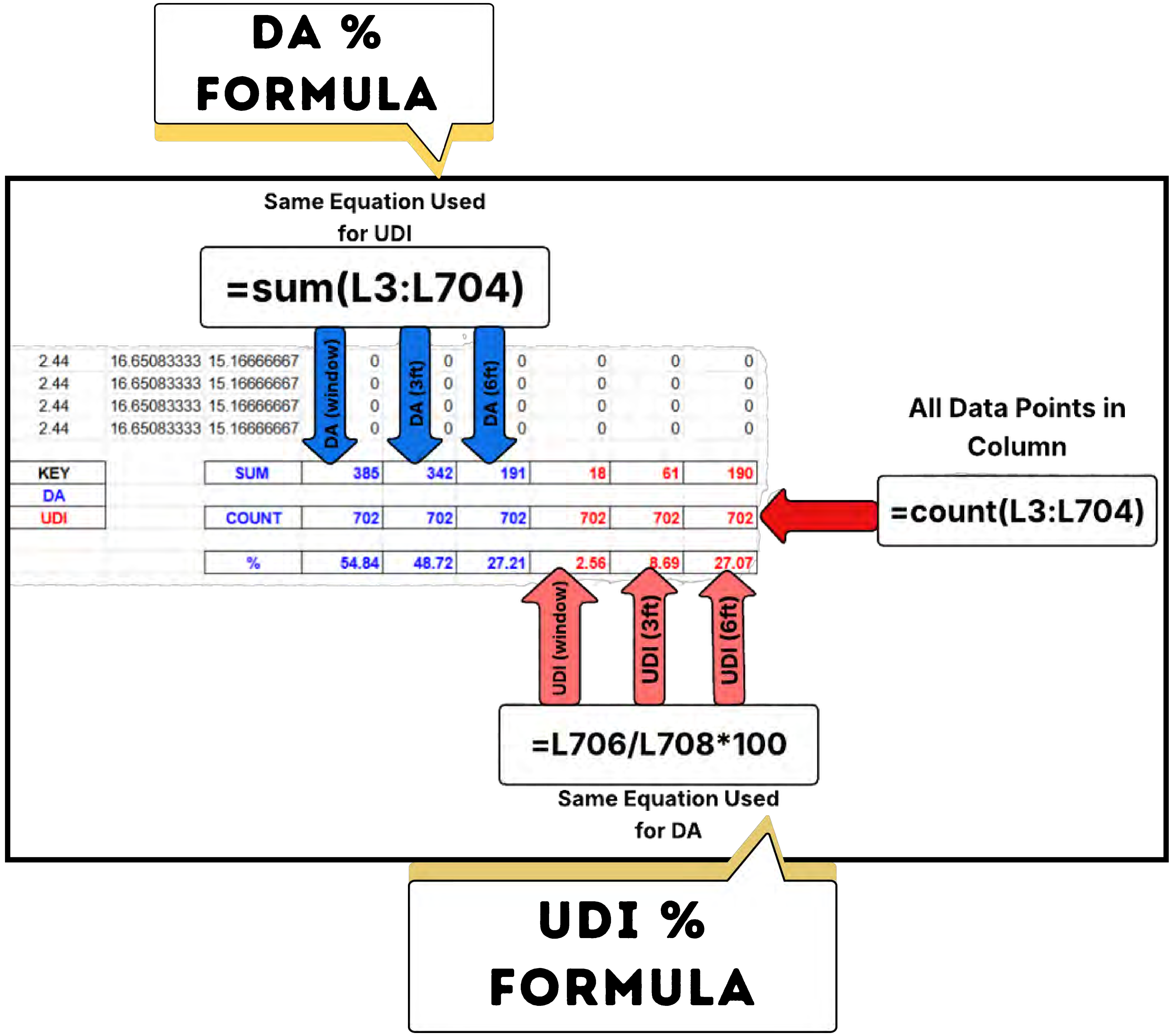
S2 Mulitplier: 13.88
S3 Multiplier: 14.76

Plot Title: N10		Time						
#	Date	Time	Hour	Business Hour	S2 (7.5 ft) (volts)	S3 (15 ft) (volts)	S2 (7.5ft) (W/m2)	S3 (15ft) (W/m2)
1	7/4/2025	1:26:56 PM	13	1	0.00633	0.00526	4.39302	3.88188
4	7/4/2025	1:31:56 PM	13	1	0.00996	0.00404	6.91224	2.98152
5	7/4/2025	1:36:56 PM	13	1	0.01041	0.0042	7.22454	3.0996
6	7/4/2025	1:41:56 PM	13	1	0.00977	0.00393	6.78038	2.90034
7	7/4/2025	1:46:56 PM	13	1	0.00984	0.00393	6.82896	2.90034

DA → **Daylight Autonomy:** How often the daylight lux can maintain a lux of 500 which is a comfortable working environment.

UDI → **Useful Daylight Illuminance:** How much Illuminance is given that can be utilized in place of artificial lighting.





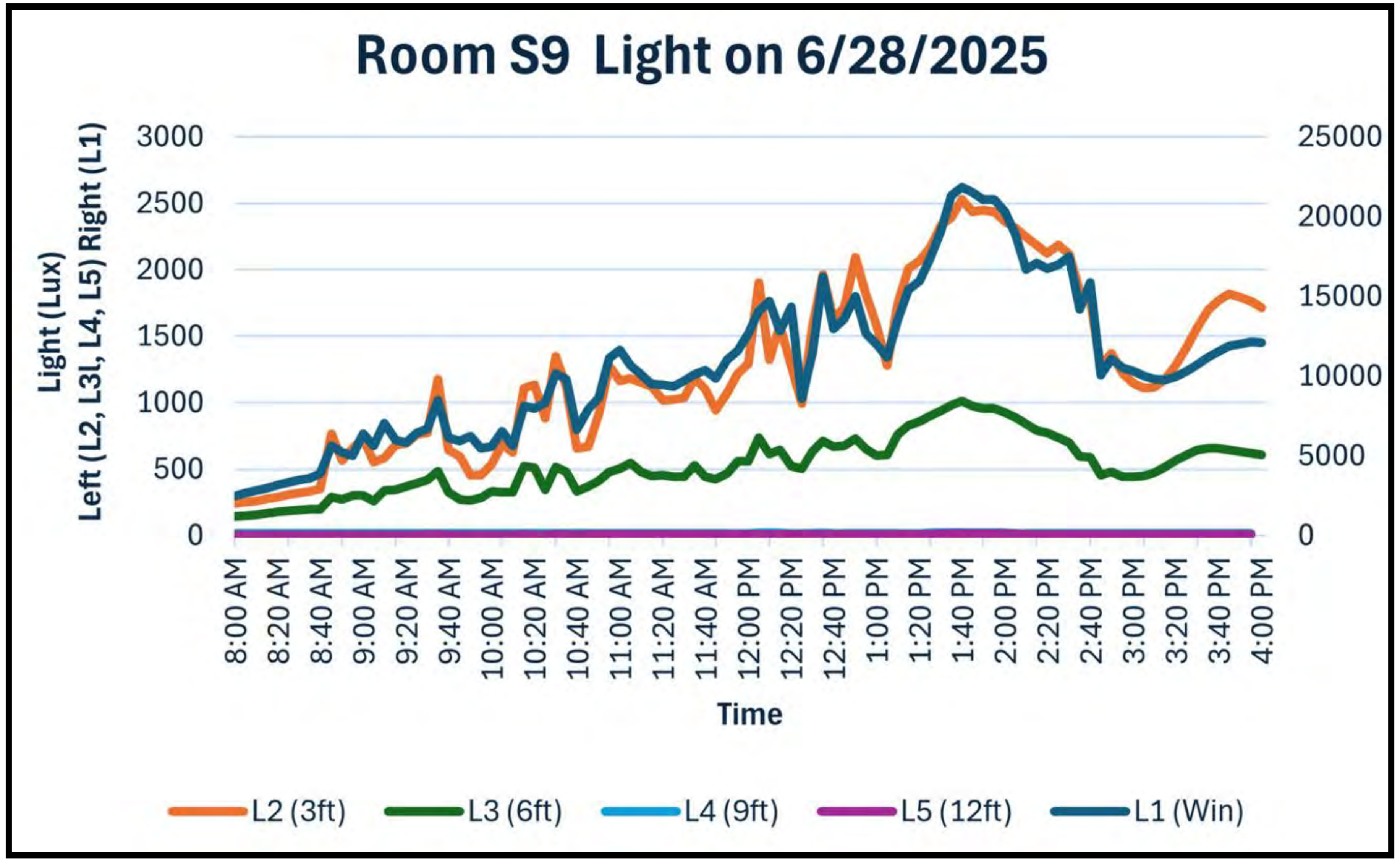
Calculate the Illuminance Needed from Artificial Lighting

=if(H3<500,500-H3,0)

H	I	J	K	L	M	N	O
L4 (9 feet) (Lux) m=3.83 g=0.6	L5 (12 feet) (Lux) m=4.05 g=3.6	DA (500lux) (9ft)	DA (500lux) (12ft)	UDI 500-1000 (9 feet)	UDI 500-1000 (12 feet)	Illuminance Needed from artifical lights (9 feet)	Illuminance Needed from artifical lights (12 feet)
24.3205	13.3425	0	0	0	0	475.6795	486.6575
21.19266667	13.73625	0	0	0	0	478.8073333	486.26375
15.57533333	10.08	0	0	0	0	484.4246667	489.92
11.93683333	7.54875	0	0	0	0	488.0631667	492.45125

Illuminance

MEASURED DATA-SOUTH FACING ROOM



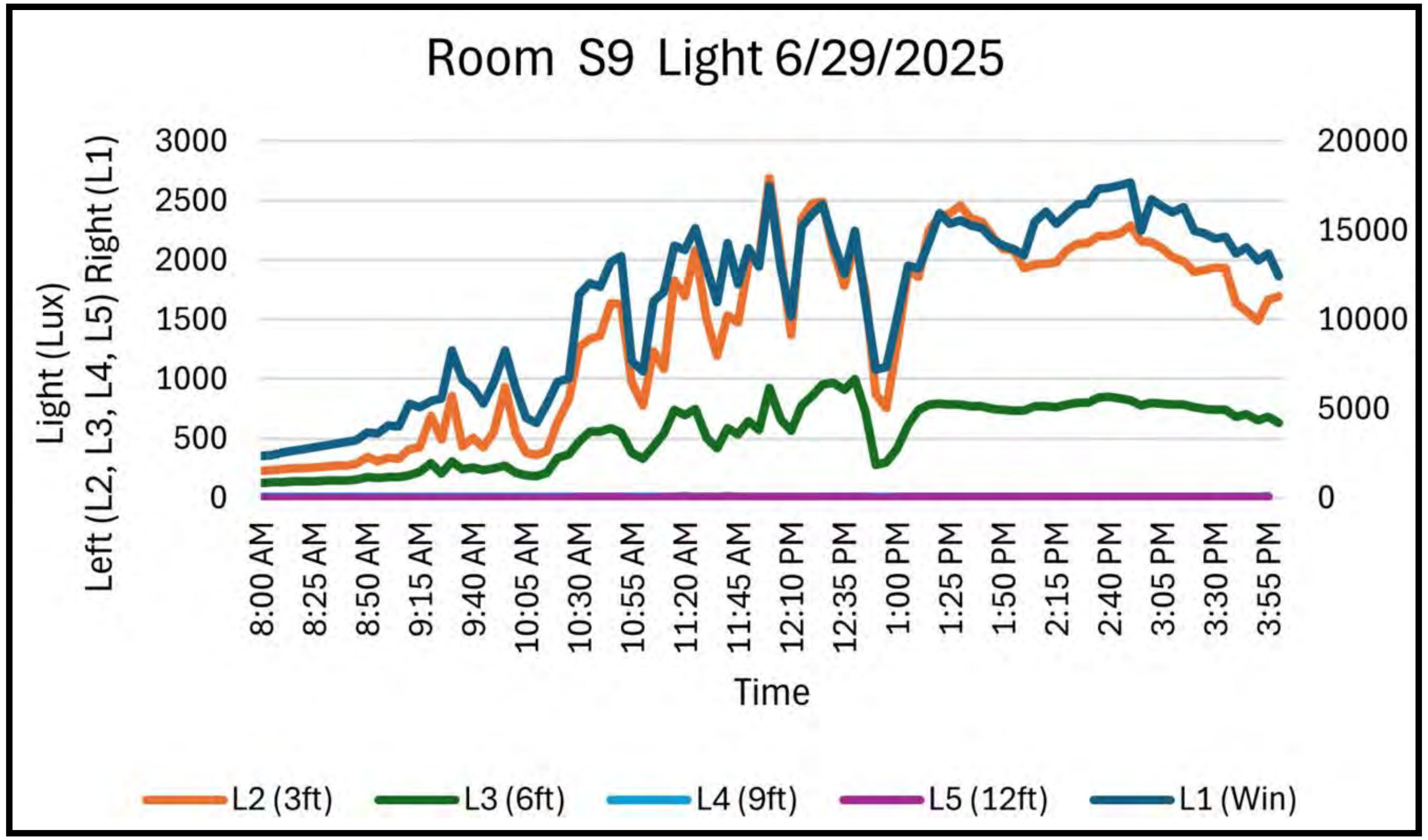
Room S9

<u>Window Dimensions</u>

Window 1: 5ft X 3ft

Window 2: 3ft 10in X 3ft 5in

Window 3: 3ft 10 in X 3ft 5 in



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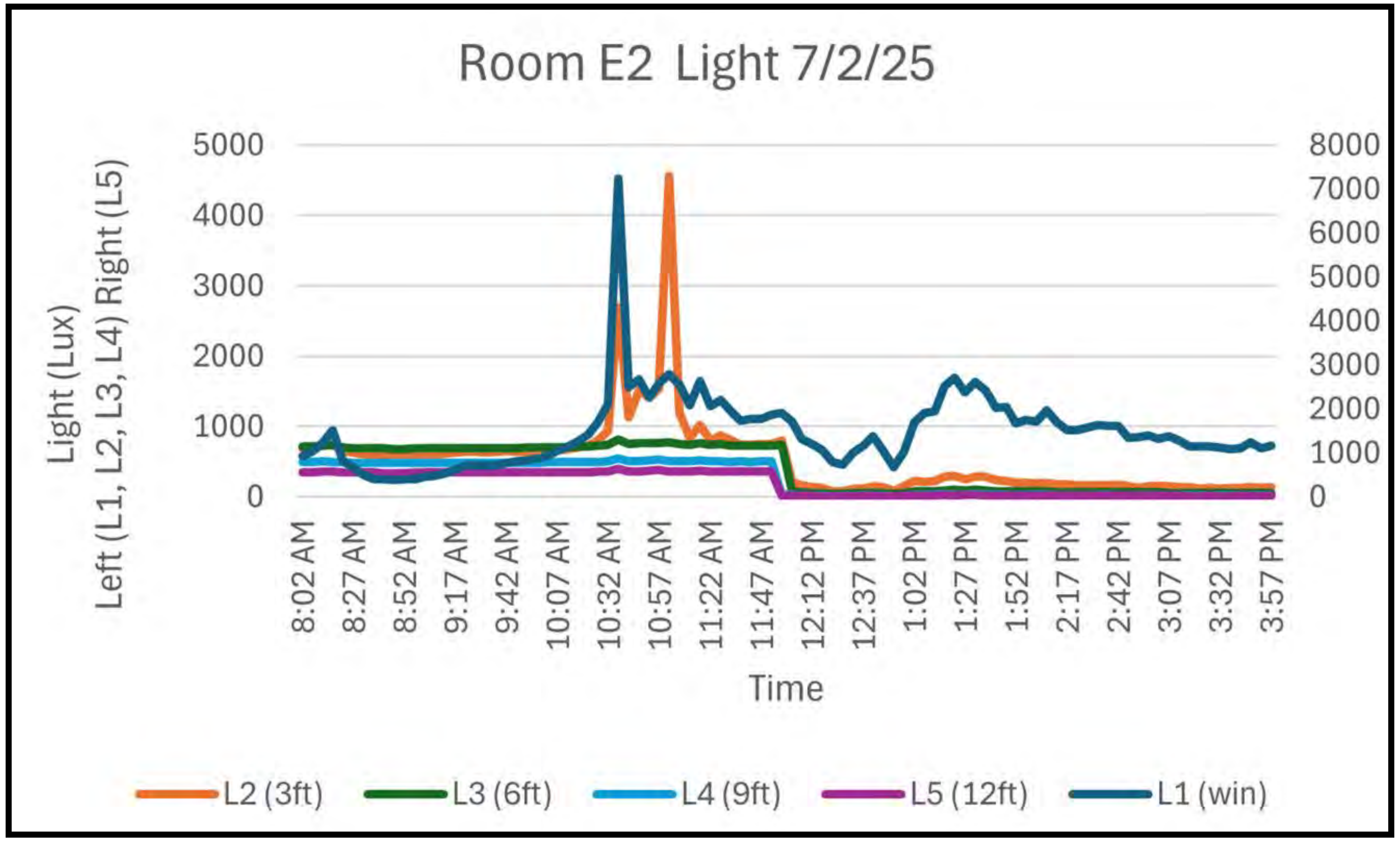
MEASURED DATA-EAST FACING ROOM



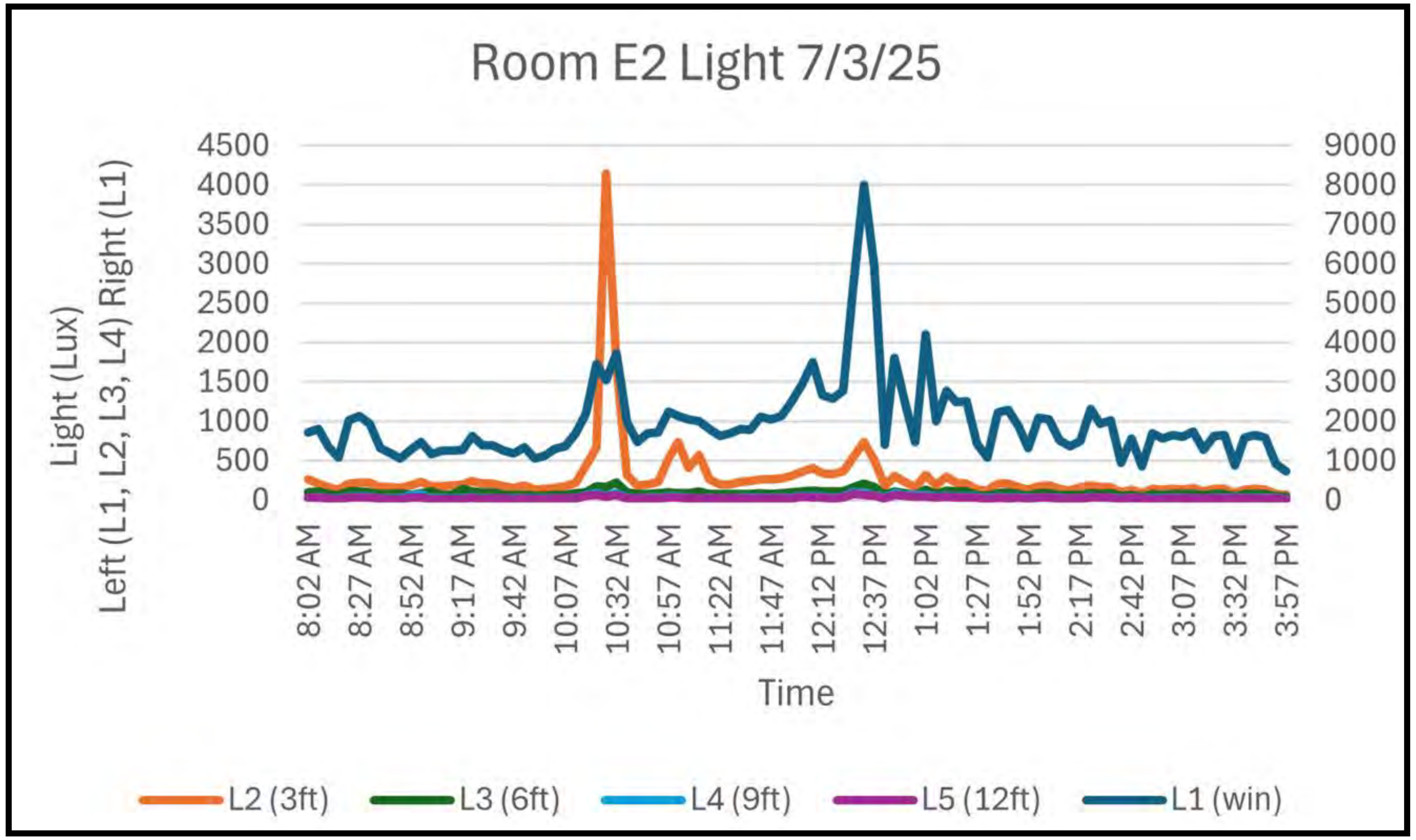
Room E2

<u>Window Dimensions</u>

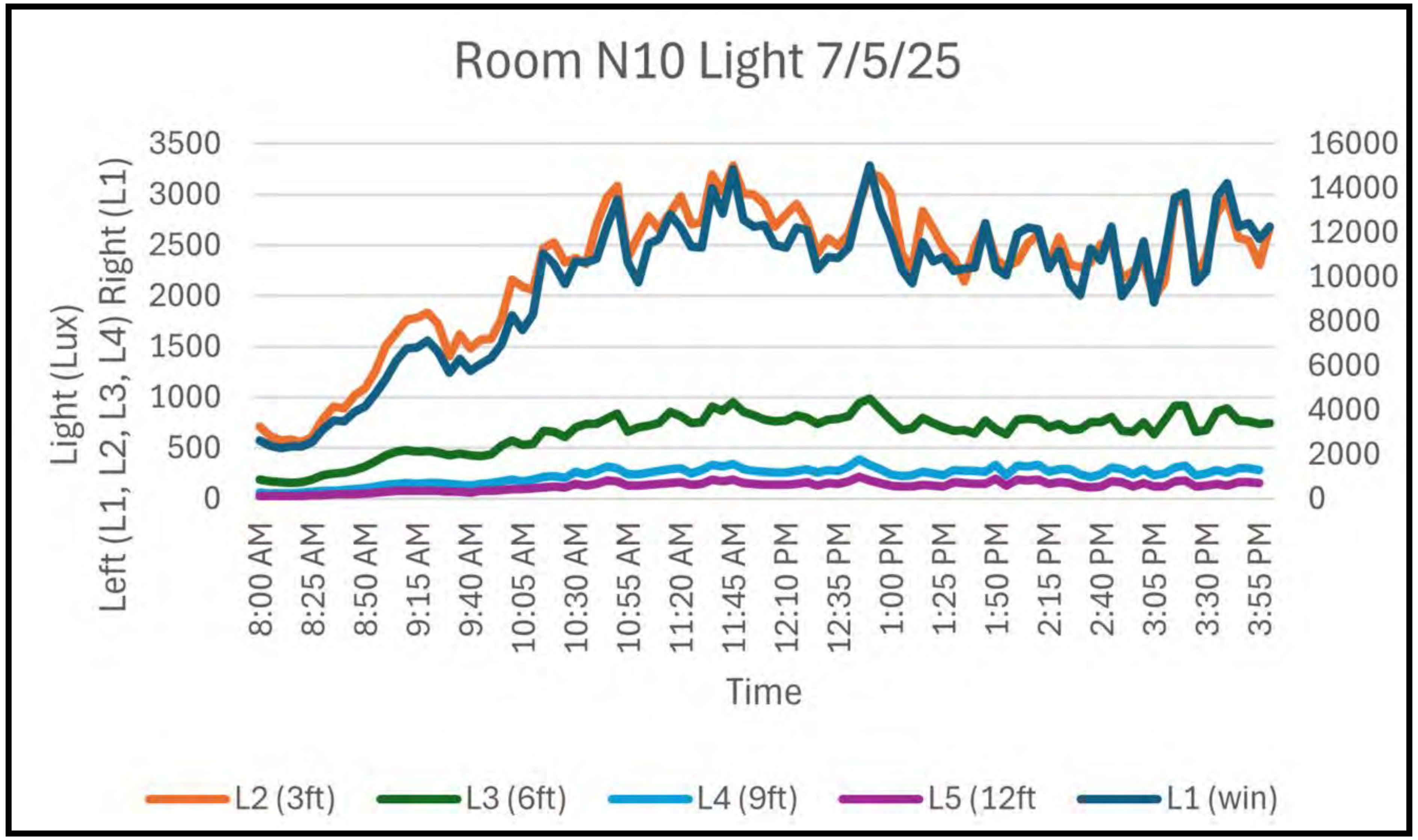
Window 1: 5ft X 3ft 5in

Window 2: 5ft X 3ft 5in

Window 3: 3ft 10 in X 3ft 5in



MEASURED DATA-NORTH FACING ROOM



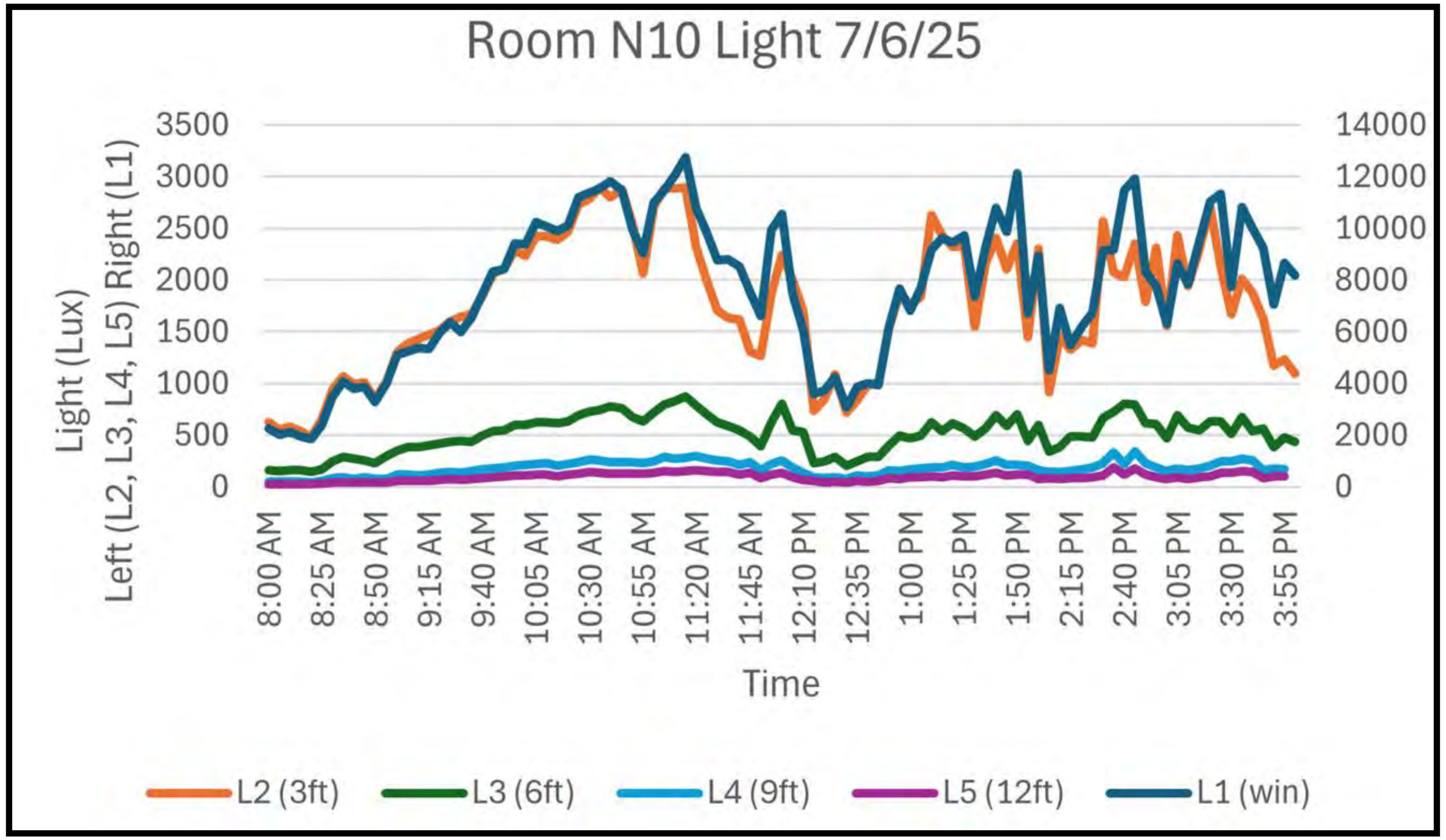
N10

<u>Window Dimensons</u>

Window 1: 5ft X 3ft 5in

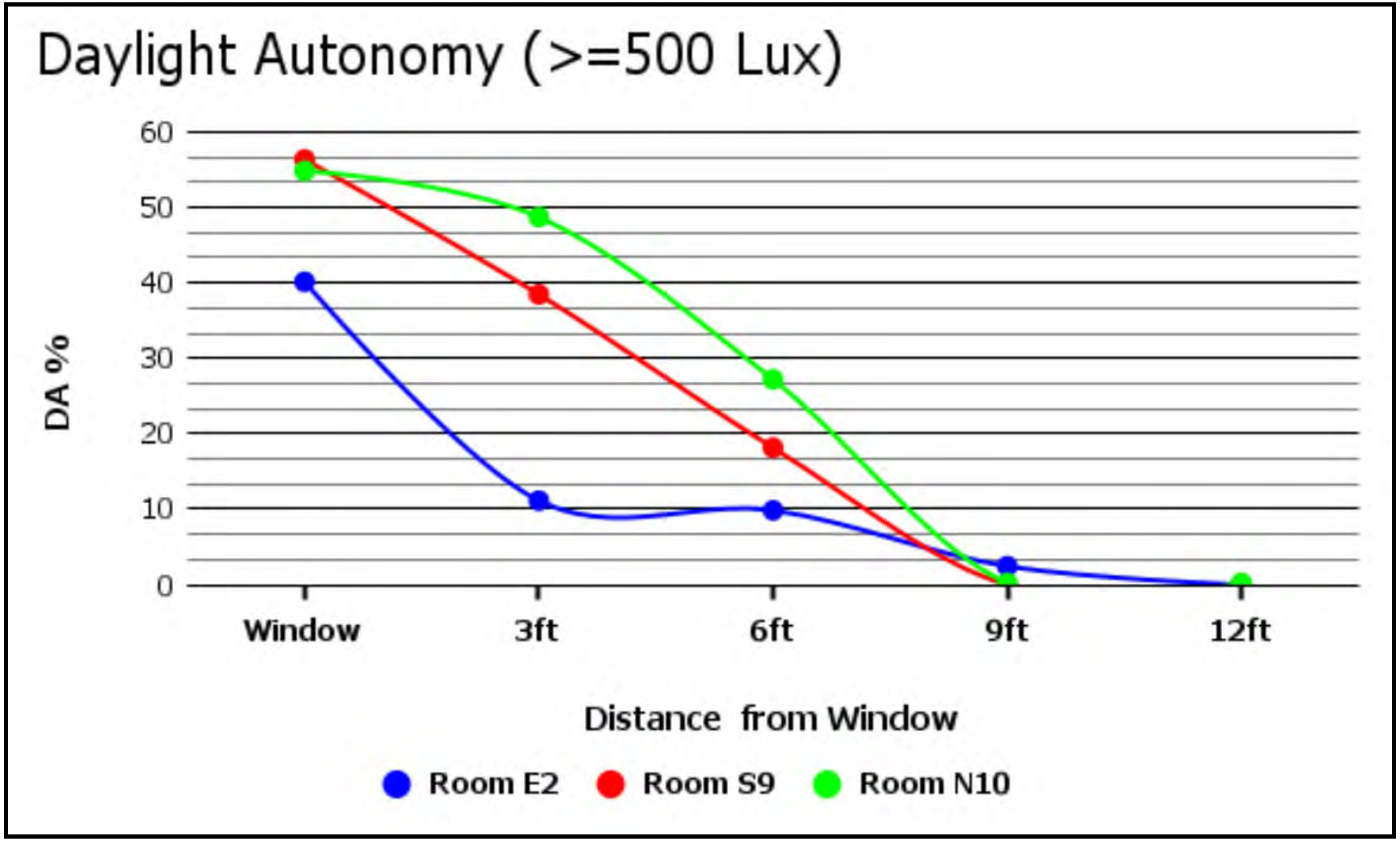
Window 2: 5ft X 6ft 9in

Window 3: 5ft X 6ft 9in

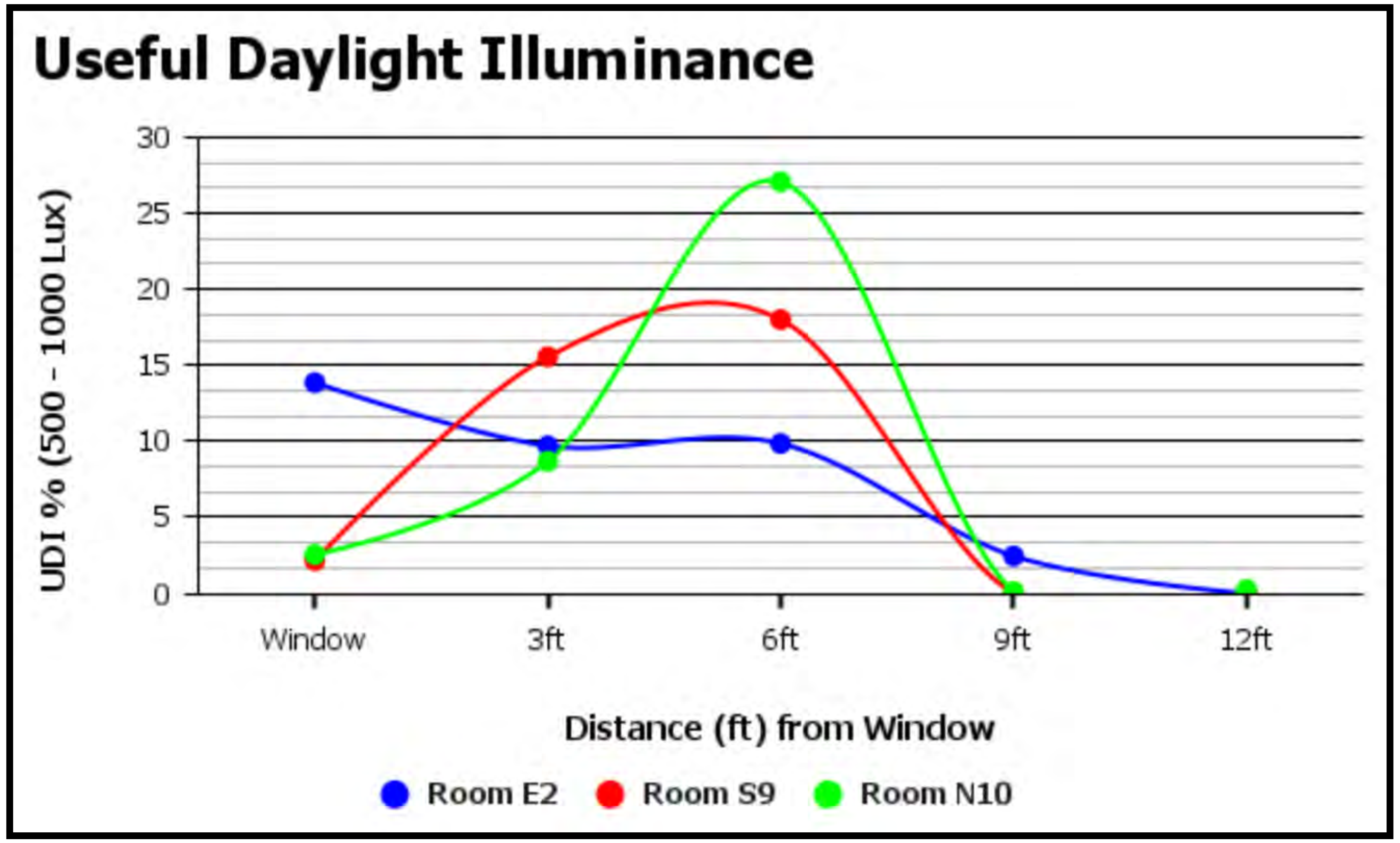


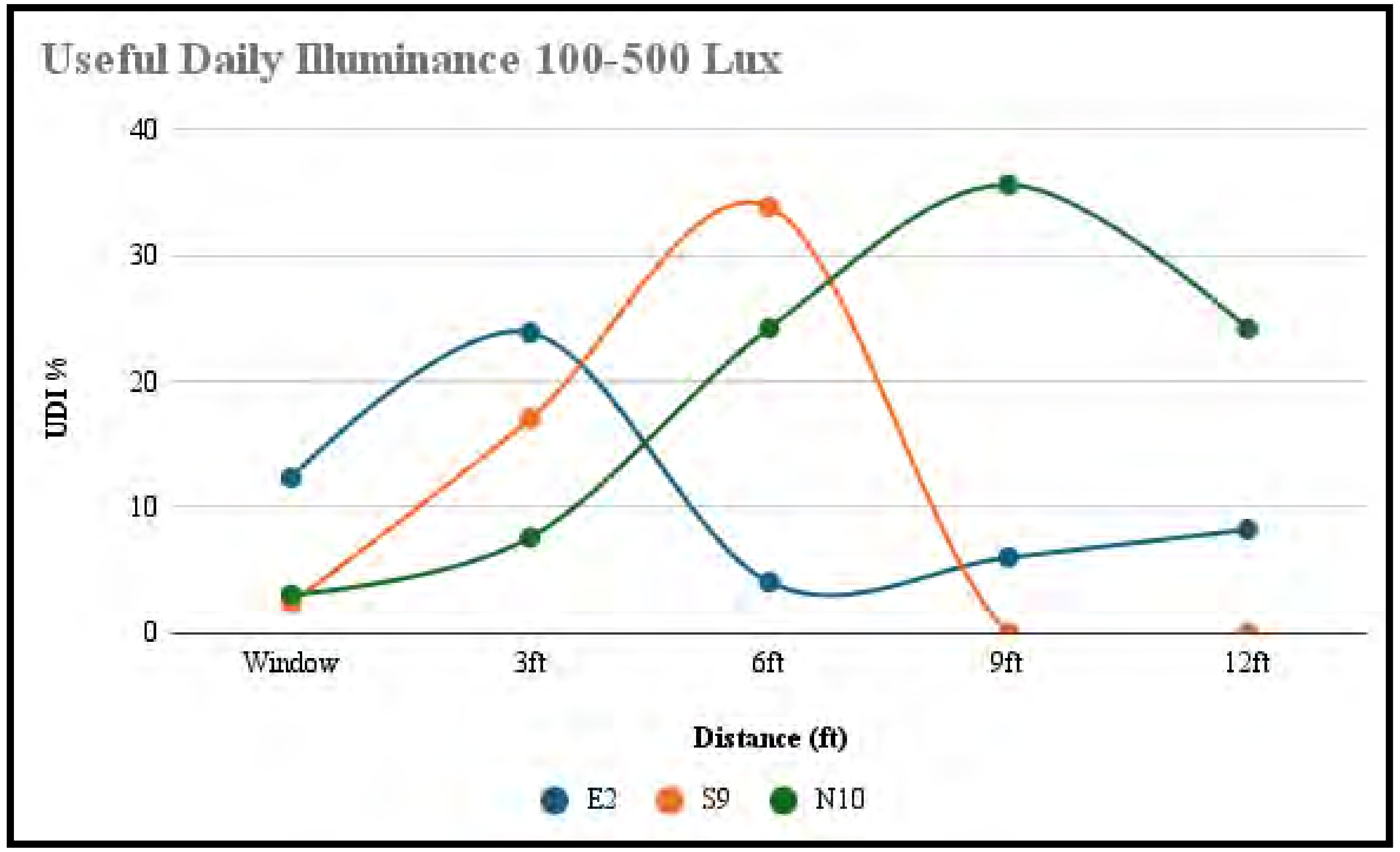
DAYLIGHTING PERFORMANCE- DA

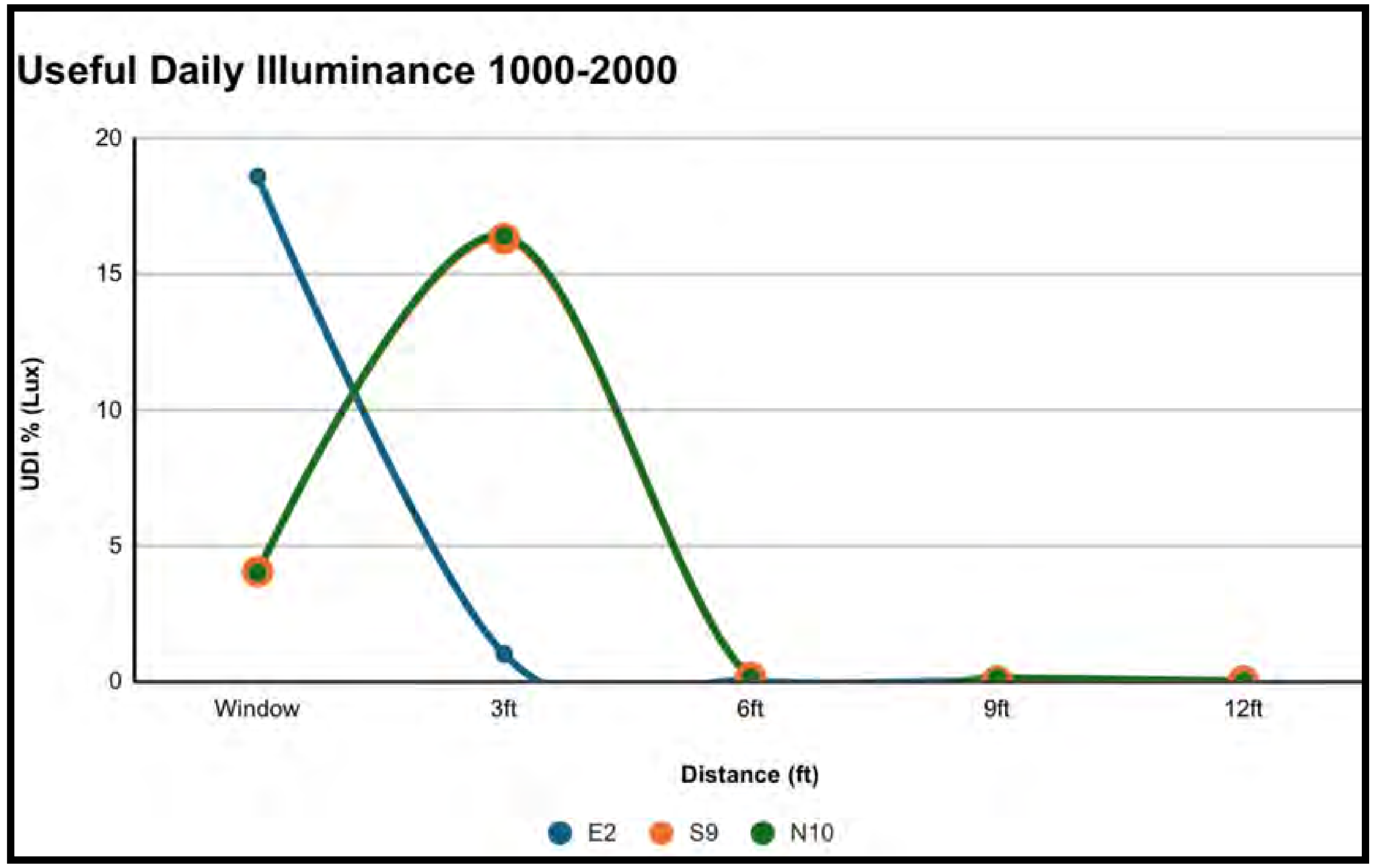
Daylight Autonomy is a metric that qualifies how much a space relies on natural daylight to meet it's illumination needs



DAYLIGHTING PERFORMANCE- UDI







2025

TEAM 3

LIGHTING ENERGY SAVINGS POTENTIAL

Room	# of Light Bulbs	Watts per Bulb	KWh Used Daily (lights ALL on)	Cost per KWh	Total Cost /Day (Lights ALL on)	Artificial Light Consumption (KWh) needed if Daylighting is Used	Total Cost of Artificial Light needed (KWh) with Daylighting	Savings / Day Estimate
S9	12	32	6.72	$ 0.0494	$ 0.33	1.183288	$ 0.06	$ 0.27
E2	12	32	7.04	$ 0.0494	$ 0.35	4.78094825	$ 0.24	$ 0.11
N10	12	32	7.104	$ 0.0494	$ 0.35	2.541737	$ 0.13	$ 0.23

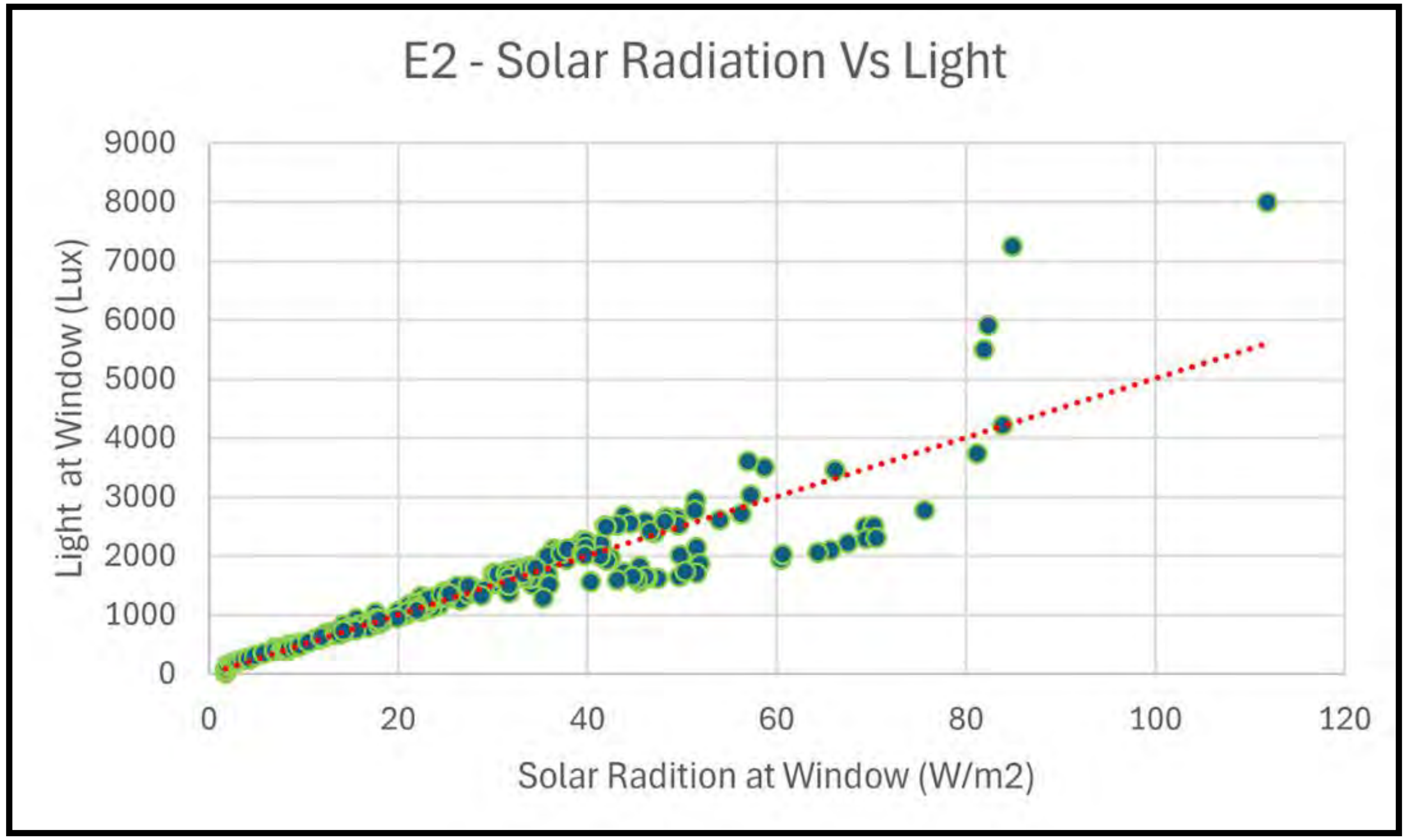
Calculated by taking the average of illuminance needed at 3ft, 6ft, 9ft, & 12ft

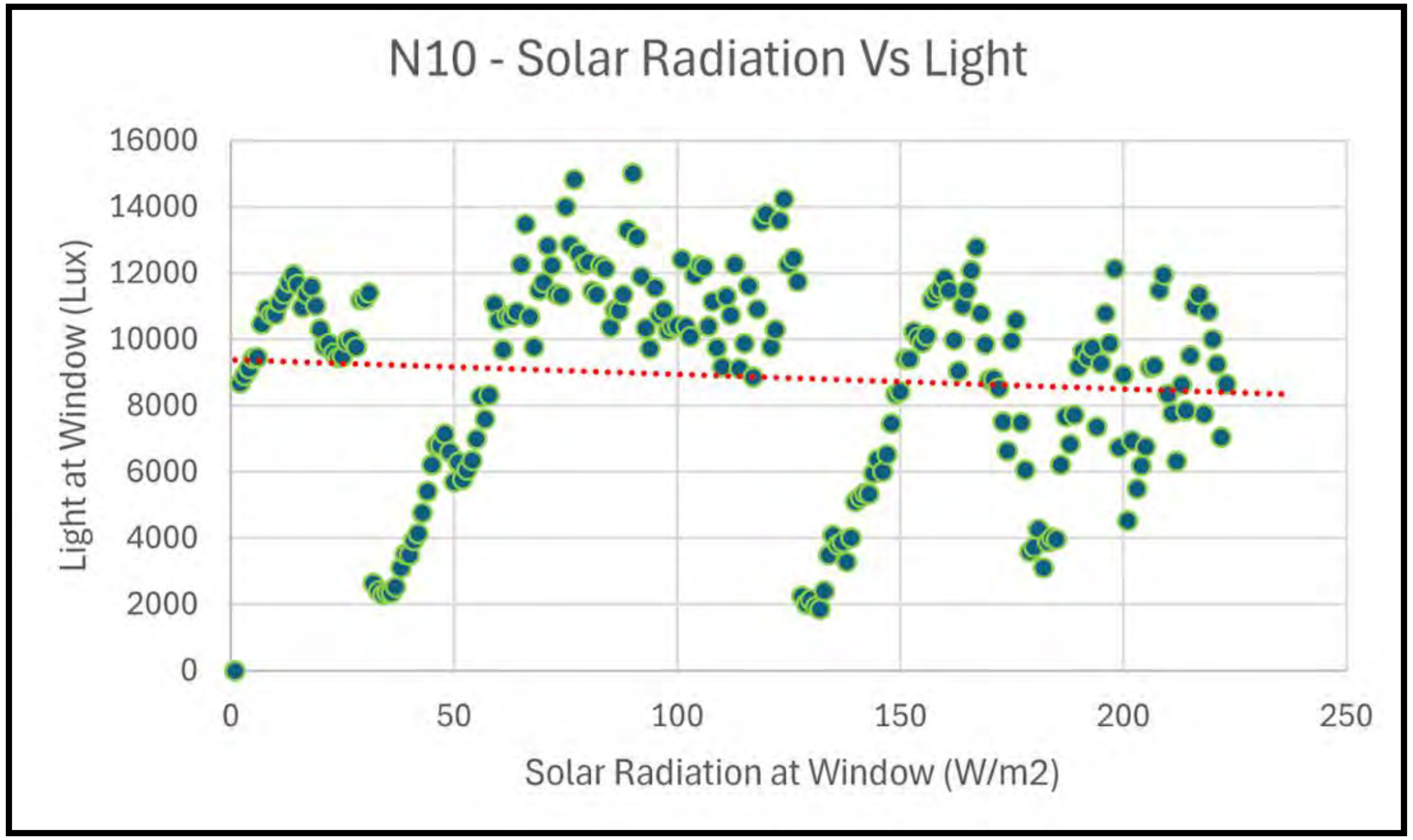
Illuminance Needed from artifical lights (window)	Illuminance Needed from artifical lights (3 ft)	Illuminance Needed from artifical lights (6 ft)	L4 (9 feet) (volts)	L5 (12 feet) (volts)	L4 (9 feet) (Lux) m=3.83 g=0.6	L5 (12 feet) (Lux) m=4.05 g=3.6	Illuminance Needed from artifical lights (9 feet)	Illuminance Needed from artifical lights (12 feet)	average illuminance needed from artificial lights	needed artificial light power	power if light is always on
0	388.4708	457.23	0.00244	0.00896	15.57533	10.08	484.4247	489.92	455.011375	349.448736	384
11.39	417.3742	456.0167	0.00187	0.00671	11.93683	7.54875	488.0632	492.4513	463.4763125	355.949808	384
66.9	435.2817	460.5667	0.00183	0.00637	11.6815	7.16625	488.3185	492.8338	469.2501459	360.384112	384
257.83	450.99	466.33	0.00111	0.00351	7.0855	3.94875	492.9145	496.0513	476.5714375	366.006864	384
474.38	477.38	474.52	0.00072	0.00187	4.596	2.10375	495.404	497.8963	486.3000625	373.478448	384

2 light bulb*6light fixtures*32W/bulb

Average illuminance needed /500*384

RADIATION VS. LIGHT





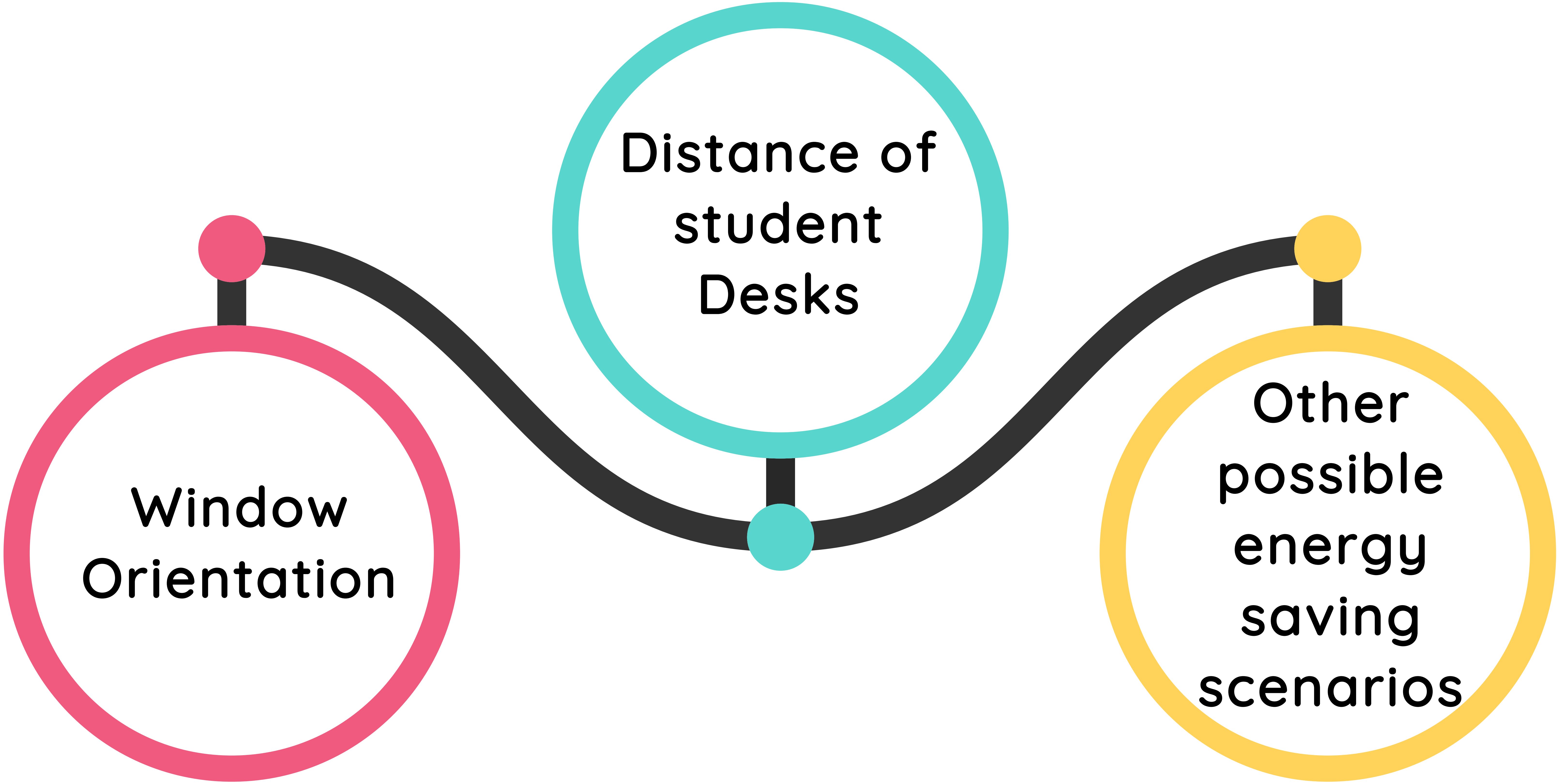
WHY IS THIS IMPORANT?

National weather station only measures solar radiation so we are looking at light as the function of solar radation.

Can help make predictions on daylight which would help decrease energy comsumption.

2025

CONCLUSION



TEAM 3

2025

STUDENT MODULES

TAUGHT FALL 2025

TEAM 3

STUDENT OBJECTIVE

Students will investigate how natural daylight and artificial room lighting affect productivity and focus within a learning environment. Using their findings, they will design and present their own ideal classroom space that promotes effective learning and conservation of energy.

Social Emotional Learning

a process that helps individuals develop the knowledge, attitudes, and skills to understand and manage emotions, set goals, show empathy, build positive relationships, and make responsible decisions

- **Self-awareness:** Recognizing one's own emotions, strengths, and weaknesses.
- **Self-management:** Managing emotions, thoughts, and behaviors effectively.
- **Social awareness:** Understanding the perspectives and emotions of others.

2025

TEAM 3

11TH AND 12TH GRADE-PHYSICS

ENGAGE: Light Concept Map & Daylighting Summary Salad

EXPLORE 1: Does Daylight Heat up a Room?

- Objective: Observe how sunlight affects classroom temperature and energy consumption

EXPLORE 2: Measuring Light Intensity in the Classroom

- **Objective**: Measure & analyze natural and artificial light levels in various parts of the classroom during different times of the day, and understand how spatial variations impact energy consumption and student comfort.

EXPLAIN: Daylighting, Energy, and Human Health

- **Objective**: Discuss how daylighting can impact energy consumption and human health

Elaborate: Real World Connections

- Objective: Students will create real world connections of the idea of bringing more daylight into the classroom through a choice board..

EVALUATE: Evaluate: Design a Daylit Classroom

- **Objective:** Use your data and physics principles to propose an optimized, energy-efficient classroom design.

TEKS:(3) Scientific and engineering practices. The student develops evidence-based explanations and communicates findings, conclusions, and proposed solutions. The student is expected to:
(A) develop explanations and propose solutions supported by data and models and consistent with scientific ideas, principles, and theories;
(B) communicate explanations and solutions individually and collaboratively in a variety of settings and formats; and
(C) engage respectfully in scientific argumentation using applied scientific explanations and empirical evidence.

Scan to access full Lesson Plans

2025

TEAM 3

PART 1: SOCIAL EMOTIONAL LEARNING- SURVERY

Classroom Lighting Survey

Name (Optional): ________________________ Date: ________________________

Please rate each statement about the lighting in your classroom.

Scale:

1 = Strongly Disagree   2 = Disagree   3 = Neutral   4 = Agree   5 = Strongly Agree

	Statement	1	2	3	4	5
1	There is enough natural daylight in my classroom during the school day.					
2	The classroom lights are bright enough for me to see clearly.					
3	The lighting in my classroom helps me stay focused and alert.					
4	I prefer to have natural daylight over artificial lights when in class.					
5	Too much sunlight makes it hard for me to see the board or computer screen.					
6	I feel more comfortable in a classroom with natural daylight.					
7	Artificial lights in the classroom sometimes give me a headache.					
8	The lighting in a classroom changes daily in each of my classes.					
9	I can easily read the material in class with the current lighting.					
10	I would learn better if the lighting in the classroom used more natural daylight.					

The handout has 10 student-friendly scaled questions (using a 1–5 Likert scale) about daylight and artificial light in a classroom. These can help gather opinions on lighting quality, comfort, and usefulness.

PART 2: STUDENT EXPERIMENT - WHOLE CLASS

Before students begin working on their projects to design the most effective classroom layout, they will conduct a self experiment with the provided material.

They will have to read the article, answer the questions and then data will be looked at for each scenario that is tested. This way students will have a better understanding of how lighting affects their learning and those around them.

PART 3: DAYLIGHT CONSERVATION RESEARCH AND EXPERIMENT

Students will research daylight conservation in schools then get a chance to measure how much daylight comes into the class and determine how much can their school save.

PART 4: CLASSROOM DESIGN PROJECT

Students will investigate how natural daylight and artificial room lighting affect productivity and focus in a learning environment. Using their findings, they will design and present their own ideal study or classroom space that promotes effective learning.

MATH 8/ALGEBRA

2025 STUDENT MODULE TIMELINE

1. **Social Emotional Likert Activity**
   Students will get introduced to daylighting and how this affects them personally.

2. **Human Experiment**
   Students will take part in an experiment to see how lighting within the class affects their own productivity and even their scores.

3. **Daylight Conservation Research and Experiment**
   Students will research daylight conservation in schools then get a chance to measure how much daylight comes into the class and determine how much can their school save.

4. **Classroom Design Project**
   Students will use everything they have learned so far about daylighting and conserving energy to design a classroom.

MATH Connection:

- Trend lines
- proportional
- non-proportional
- plotting points
- scatterplots
- area/perimeter

TEKS:

- 8.5A
- 8.5B
- 8.5D

Scan to access full Lesson Plans

TEAM 3

2025

MATH 8/ALGEBRA

2025

TEAM 3

Thank you!

Let us know if you have questions or clarifications.

Scan to access full
Research Project Material
and Student Modules

Acknowledgement
This material is based upon the 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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POTENTIAL OF CONVERTING FOOD WASTE INTO RENEWABLE ENERGY IN THE BACKYARD

Project overview

Introduction

Facing fast-growing and concerning environmental challenges due to the rapid exploitation of fossil fuels, there is a driving force toward more sustainable practices and a shift toward the use of renewable energy sources such as solar energy, wind energy, hydro energy, and energy generated from food waste.

Instead of throwing out food leftovers, imagine if we could convert that food into energy to power our homes, our cars, or even our cities. We would also reduce waste and create energy at the same time.

Clean energy sources significantly reduce harmful emissions and promote the responsible and environmentally friendly use of natural resources, ensuring that future generations can thrive.

Objective

The possibility of converting food waste into renewable energy is an exacting, interesting, and “smart” way of developing technologies that will produce efficient and cost-effective power for our daily life needs. It's like **turning trash into treasure!**

A key goal of this research is to convert everyday food waste into renewable energy and to maximize energy recovery from organic waste while minimizing negative impacts on the environment.

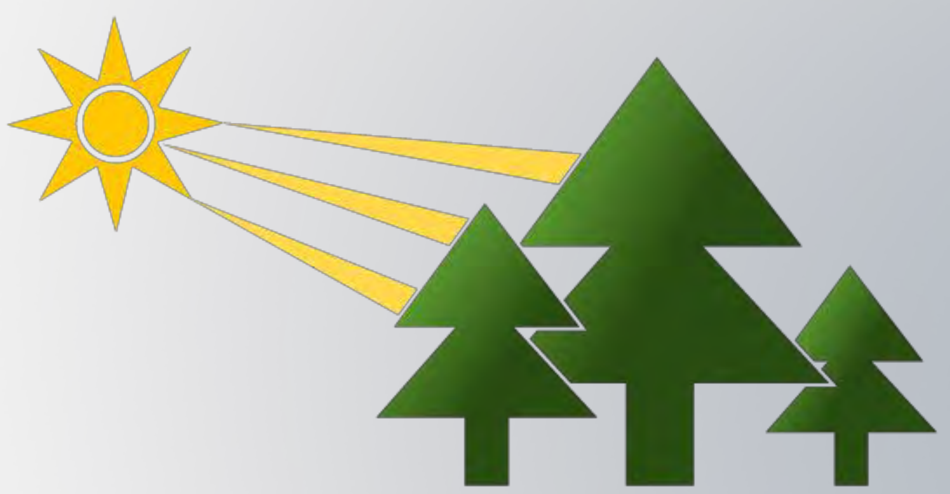
Ultimately, this research aims to create and provide sustainable solutions that address food waste management challenges and support the transition to renewable energy practices, and long-term well being for smaller communities worldwide.

What should I know about

Biomass

Biomass is organic material that comes from plants and animals. Biomass can be burned directly for heat or converted to liquid and gaseous fuels through various processes.

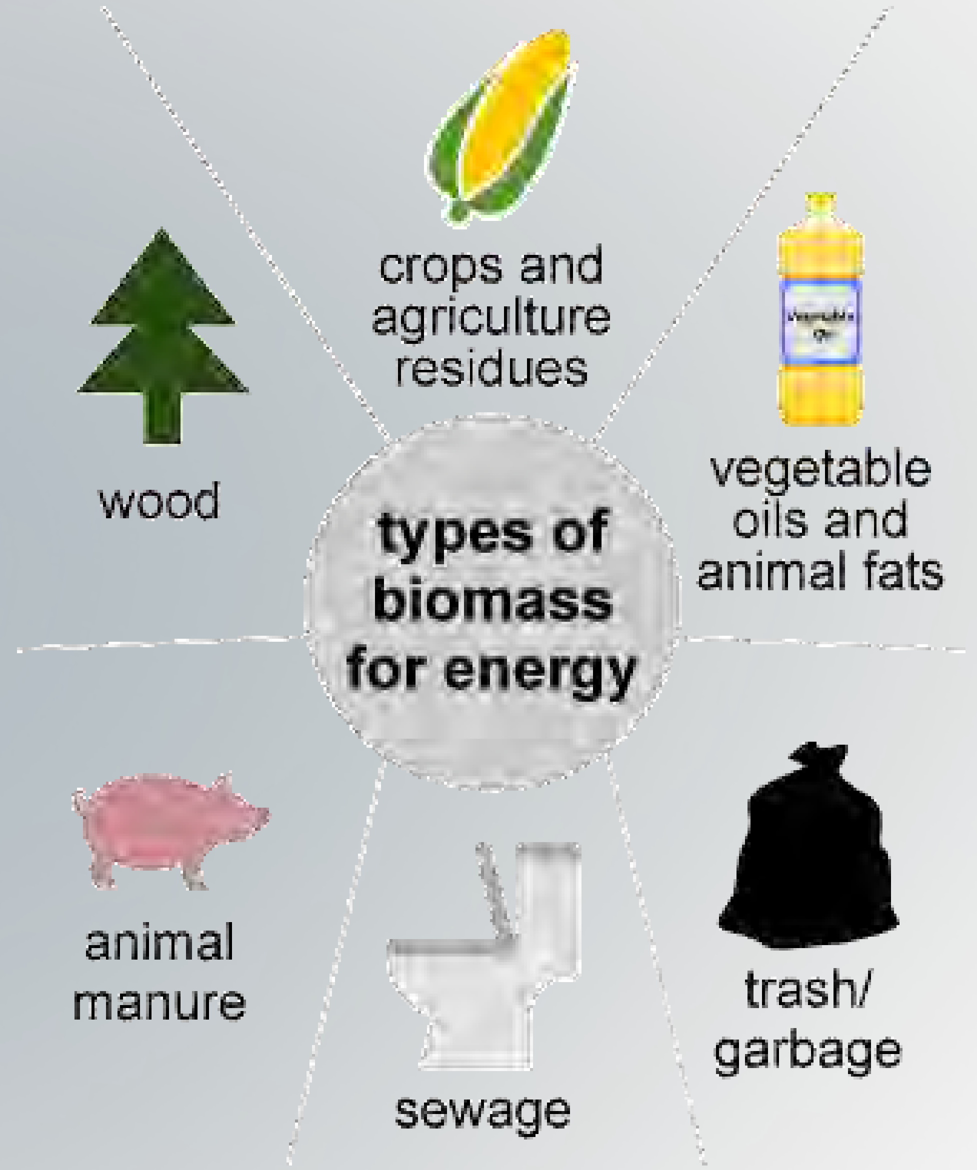
Photosynthesis



In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose—or sugar.

(water)		(carbon dioxide)		(sunlight)		(glucose)		(oxygen)
$6\,H_20$	+	$6\,CO_2$	+	radiant energy	$\rightarrow$	$C_6H_{12}O_6$	+	$6\,O_2$

Source: Adapted from The National Energy Education Project (public domain)



Source: U.S. Energy Information Administration (public domain)

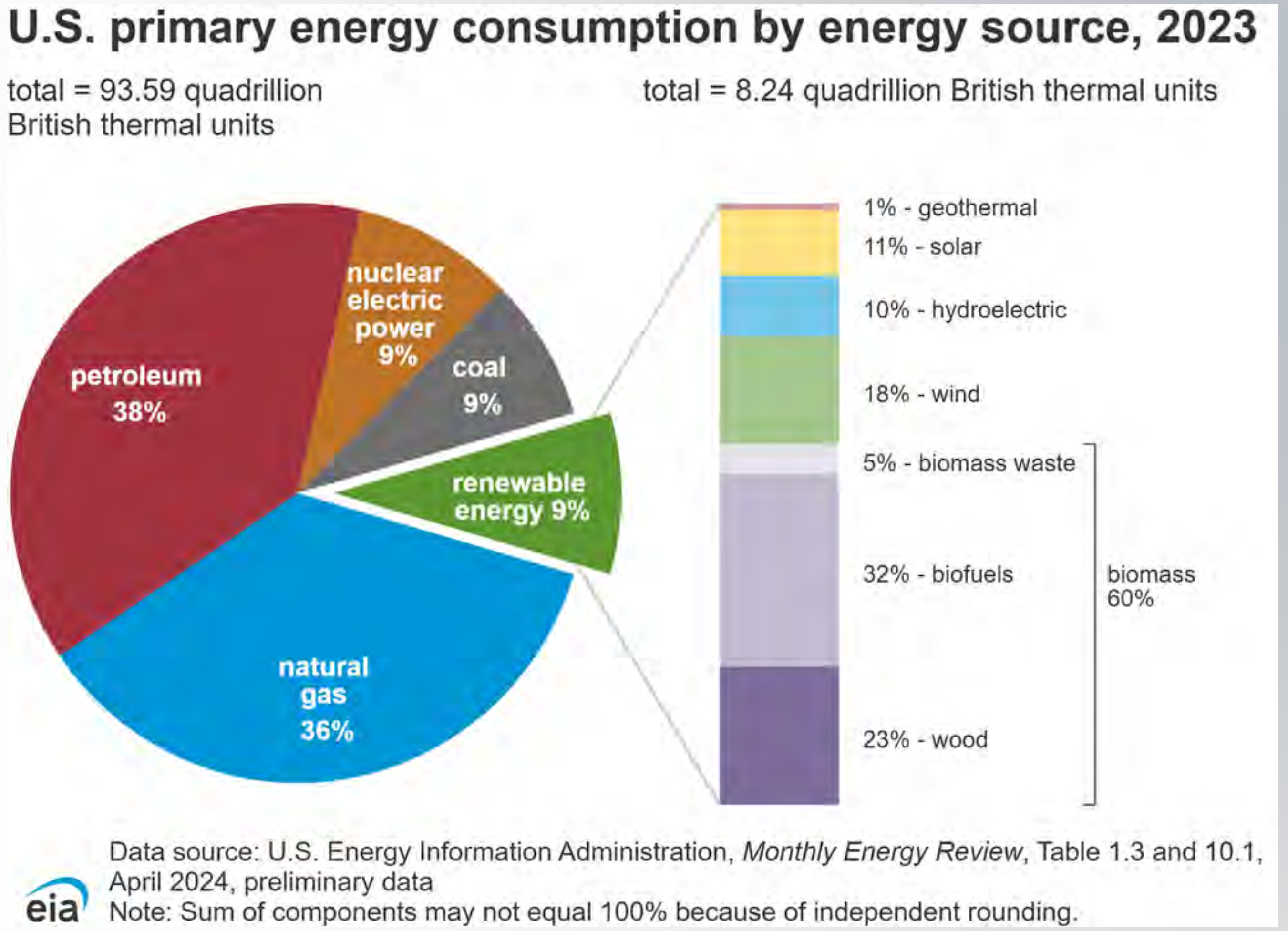
Biomass was the largest source of total annual U.S. energy consumption until the mid-1800s. After that period, coal overtook biomass as the dominant energy source due to industrialization and the rise of railroads and manufacturing.

- In 2023, biomass accounted for about 5% of U.S. energy consumption. The types, amounts, and the percentage shares of total biomass energy consumption in 2023 were:

Biofuels—53%

Wood and wood waste—39%

Municipal solid waste, animal manure, and sewage—8%



Global Energy Overview (2023)

- Total primary energy consumption: 620 EJ (Exajoule, Unit of energy equal to 10^18 joul), up 2% from 2022
- Fossil fuels (oil, coal, gas) still dominate with ~81–82% share Oil: 32%, Coal: 26%, Gas: 23%
- Renewables (including hydro, wind, solar, bio): ≈15% of global primary energy, a record high

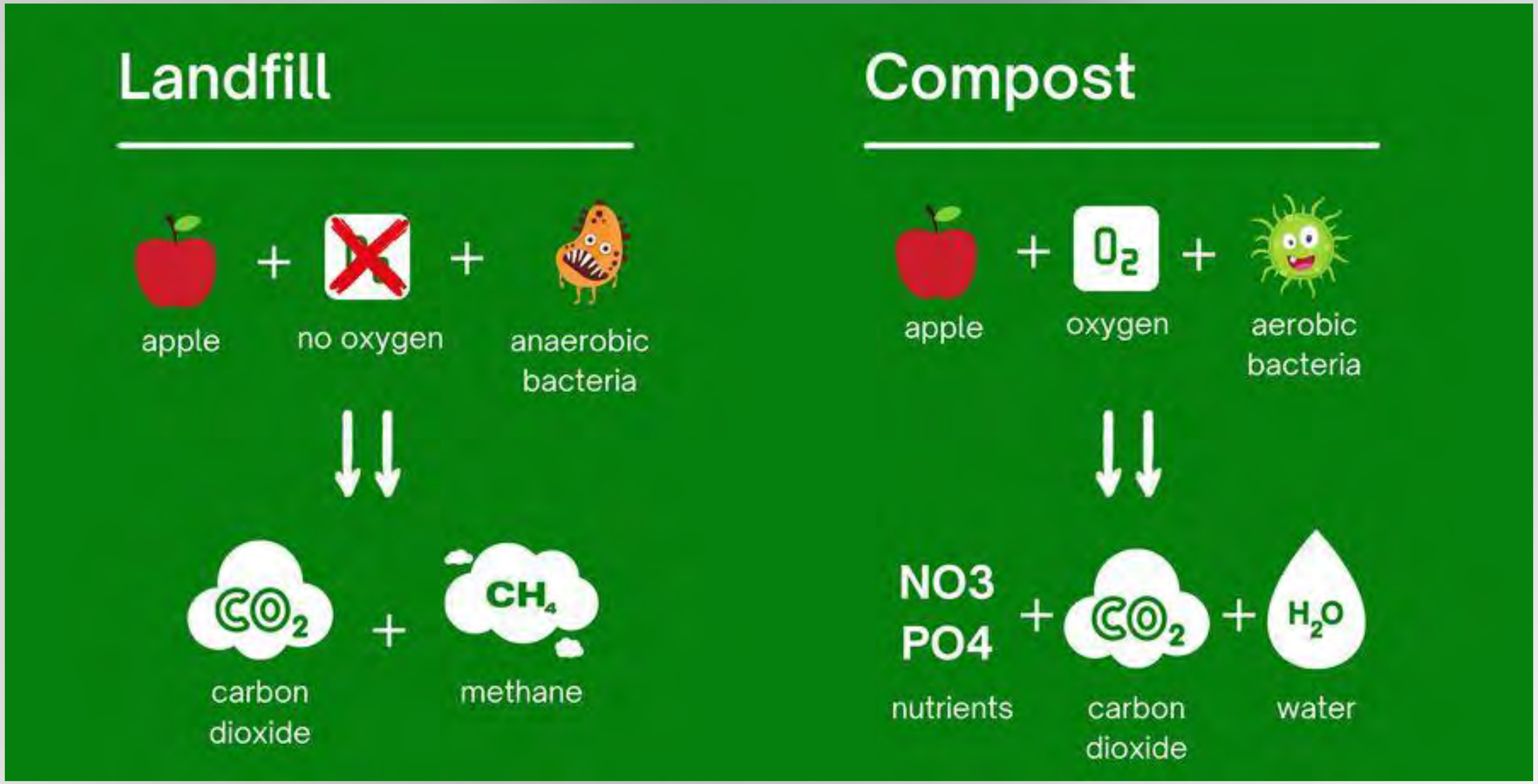
HOW Biomass is used ?

When organic materials such as plants, wood, and food waste decompose, they release energy that can be captured and converted into heat, electricity, or fuel. In composting, biomass isn't converted into energy in the same way as burning for heat or producing fuels like biogas or ethanol.

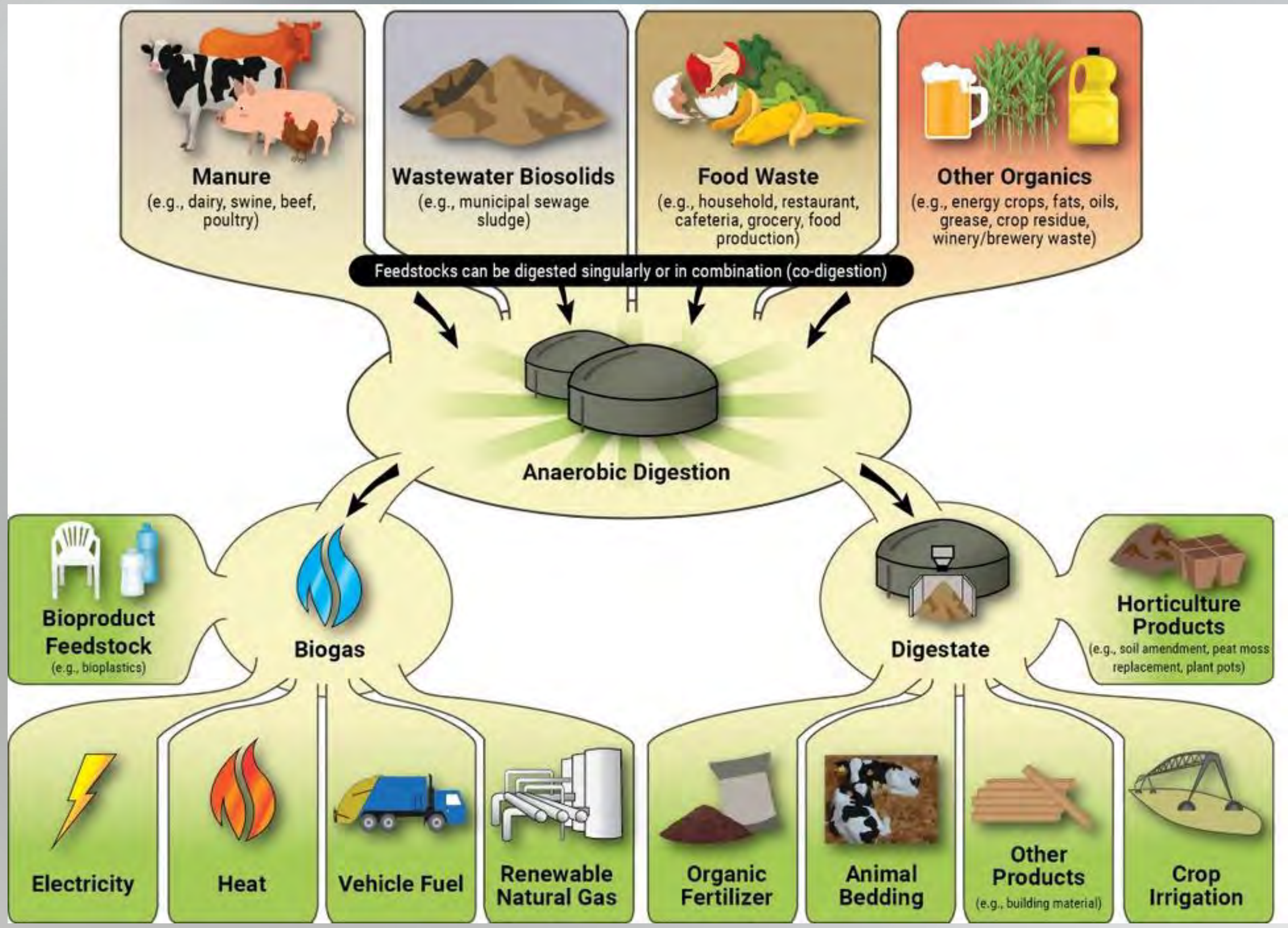
Instead, composting relies on a biological process of aerobic decomposition where microorganisms break down organic materials, releasing heat as a byproduct.

Aerobic processes require oxygen for the microbes to function. In these conditions, bacteria and fungi break down organic matter through aerobic respiration.

This process produces carbon dioxide and water, which are less harmful to the environment. Aerobic composting is a popular method for managing organic waste that has potential of converting food waste into renewable energy and its more suitable for our backyards.



Anaerobic processes occur in environments with limited or no oxygen. In these conditions, microbes such as bacteria and archaea break down organic matter through fermentation.
This process produces biogas - a blend of methane and carbon dioxide - that can be reused as a renewable energy source. Anaerobic digestion is commonly used in landfills and wastewater treatment plants.



Source: United States Environmental Protection Associations

Why Does the Pile Smell or Cool Down?

Heat-Generating Bacteria in Composting:

Pseudomonas

Bacillus subtilis

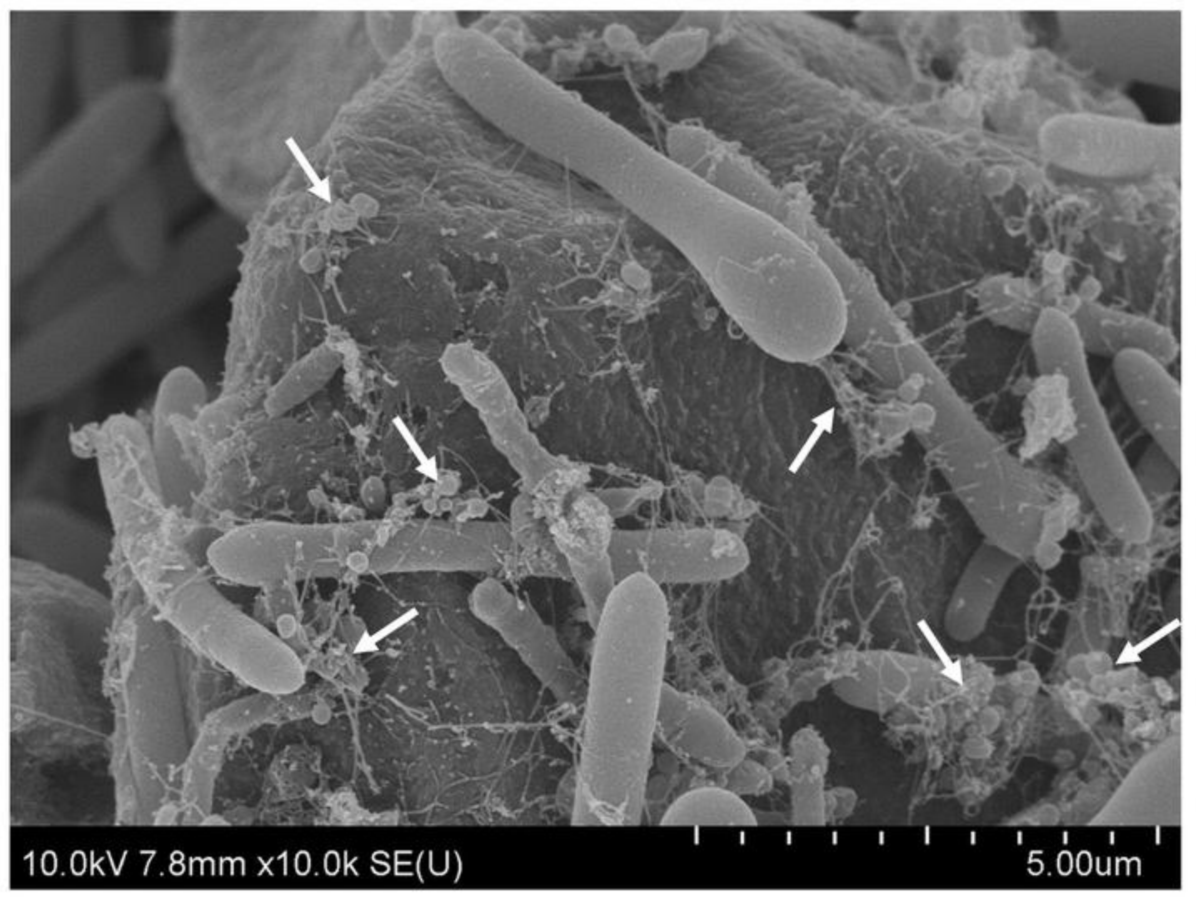
Creator: Nano Creative/Science Source/SCIENCE PHOTO LIBRARY | Credit: Nano Creative/Science Source/SCIENC

Actinomyces (especially important for lignin/cellulose breakdown

Why Does the Pile Smell or Cool Down?

If the pile gets too wet (common with high fruit/veg content), aerobic bacteria slow down, and anaerobic bacteria (like Clostridium spp.) may take over—causing odors and less heat.

Turning the pile adds oxygen and reactivates aerobic thermophiles.



DOI: 10.7717/peerj.10343/fig-2

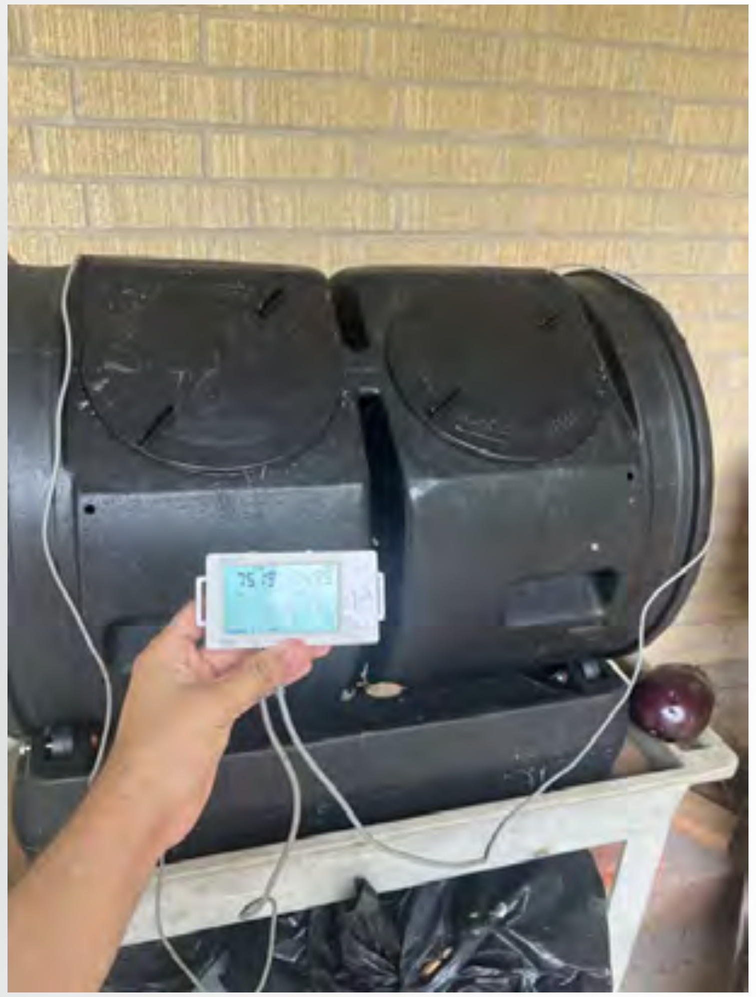
How to Support Heat-Producing Bacteria:
Mix greens (fruit/veg scraps = nitrogen) with browns (dry leaves, shredded cardboard = carbon).

Keep moisture like a "wrung-out sponge."

Turn the pile weekly to aerate.

Build the pile large enough (at least 3x3 feet) to retain heat.

Our Project Set up



Methodology

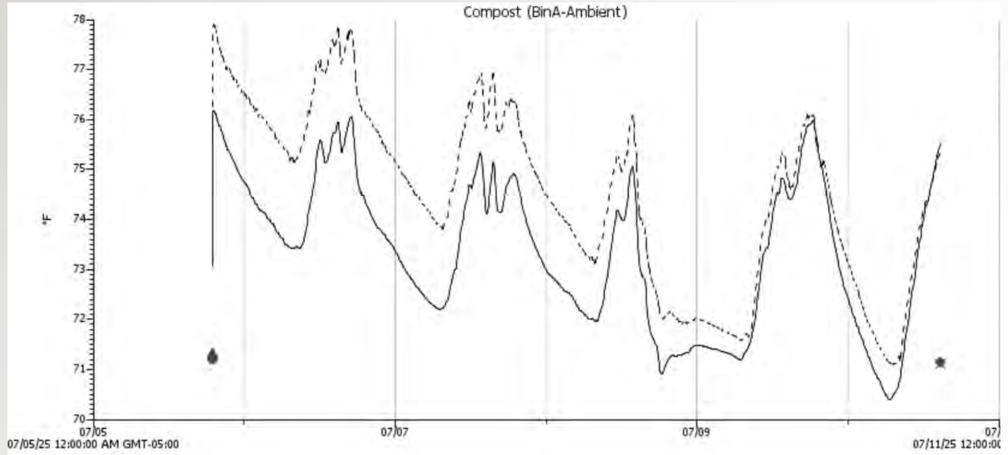
Compartment A Compartment B

01 A composting bin was divided into two compartments:
a) Compartment A, left side 3.72"
b) Compartment B, right side 2.4"

02 Thermometer was placed inside the composting bin to monitor temperature changes, which indicated microbial activity and energy release during composting.

03 Temperature data was recorded automatically every 5 minutes from July 5th to July 11th.

04 The collected temperature data was analyzed to compare the thermal energy generated by the different depth on each side of the bin.

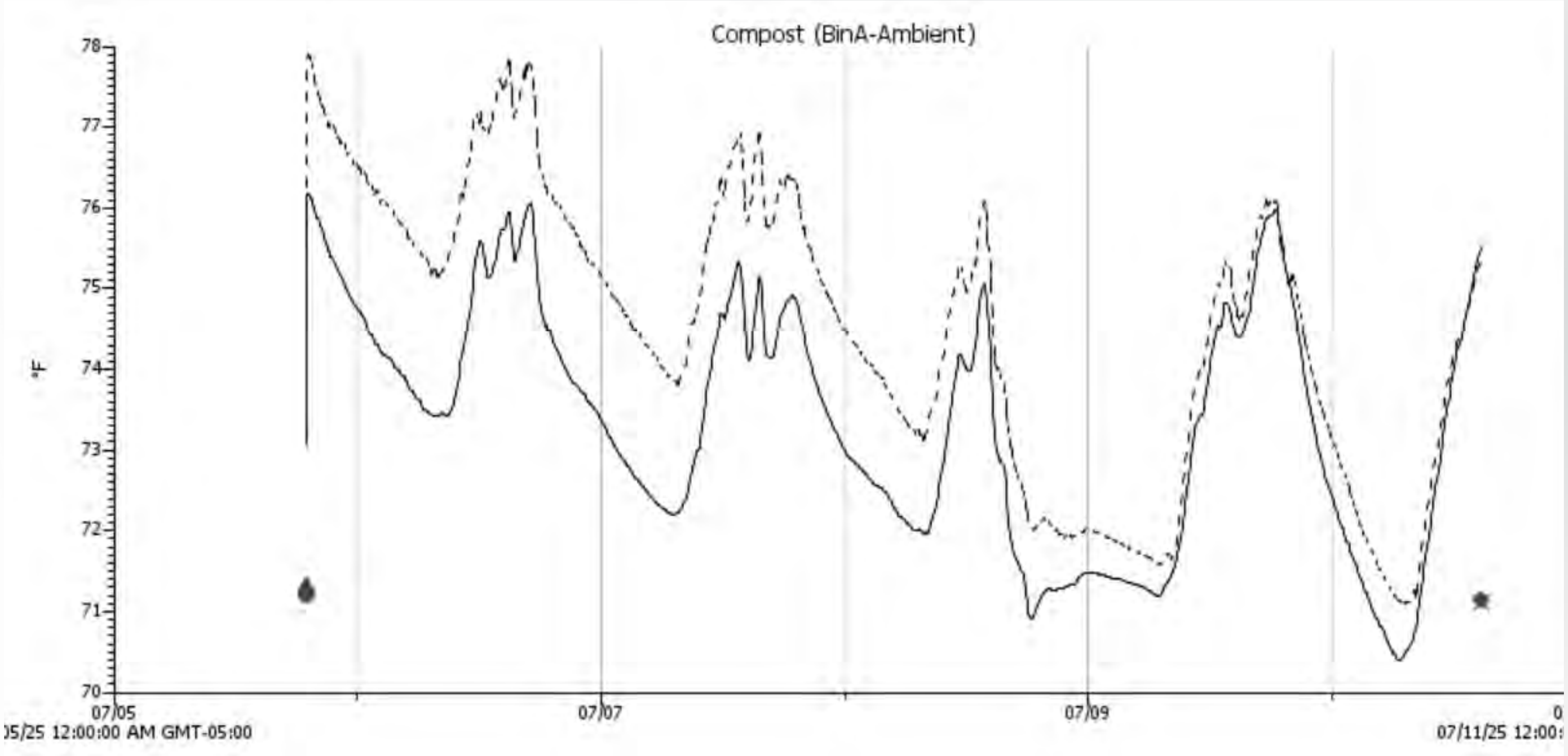


05 Results were visualized using a graph to show temperature variations over time and to compare the energy output from the left side versus the right side regarding different depth

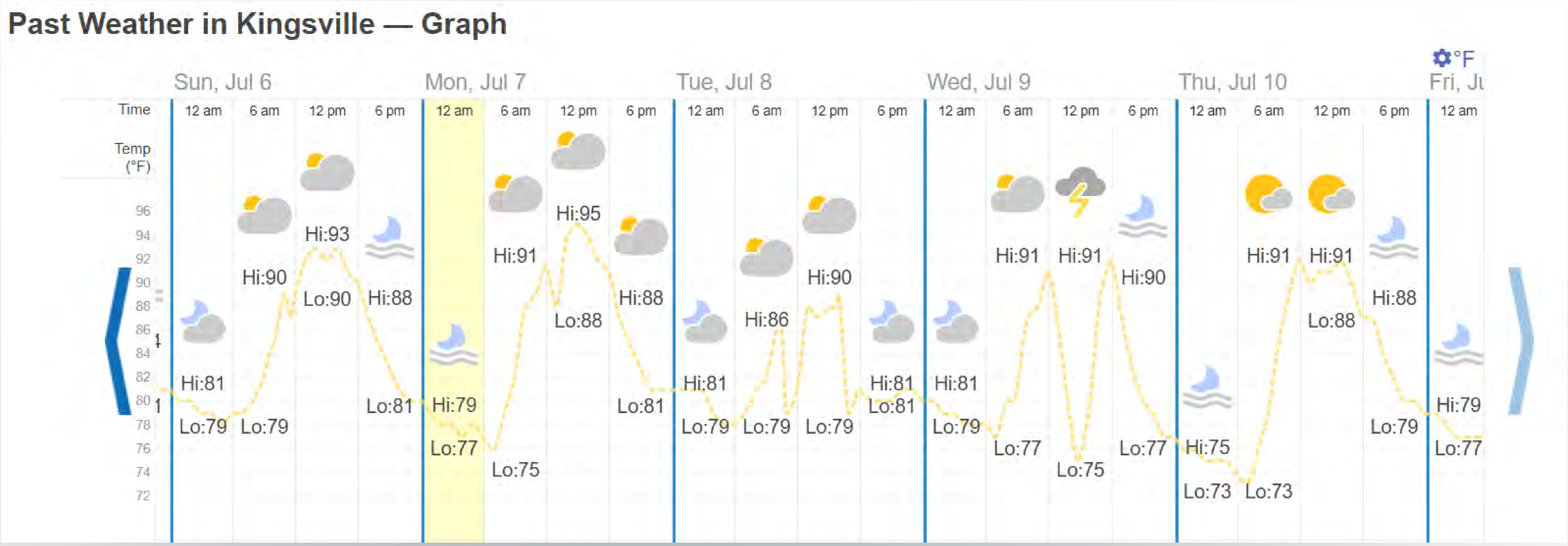
Results

Time Range: July 5 to July 11, 2025
Graph Title: Compost (BinA - Ambient)

Solid line: Temperature at 2.4"depth (Copartment B)
Dashed line: Temperature at 3.72" depth (Compartment A)
Symbols:
? = Start
▲ = Button Up
◆ = Host Connected
✕ = End of File



Results



Visible fluctuations in temperature can be attribuied to the ambient temperatures of the South Texas weather.

Analysis

The temperature was fluctuating between ~70˚F and ~78˚F over the course of 6 days due to day/night changes and different microbial activity within the compost . We can conclude that the compost is not creating a discernable heat difference from the ambient temperature.
Compartment B had a depth of 2.4" and recorded a lower temperatures than Compartment A with a depth of 3.72", indicating that deeper compost retains more heat, higher temperature trends and is more stable.

Key Findings

-Stable but low composting activity:
The temperature remains relatively cool (low 70s ˚F), which suggests compost is in a stagnant phase rather than an active thermophilic phase.

-Depth matters: Deeper areas maintain slightly higher and more stable temperatures which is important for microbial breakdown efficiency.

-Lack of microbial heat spike and activity. The composting process must be active in order to generate heat.

Conclusion

This six-week research project aimed to explain how much thermal energy can be generated and evaluate composting efficiency in our backyard composting bins by monitoring temperature fluctuations in a single compost bin with compartments A and B from July 5 to July 11, 2025.

Data collected showed that temperatures ranged between 71°F and 78°F, with the deeper compartment A (3.72") maintaining slightly higher and more stable temperatures than compartment B (2.4"). These readings were below the optimal temperature range, which should be between 130°F and 160°F, required for rapid microbial activity, the start of decomposition, and heat release.

Given the six-week limited time window, the compost has not reached its full decomposing potential. This study showed some biological activity, but the conditions were not sufficient for active decomposing that would generate the heat nor biogas needed for energy conversion. However, further long-term studies are needed and recommended to explore the feasibility of converting food waste into energy in our backyards.

Q&A Session

Reality Check

How realistic is harnessing energy from food waste?

The answer would require another question- what are the expectations?

Is energy released? Yes...
But...

Learning Module

Converting Food Waste into Renewable Energy: Transforming Trash into Treasure

LEARNING OBJECTIVE:

I will analyze the impact of human activities on the environment, describe the interdependence of organisms in an ecosystem, and explain the process of composting and its role in converting food waste into renewable energy.

We will:

Evaluate the impact of waste management methods such as reduction, reuse, recycling, upcycling, and composting on resource availability in the local environment. TEKS ENV.5.F (ENV.6D)

Explain the flow of energy in an ecosystem, including conduction, convection, and radiation. TEKS ENV.6.C (Science.ENV.7C)

Investigate and explain the effects of energy transformations in terms of the laws of thermodynamics within an ecosystem. TEKS ENV.6.D (Science.ENV.7D)

KEY POINTS:

The process of composting involves the breakdown of organic matter by microorganisms, producing nutrient-rich soil.

Food waste significantly contributes to landfill mass and greenhouse gas emissions.

Ecosystems rely on the recycling of nutrients, and composting facilitates this process.

The interdependence of organisms plays a crucial role in maintaining a balanced ecosystem

ACTIVITY

Students will complete a project where they set up a composting bin and create a presentation based on the composting processes and its benefits, demonstrating their understanding of the interdependence of organisms and the impact of food waste on the environment.

Renewable Energy and Composting: Potential of Transforming Food Waste into Sustainable Power

Learning Modules

Module 1

Engagement 1 Day (50 min class)

What Happens to Our Food Waste?

Opening question: Where does your lunch waste go?
Quick facts: Americans waste 30-40% of their food supply
Class discussion: Environmental impact of food waste in landfills •
Demonstration of decomposing food samples in sealed containers • Students will brainstorm the ways to reduce food waste • Directive for food waste collection begin on day 1

Learning Modules

Module 2

Guided Activity 3 Days (150 min)

Backyard Biogas Engineering Design Challenge

In teams, students design a small-scale compostng system suitable for a backyard- that will be utilized for 4 wks.

Students will explore and include methods for monitoring temperature/moisture, list of materials, potential outputs- formulation of hypothesis and application of scientific method.

Learning Modules

Module 3

Exploration 3 Days (150 min)

Understanding Composting Basics, Nutrient and Energy Cycling

How composting and anaerobic digestion return nutrients to the environment,
Compare composting to other waste methods

Definition of Composting- The natural process of decomposing organic matter

- Green materials (Nitrogen-rich): Food scraps, grass clippings
- Brown materials (Carbon-rich): Dry leaves, paper
- Water and oxygen

Activities: Students build mini compost in a jar. Students will predict what will happen over a week regarding smell and color change

"Which waste system is best for energy and the environment?"

Students will record their findings in their science journal. Students will research landfilling, composting, and anaerobic digestion and compare and contrast researched waste management systems.

Learning Modules

Module 4

Understanding 1 Day (50 Minutes)

The Inivisible World of Microbes

Students will explain aerobic and anaerobic processes and the importance of microorganisms.

Activity : Students will play "Microbe Match Game" in order to understand the role of bacteria in breaking down organic matter.

Students will be provided cards with the names of different bacteria involved in waste digestion (e.g., methanogens, acidogens), and cards with their functions. Students will match bacteria to their roles.
Extension: Quiz at the end for reinforcement and overall understanding

Learning Modules

Module 5

Analysis 2 Days - (100 minutes)

From Waste to Energy

- Aerobic Vs. Anaerobic digestion process

Bacteria break down organic matter

Production of biogas (mainly methane), heat, compost

Benefits: Reduction of greenhouse gas emissions, production of renewable energy, and fertilizer as byproduct

Activity- Student will collect and share data from the compost bin readings. Data collected will be recorded in science/composition journals for analysis. Students will work in small groups and share their findings and initiating whole class collaboration.

Students will explain aerobic and anaerobic processes by creating a diagram.

Learning Modules

Module 6

Conclusion 3 Days (150 minutes)

Real World Application

The Students will apply learning from their practical design and explain The Science of Decomposition and the Potential of Converting Food Waste into Renewable Energy in our Backyards.

Activity: School research project presentation, discussion, and reflection on the interdependence of energy production, consumption, and ecosystem health.

Key Sources & Acknowledgements

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Thank you

Mitigating the Loss of Potential Energy Production in Wind Farms Due to Wake Effect

TEACHER PARTICIPANTS:

GORDON HALEY & KATIE DOYLE

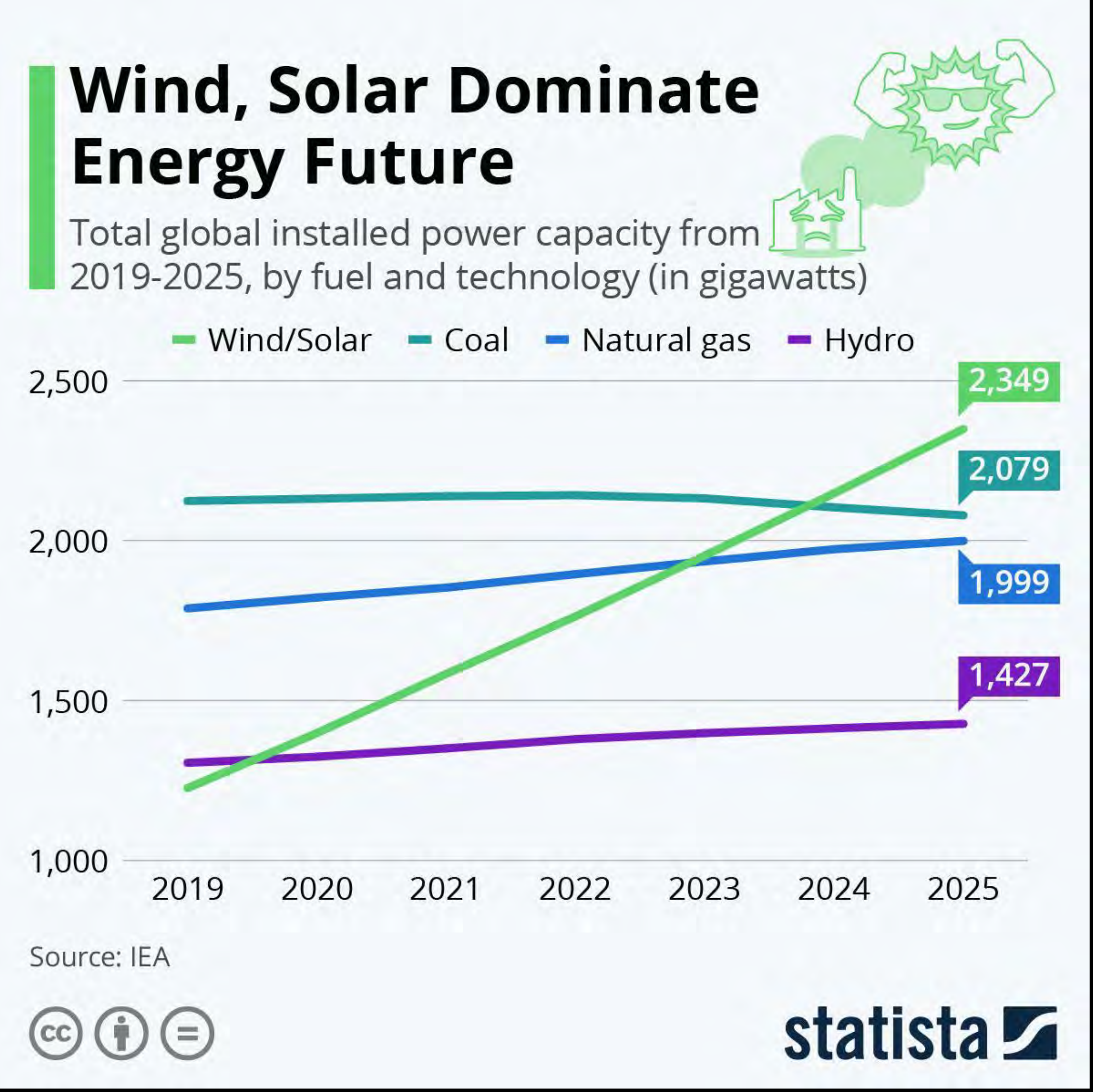
PROFESSOR: DR. KAI JIN

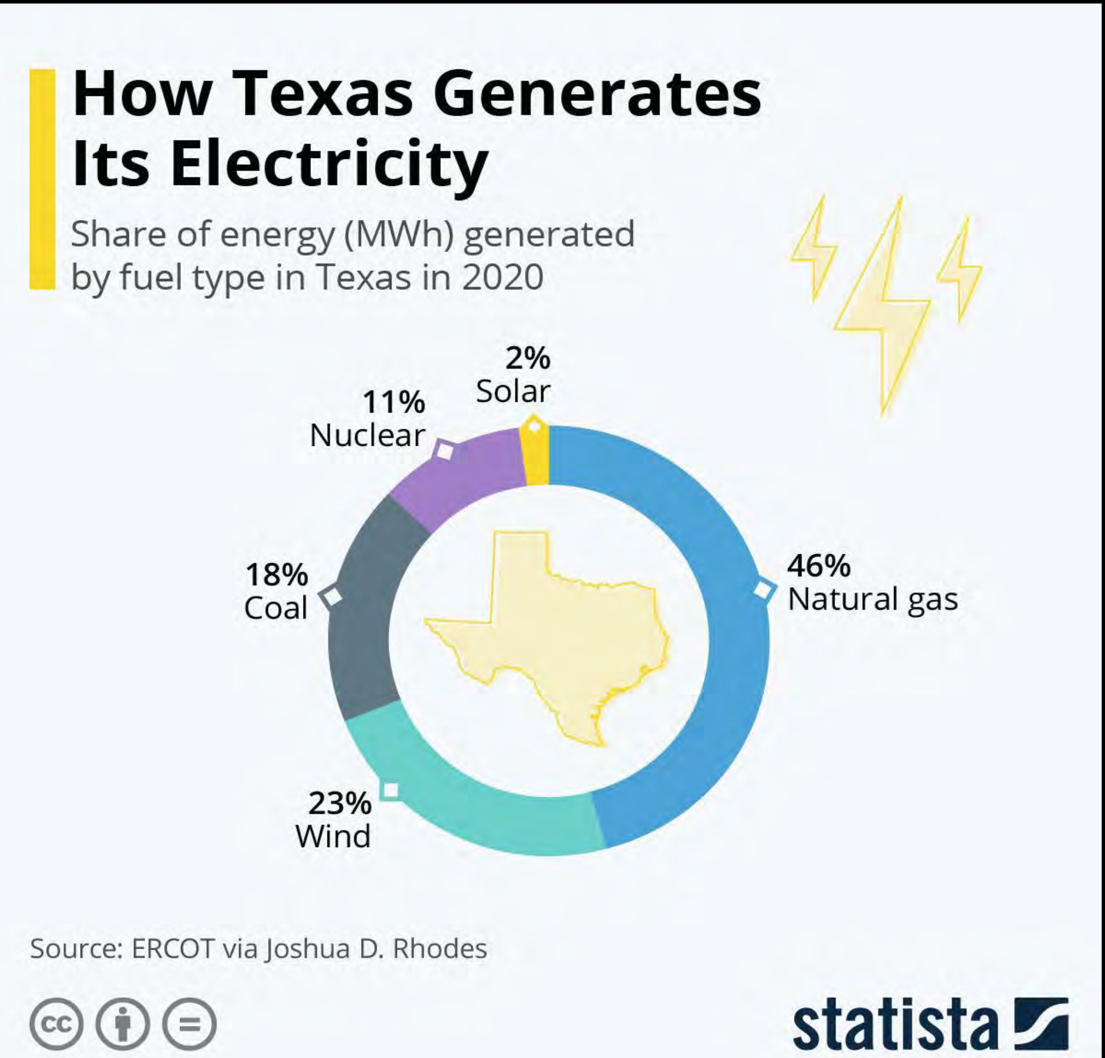
STUDENT MENTOR: THEOPHILUS ADU-AZUMAH

INDUSTRIAL ADVISOR: RICHARD

BACKGROUND RESEARCH

- Renewable energy has been rapidly growing in the past several decades.
- In recent years, electricity generated from wind turbines has surpassed coal as the second-largest contributor to energy production in the United States, underscoring its expanding role in the energy sector.
- Wind energy has emerged as a leading candidate among renewable energies due to its scalability, cost-effectiveness, and zero carbon emissions during operation.
- In the US, wind energy accounts for 10% of all energy, making it the largest renewable energy source. Texas is the current leader in wind energy, at approximately 22% of the Texas grid.
- Wind farms, particularly in regions like Texas, have seen a dramatic rise in capacity, driven by both policy incentives and technological advancements.





Background Research on Wake Effect

- The wake effect causes turbulence and wind speed loss in different areas of a wind farm, resulting in an overall reduction in power production.
- Wake losses can account for 10–20% of total energy production loss in large-scale farms.
- Wind turbines continue to rapidly increase in height with projections indicating hub heights exceeding 150 meters.
- Larger turbines are capable of accessing stronger and more consistent wind resources; however, they are also more susceptible to aerodynamic interactions, such as wake effects, which can significantly diminish downstream turbine efficiency.

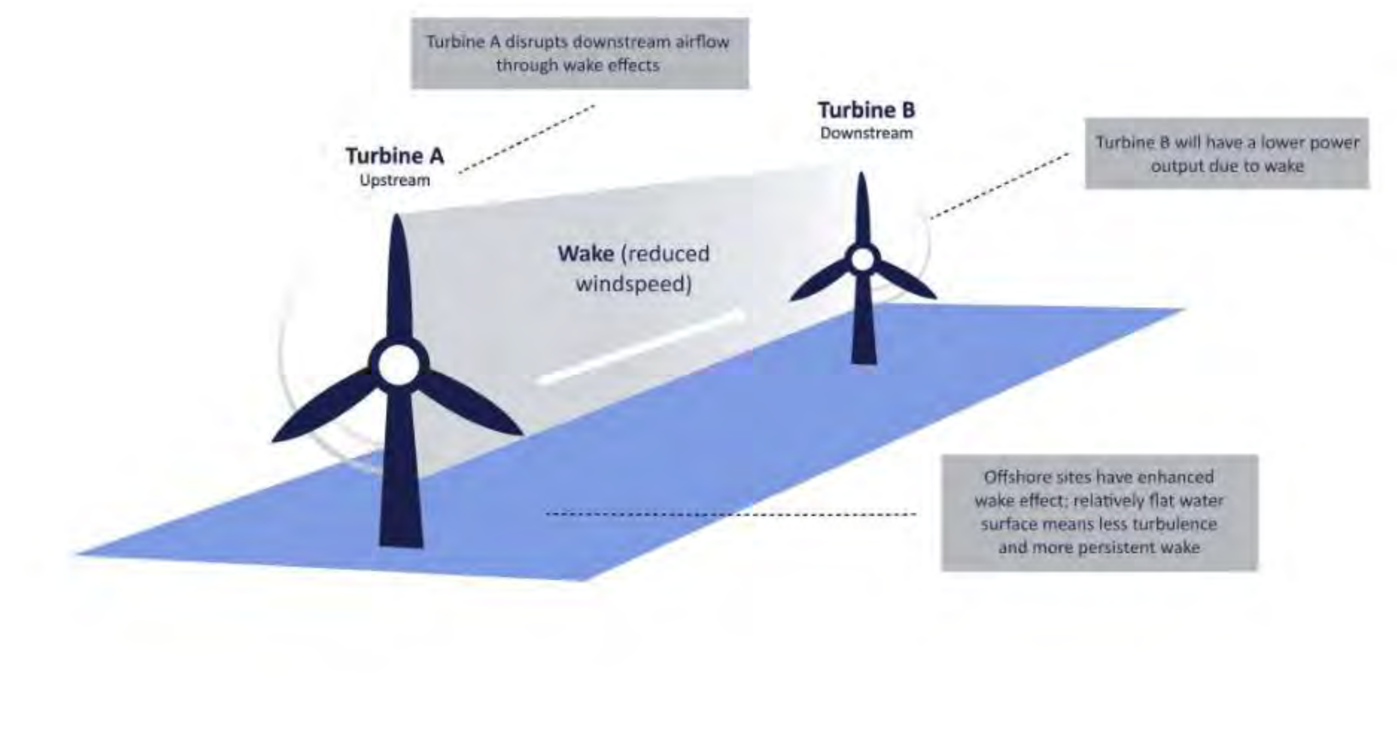


Figure 1. Displays model of wake effect on two linear turbines.

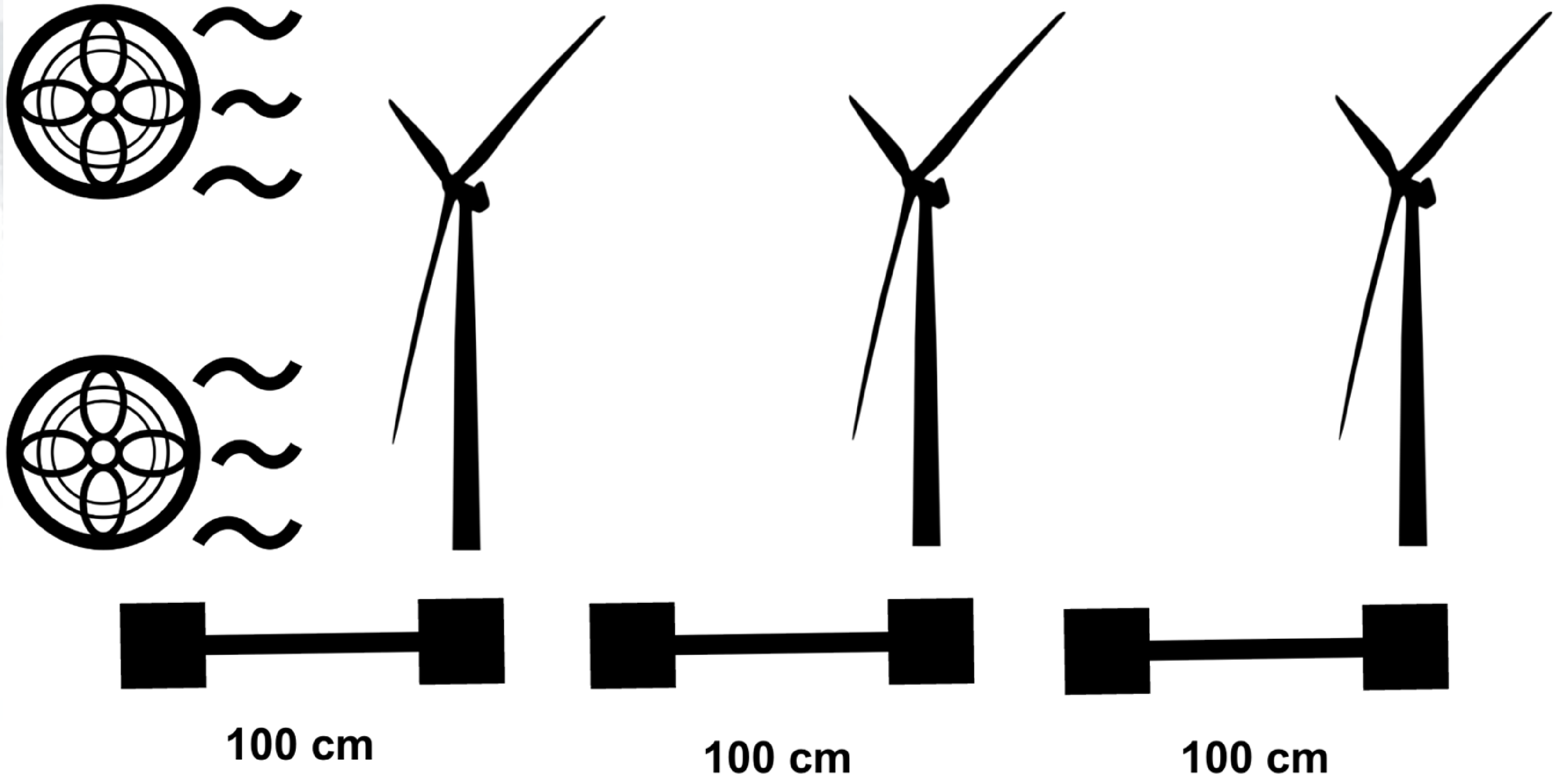
Research Objectives

- Investigate whether varying the vertical height of wind turbines can reduce the wake effect compared to using turbines at uniform heights.
- Investigate whether staggering the horizontal positions of turbines, combined with height variation, can further minimize the wake effect and improve overall energy output.
- Translating this research into hands on meaningful curricula for students across different grade levels.

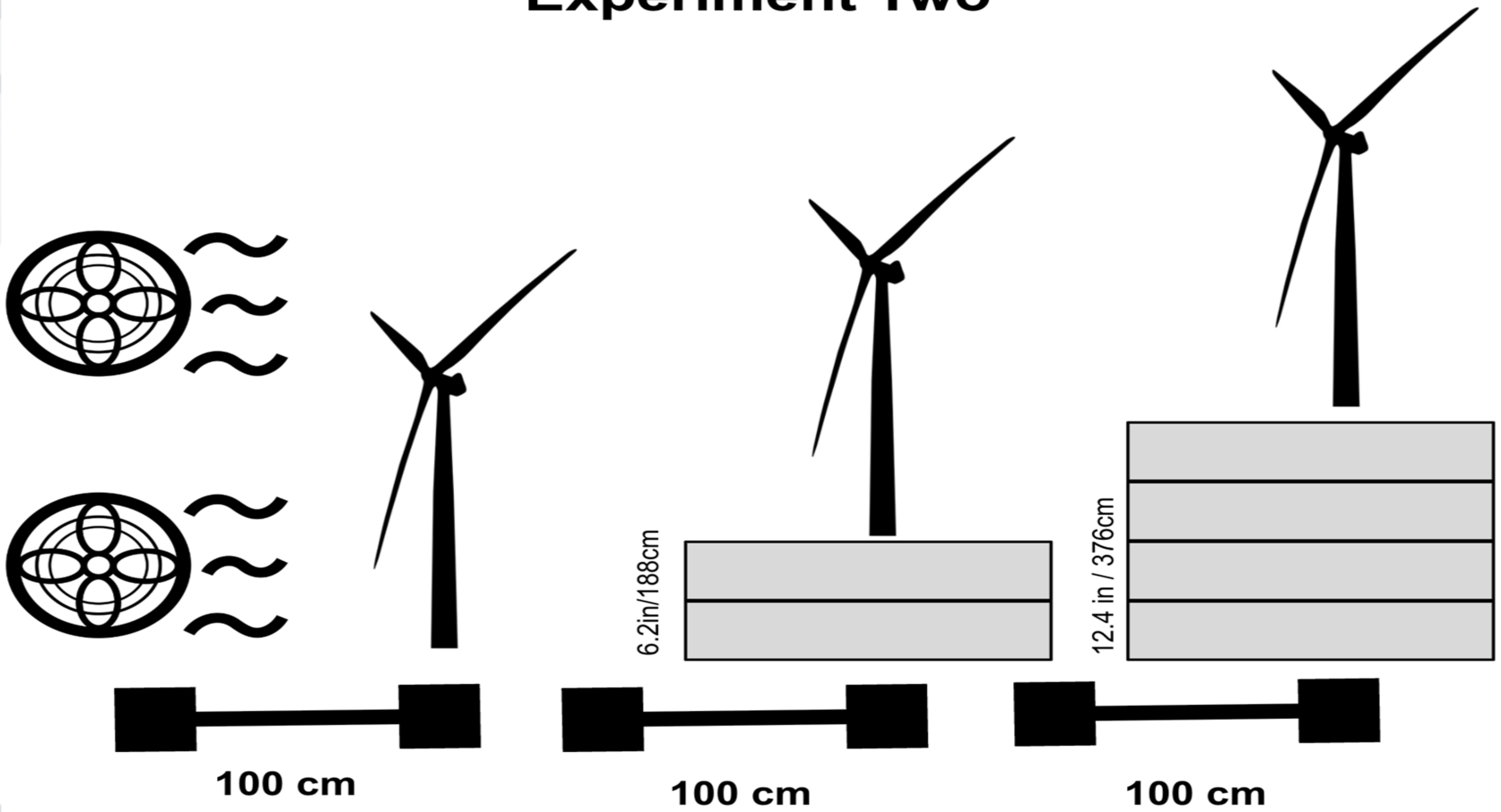
Equipment

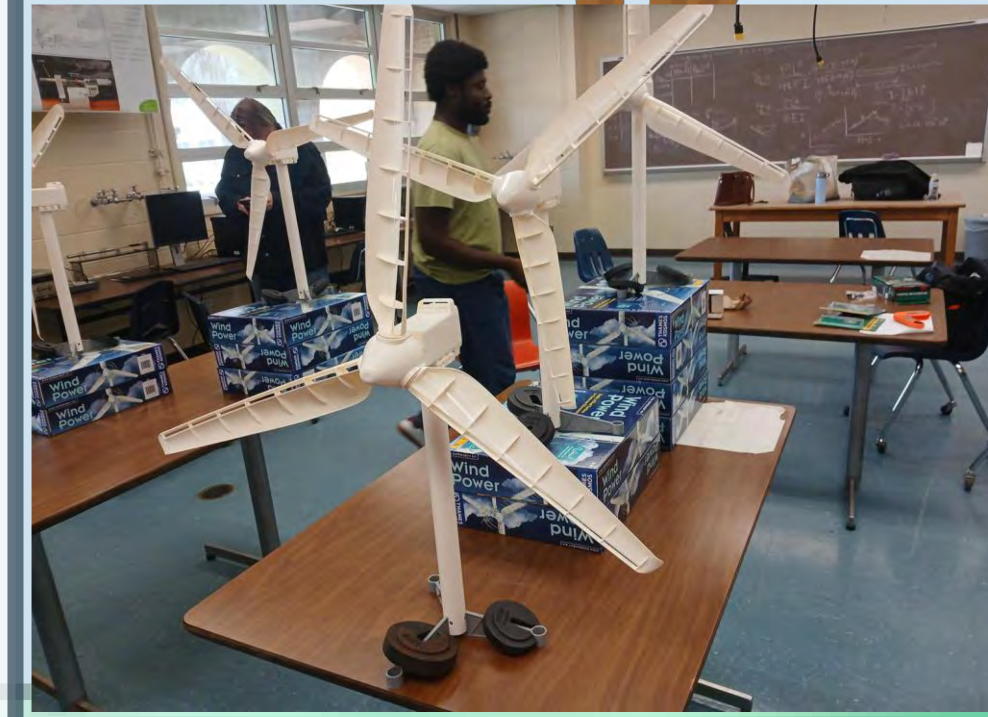
- Prototype wind turbines
- Adjustable platforms for variable height simulation
- Wind blower (to simulate wind conditions)
- Anemometer (to measure wind speed at different points)
- Multimeter (to measure voltage/current from turbines)
- Log Sheet/Data Sheet

Experiment One

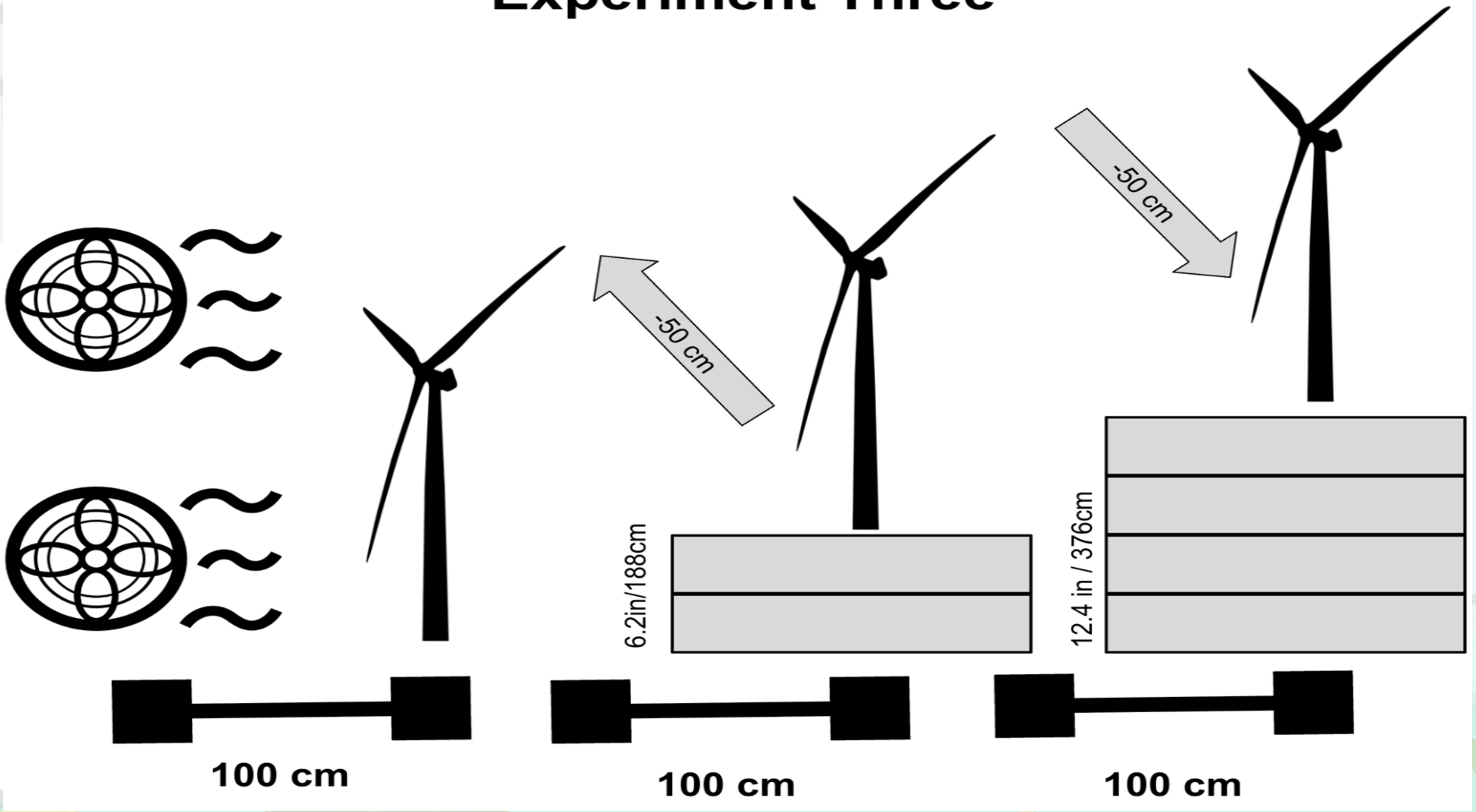


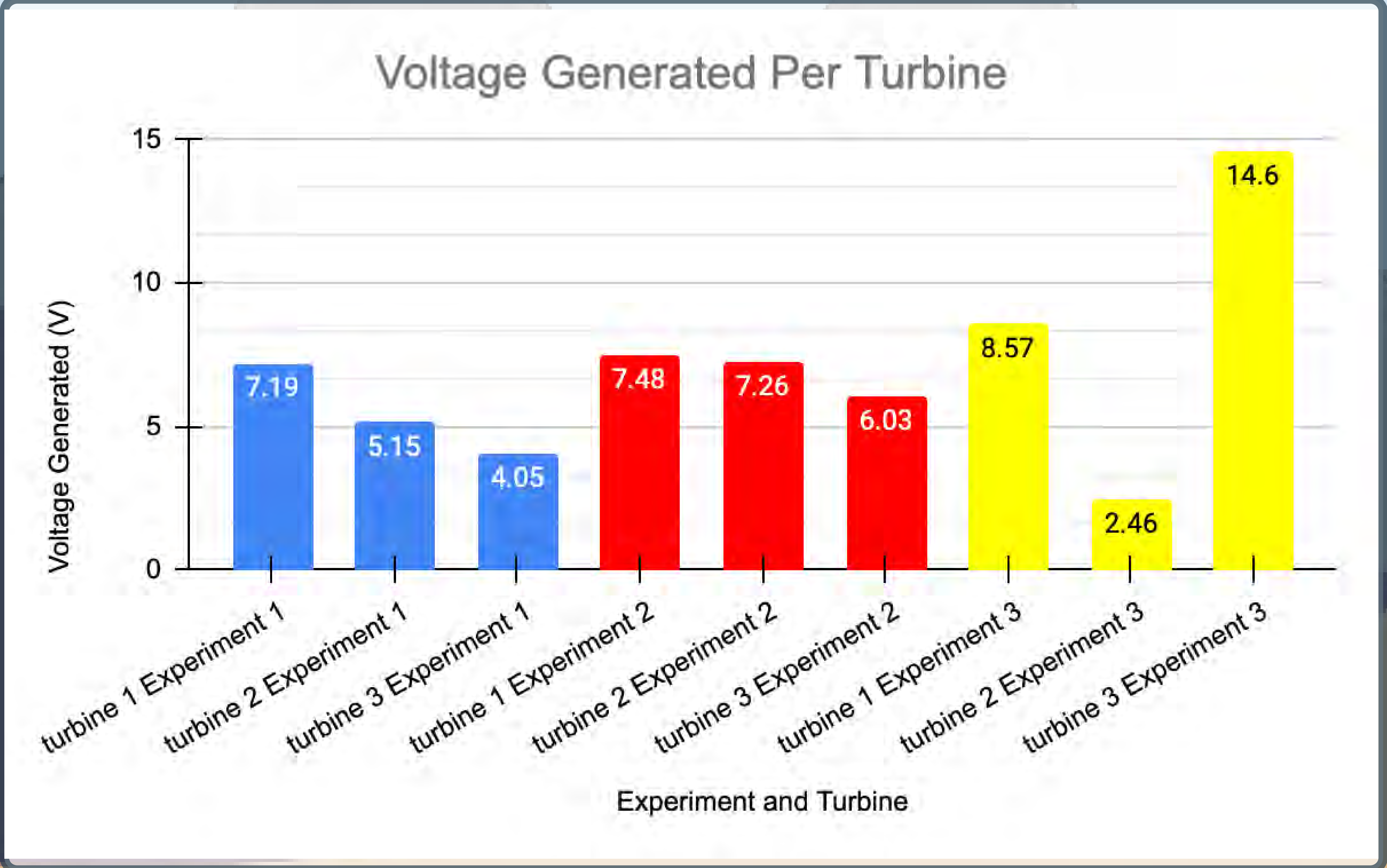
Experiment Two





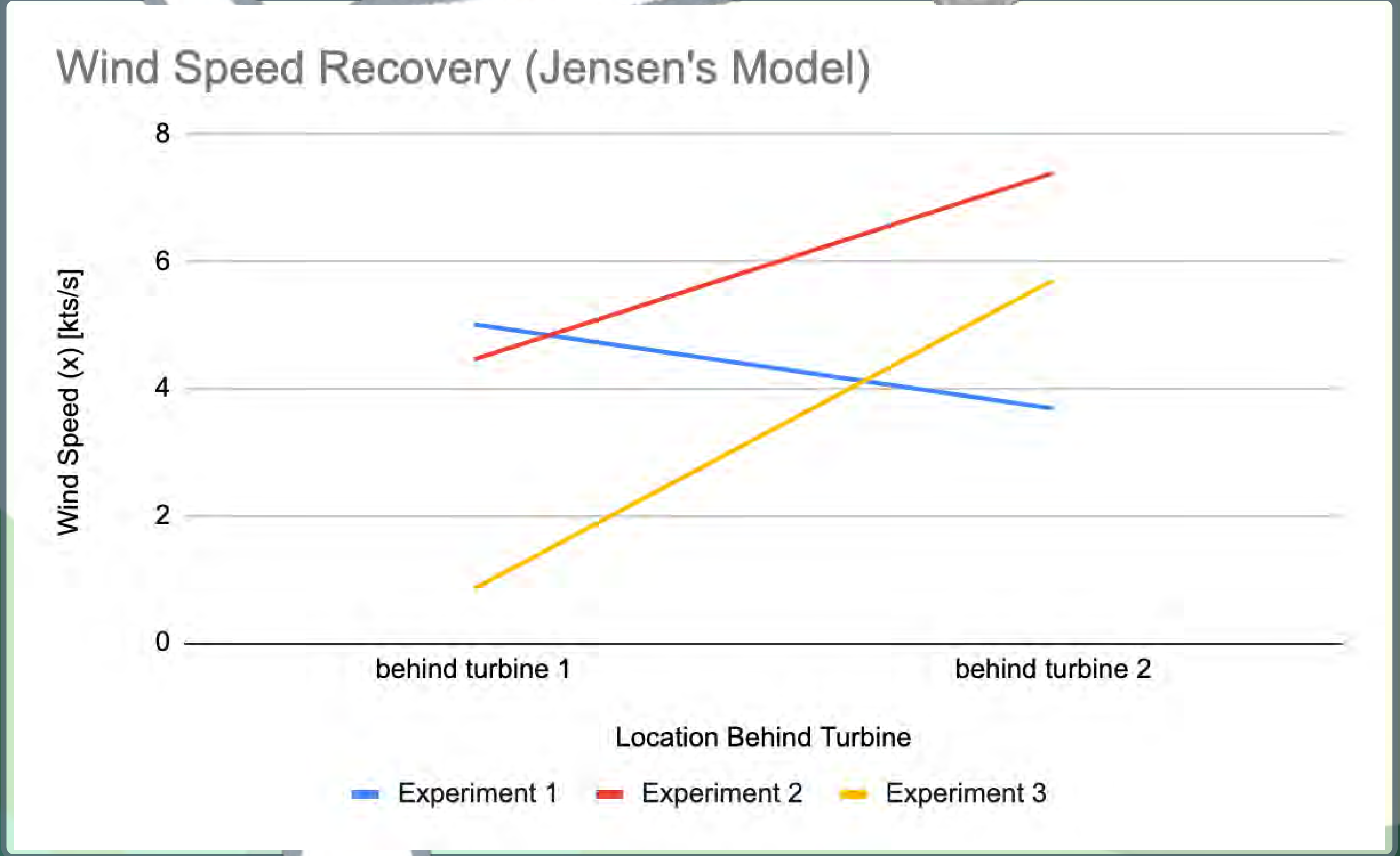
Experiment Three





- Experiment 1, shows a classic wake effect pattern with voltage and wind speed decreasing on each subsequent wind turbine. Each hub height remained constant meaning a turbulent wake was generated.
- Experiment 2, increased hub heights are utilized to reduce wake effect in Turbine 3, but generated a huge wake effect in turbine 2.
- Experiment 3, shows the most pronounced wake effect and the strongest recovery.

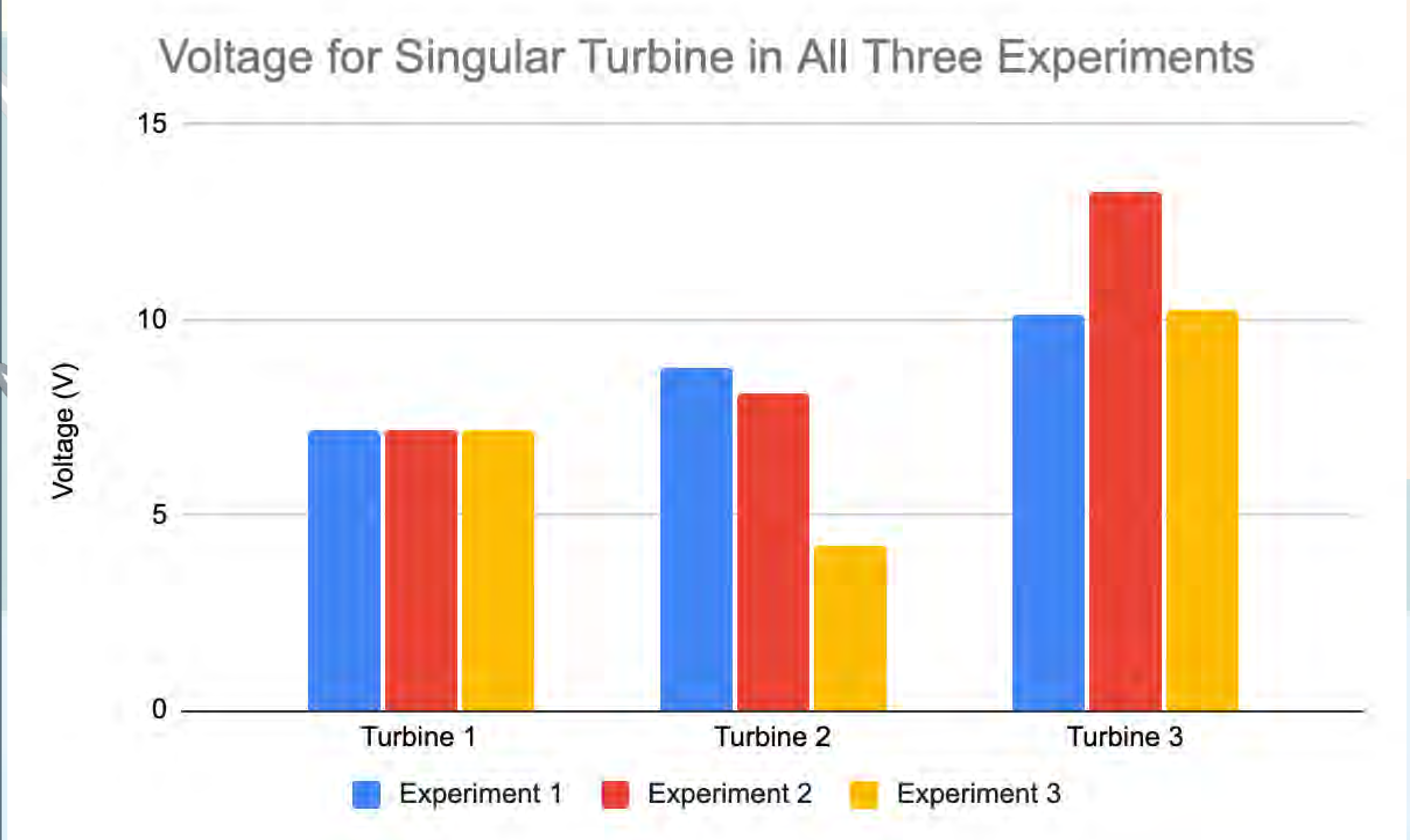
Jensen's Model

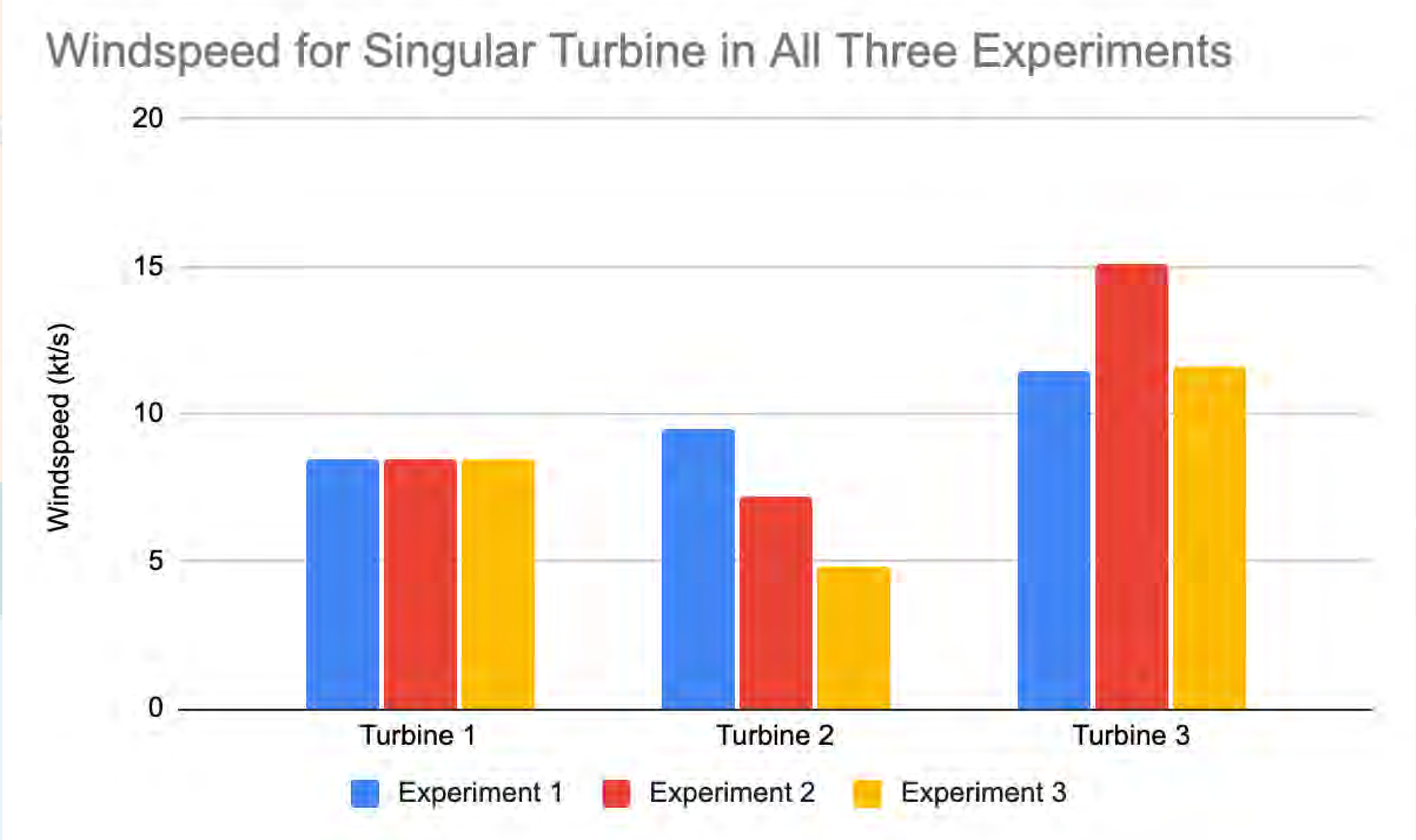


$$U_x = \left\{ U_0 (2a) \frac{2a}{1+\frac{\alpha x}{r_0}} \right\}^2$$

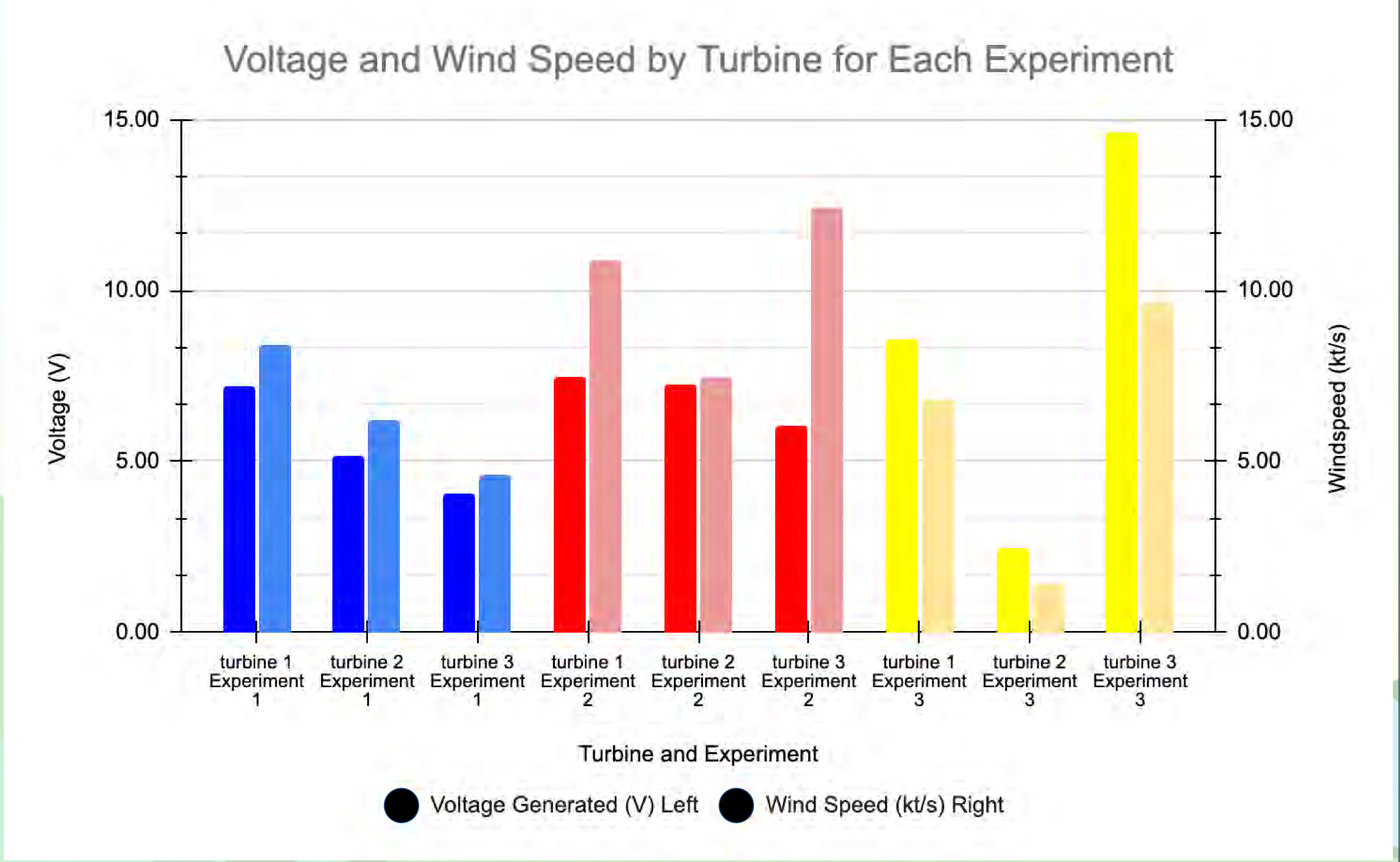
- Widely accepted tool in wind energy that simplifies complex aerodynamic interactions within a wind farm.
- Experiment 1, we see a standard, pronounced wake effect in turbine 2 and a cumulative wake effect in turbine 3.
- In Experiment 2, we see a decrease in wake effect with turbine 2. This shows that wind speed is increasing behind the second turbine. The increased vertical heights of each turbine helped flow recover before reaching turbine 2 and turbine 3, thereby mitigating waking effect.
- Experiment 3, turbine 2 demonstrated such a low value and then rebounded extremely high in turbine 3.

Singular Turbine for All Three Experiments





- The chart confirms the relationship between wind speed (kt/s) and average voltage (v) generated by the three wind turbines in all three configurations.
- In all three configurations turbine 2's wind speed and voltage decreased. Since there were no other turbines this was from the wind flow decreasing, not the wake effect.
- Turbine three consistently has the highest wind speed and produces the highest voltage output.
- This is likely due to the second fan's air flow combining with the first fans at turbine 3's location.



Overall

- Experiment 1, standard wake and compounding wake effect.
- Experiment 2, lessen wake effect and strong rebound for turbine 3.
- Experiment 3, had extreme wake effect in turbine 2 and strongest voltage generated in turbine 3.

Conclusions

- These findings suggest that while combined vertical and horizontal staggering holds promise, careful spatial optimization is critical to avoid unintended flow disruption, particularly in midstream turbine positions.
- Overall, the data underscores the potential of hub height variation as a low-complexity, passive solution for reducing wake effects and improving wind farm energy yield.
- Controlled classroom-based experiments using cost-effective, scalable materials, can provide a safe, fun learning experience for students.

Future Studies

- Need for further investigation into optimized linear and nonlinear layouts, particularly those that balance flow distribution across all turbine positions.
- Future research should incorporate more complex modeling tools, such as computational fluid dynamics (CFD)
- Explore additional variables including atmospheric stability, yaw control, and rotor diameter scaling to validate and extend the applicability of these findings to full-scale wind farm environments.

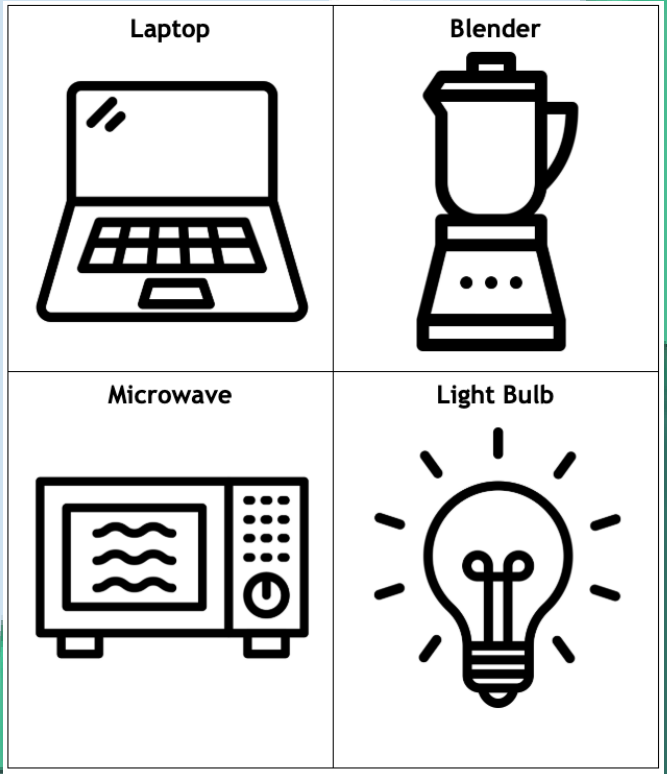
Curriculum Modules

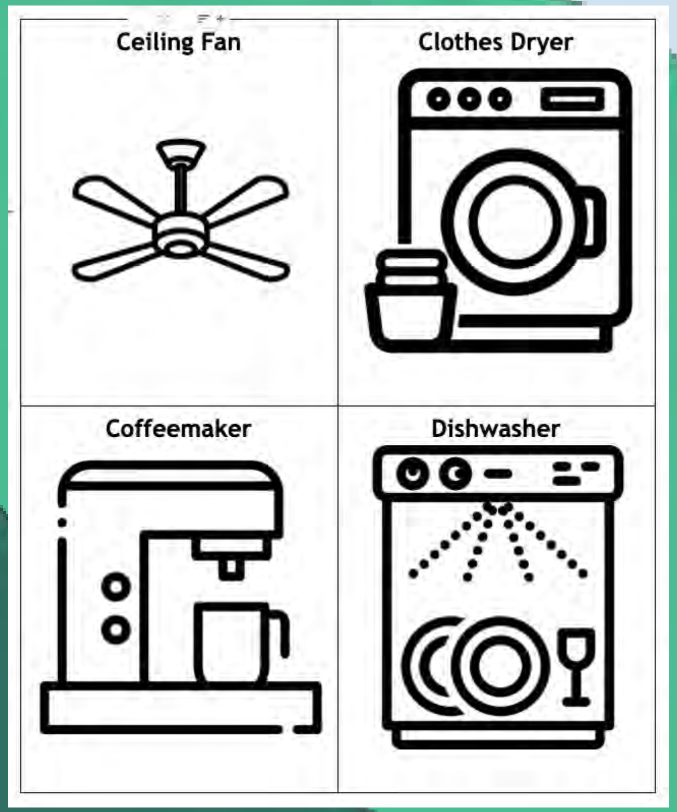
Modules will aid in student understanding of the following science and environmental biology principles:

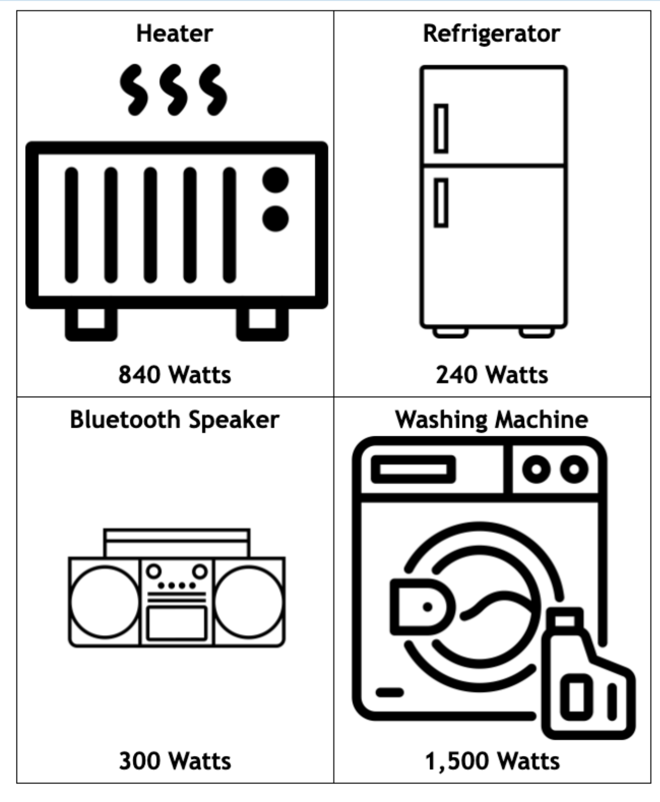
- Engineering design process
- Renewable Energy
- Energy Generation using wind power

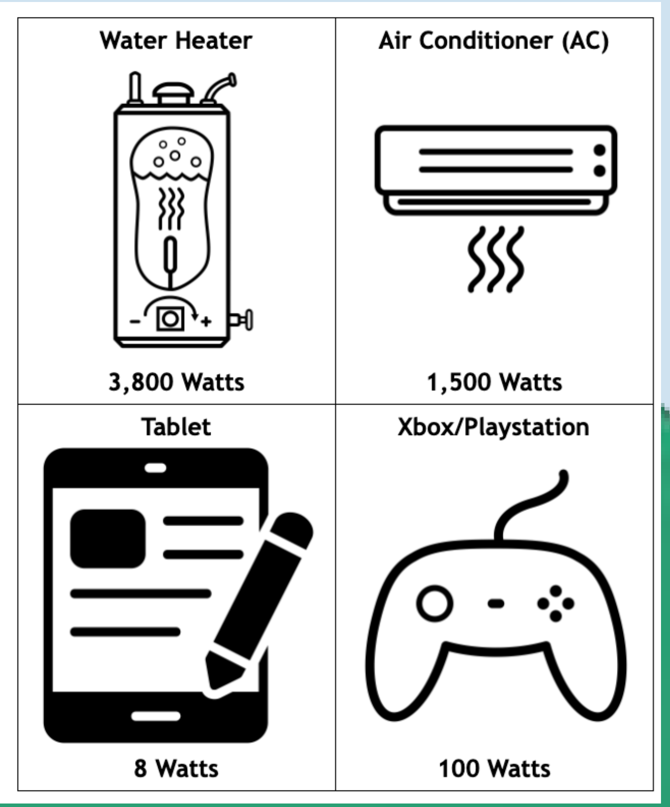
Lesson 1: Energy Card Sort

- Students will be able to begin to understand that devices we use everyday require electrical power.
  - Students sort items in order of least energy expensive to most energy expensive.
  - Students calculate how much energy they use on a daily basis.



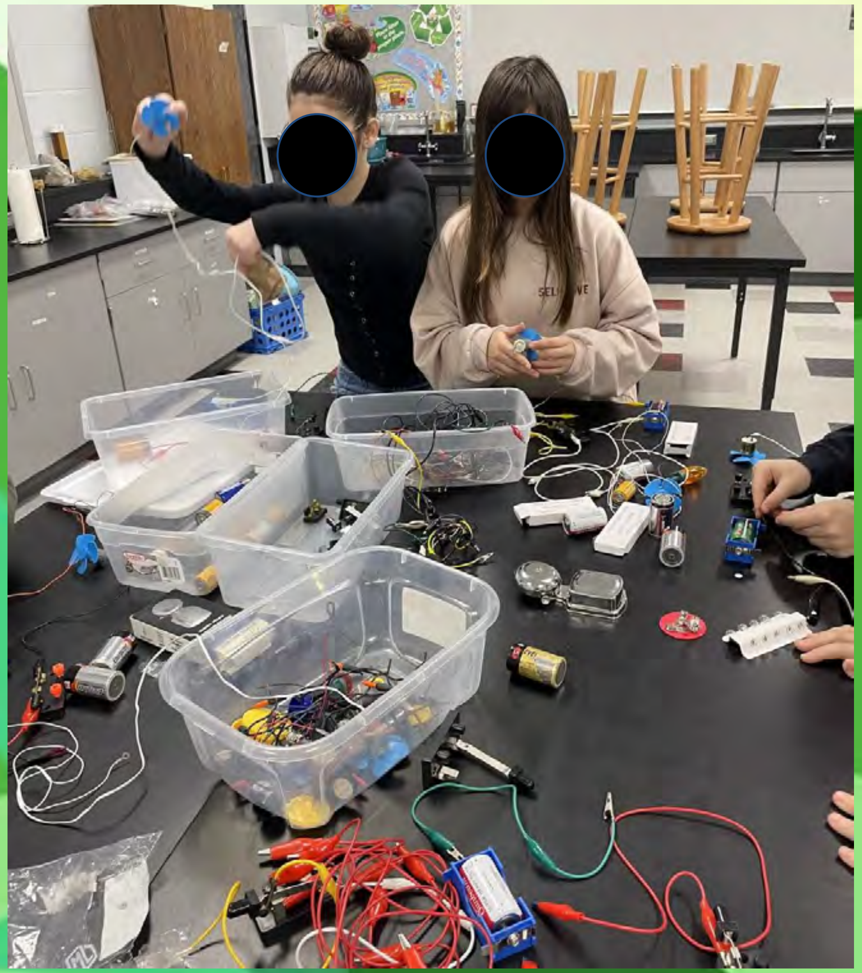


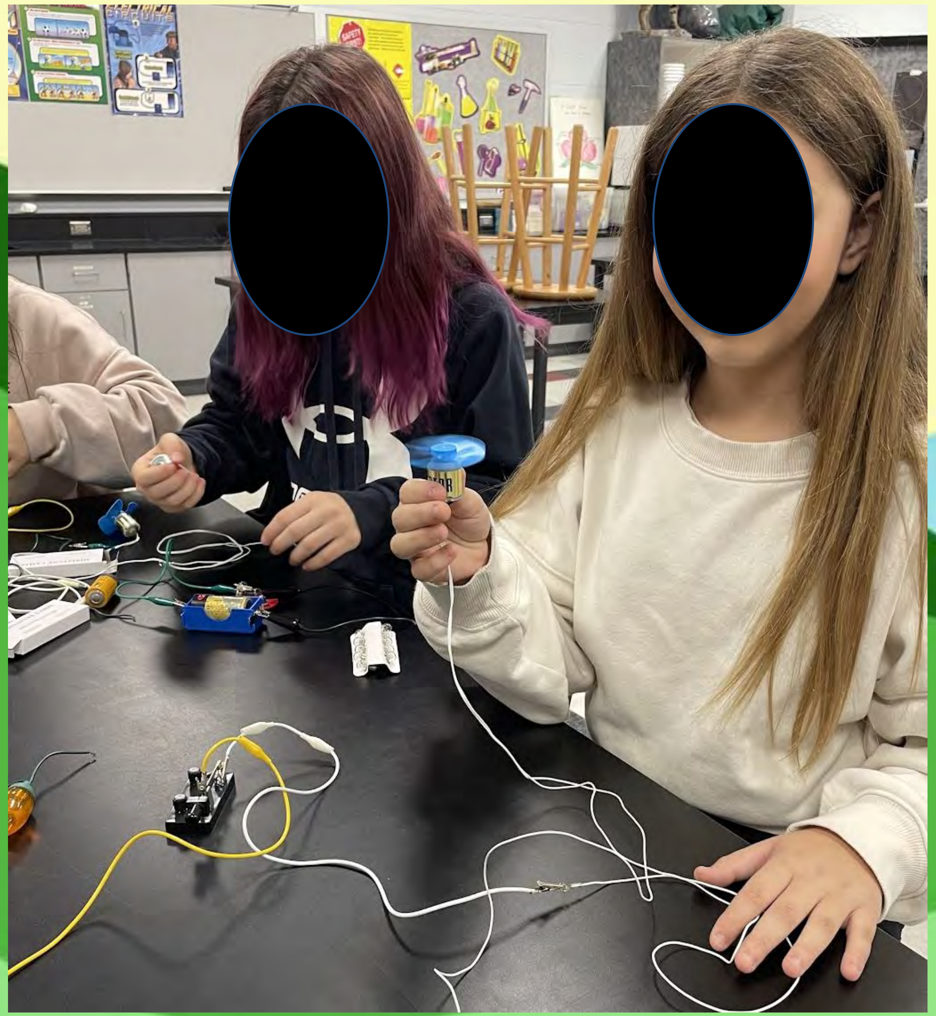


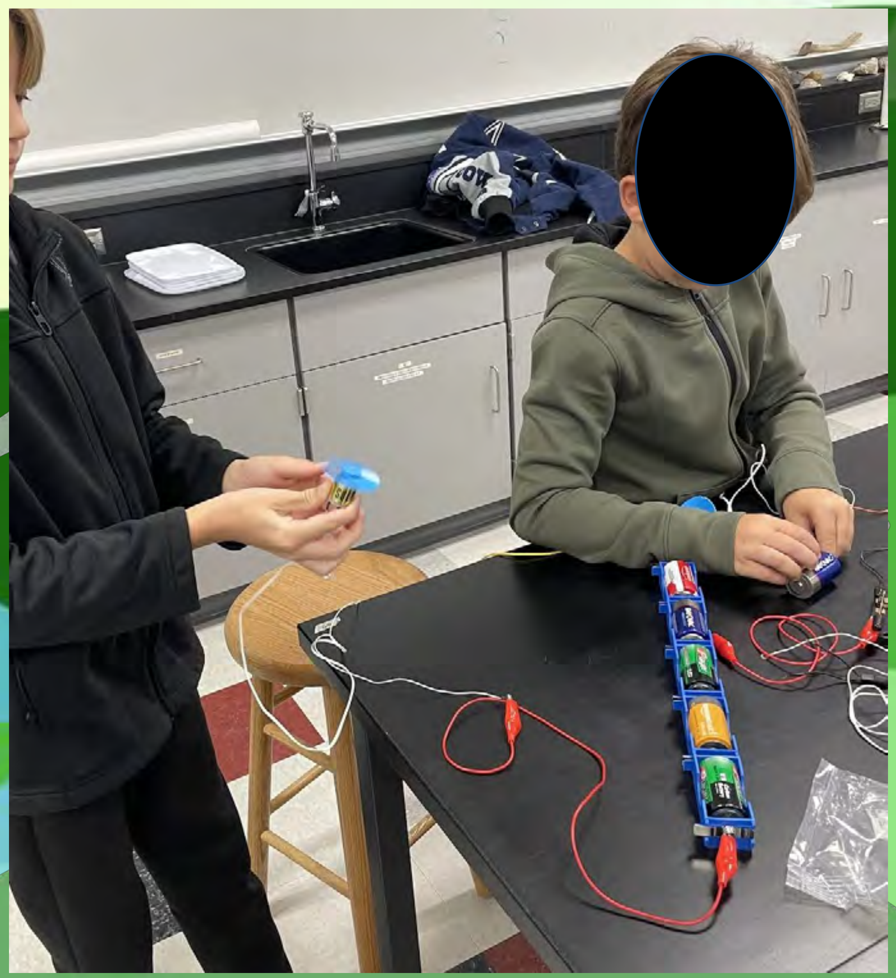


Lesson 2: Circuit Building Using Wind Turbine

- Students will be able to build basic circuits using energy generated by wind turbines and understand that wind energy can be used in place of traditional electricity such as batteries. energy they use on a daily basis.







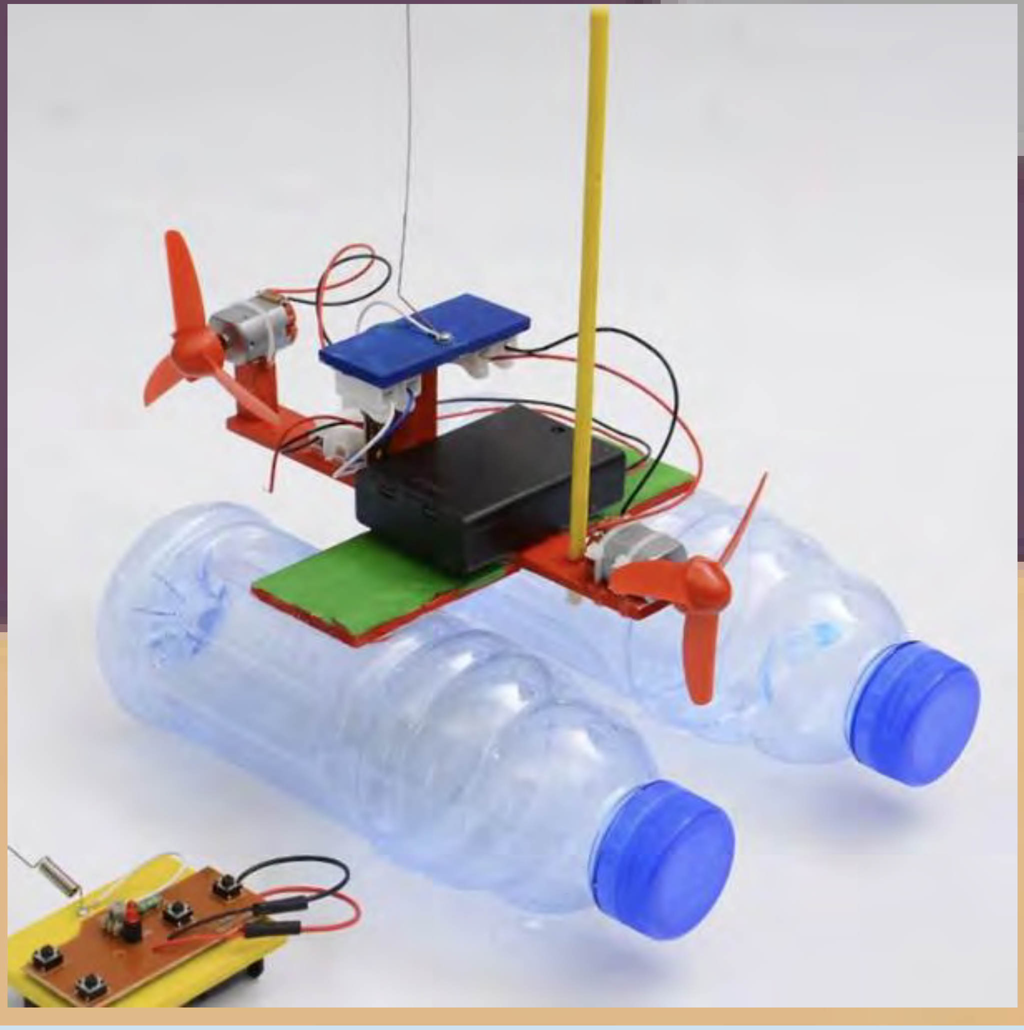
Lesson 3: Measuring Power Generation

From Placing Turbines at Various Locations

- Students will measure wind output at different locations around their school and determine the best location using data collected.

Lesson 4: Create Cars, Boats, and Other Items Using Wind Turbines

- Students will create different boats and cars using the engineering process.



Lesson 5: Create a model of an offshore wind Turbine

- Students will design and test out a floating wind turbine

THANK YOU

Acknowledgement

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