Efficient placement of vertical-axis wind turbines

Hyogo Prefecture, Kakogawa Higashi High School
Science & Math Course　Science Research **Group 2**

Introduction

Horizontal-axis wind turbine

- High power generation
- High noise generation
- Large land area needed

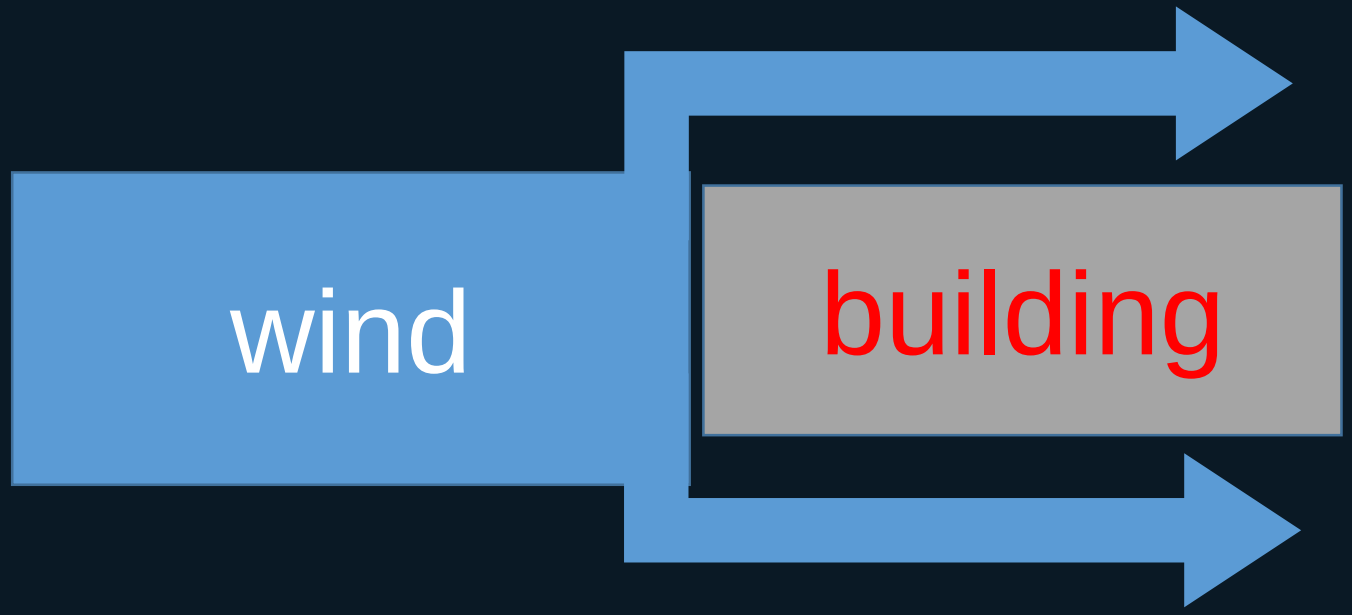
https://engoo.com/app/words/word/turbine/ks8rjzLFTau30iYYJyhiyw

Vertical-axis wind turbine

- Low power generation
- Low noise generation
- Small land area needed

https://www.es.sus.ac.jp/demae/

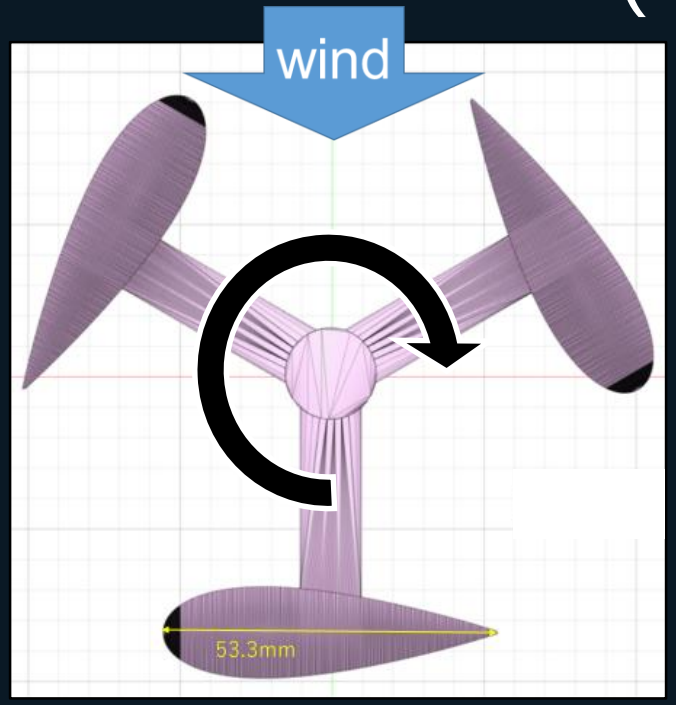
Introduction



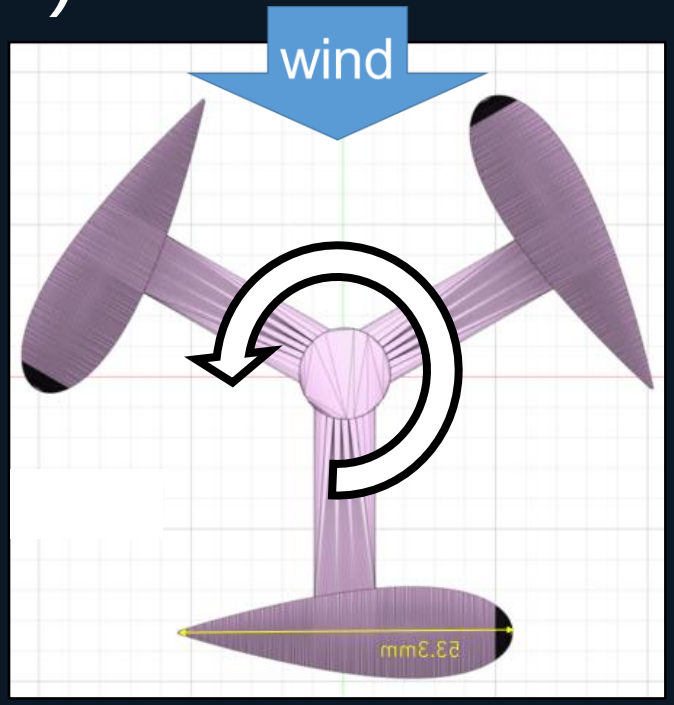
bird's eye view

3-D Printed vertical-axis wind turbines

Computer Aided Design (CAD)

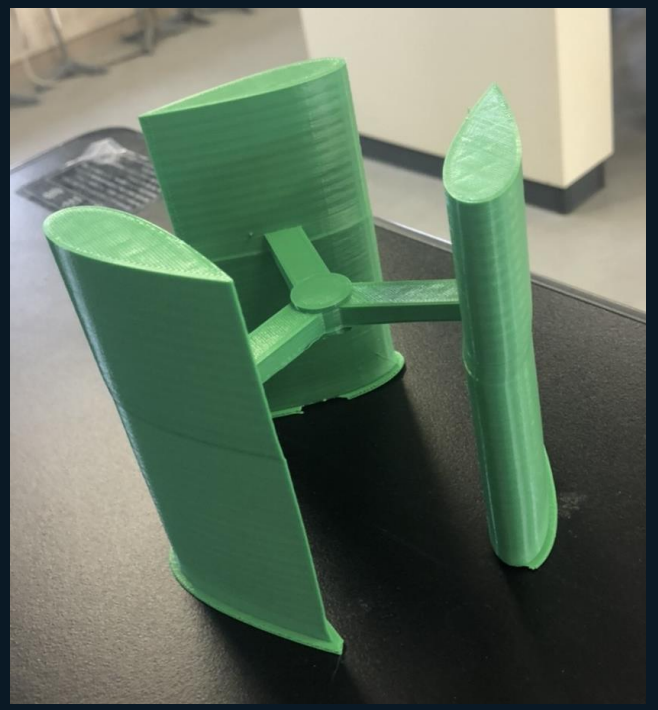


clockwise wind turbine



anticlockwise wind turbine

3-D Printed



experimental turbine

Preliminary experiment 1

Electrical power generated by the rear wind turbine

Front turbine

Measurement position 1

Rear turbine

Preliminary experiment 1

Electrical power generated by the rear wind turbine

Front turbine

Rear turbine

Measurement position 2

Preliminary experiment 1

Electrical power generated by the rear wind turbine

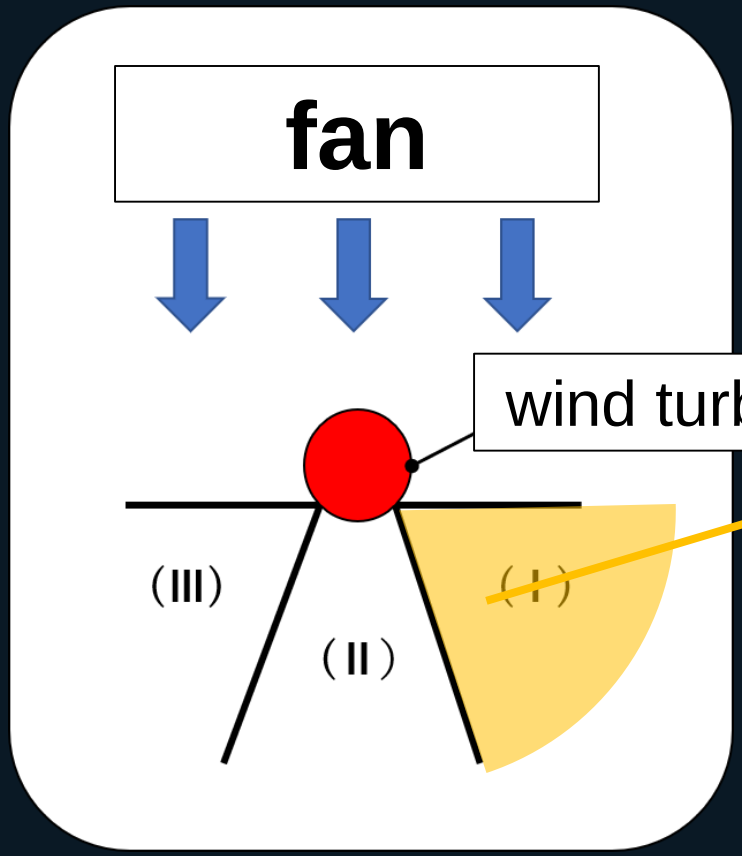
Front turbine

Rear turbine

Measurement point 3

Preliminary experiment 1

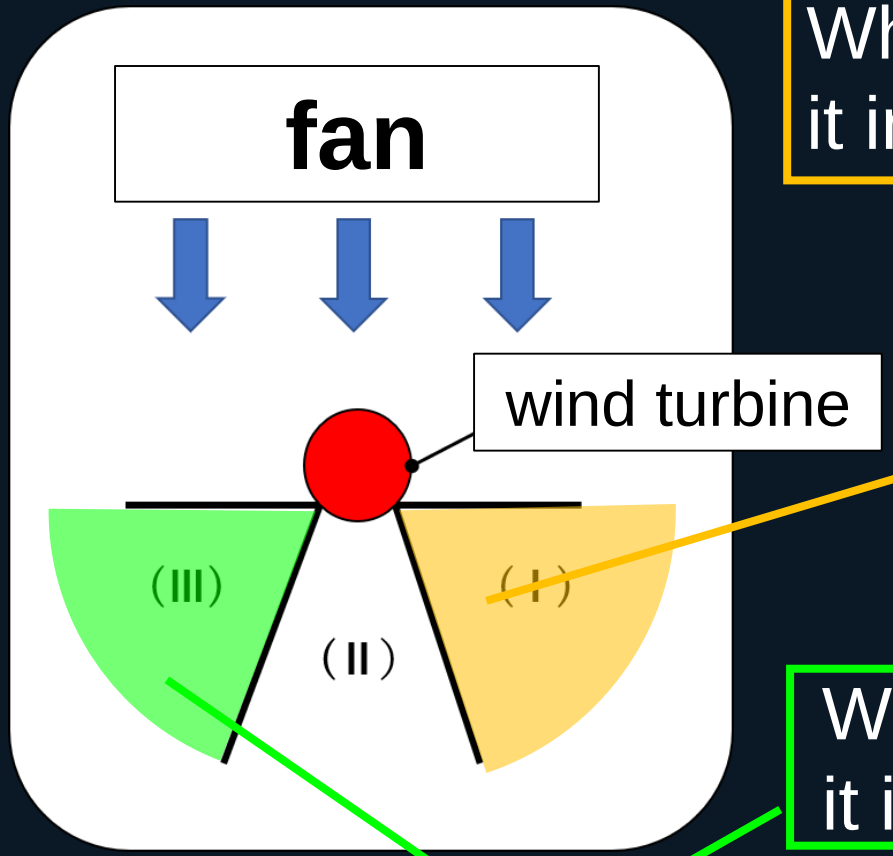
Power generated by the rear wind turbine



When the front wind turbine turn clockwise,
it increases the wind speed in area (Ⅰ).

Preliminary experiment 1

Power generated by the rear wind turbine



When the front wind turbine turn clockwise,
it increases the wind speed in area (Ⅰ).

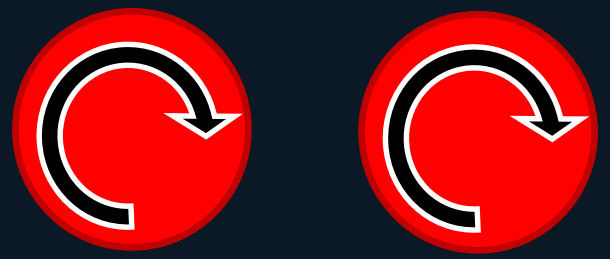
When the front wind turbine turns anticlockwise,
it increases the wind speed in area (Ⅲ).

Preliminary experiment 2

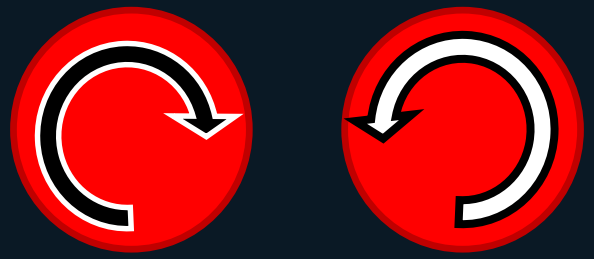
Spin direction of turbines

wind

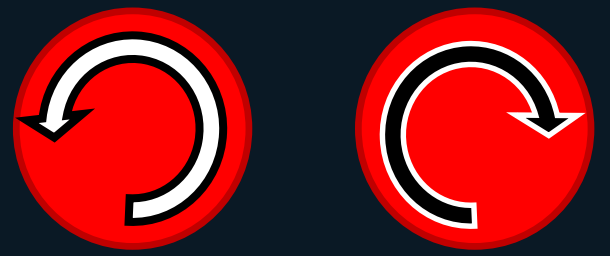
（1）both spin in the same direction



（2）both spin inwards

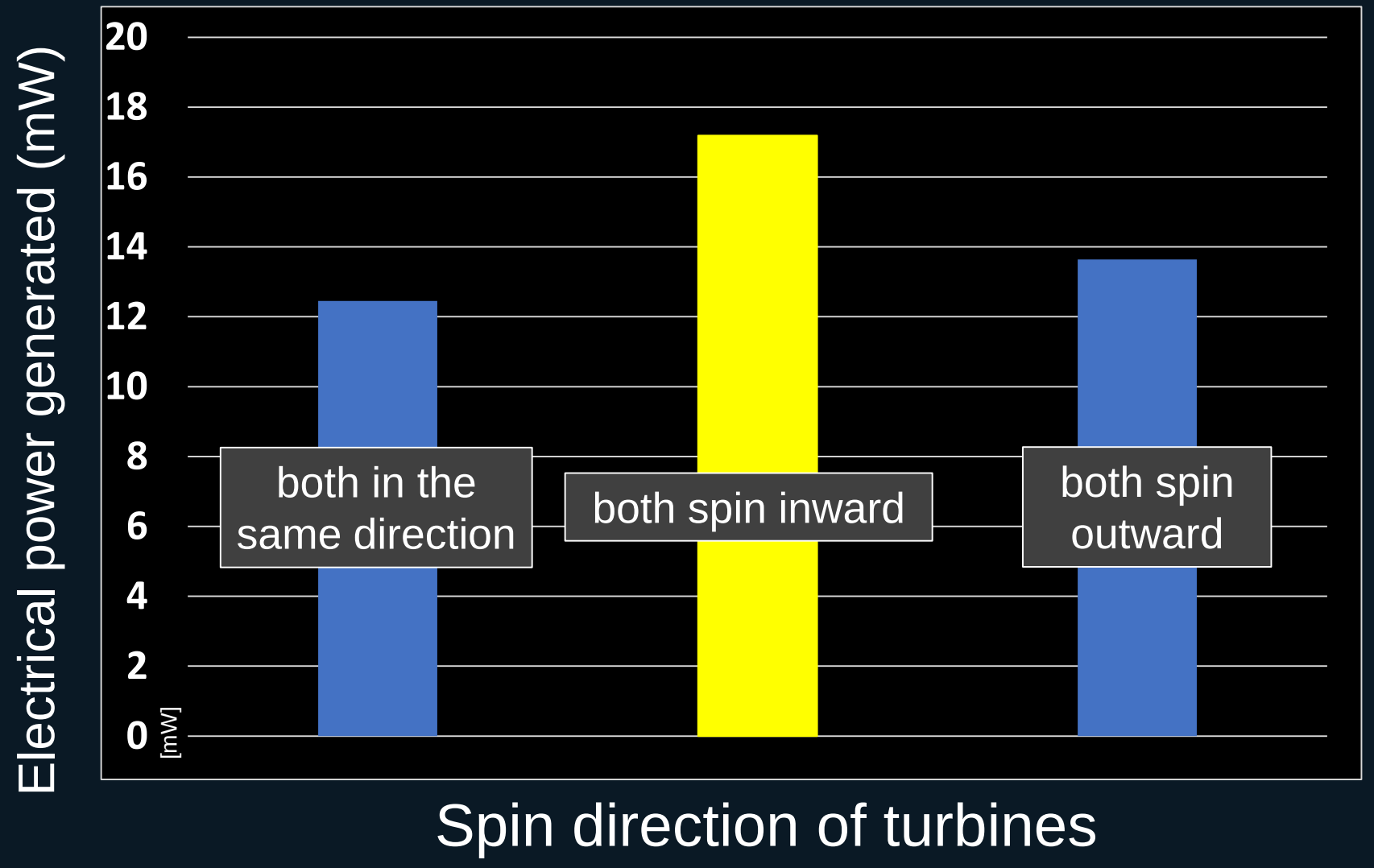


（3） both spin outwards



Preliminary experiment 2

Electrical power generated for each direction of turbine spin



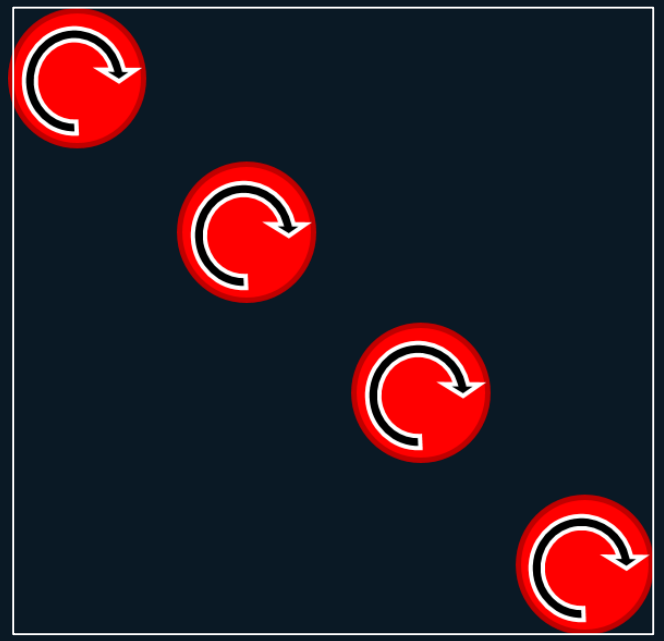
Experiment 1 5 sets of turbine arrangements

4 turbines per set

set 1

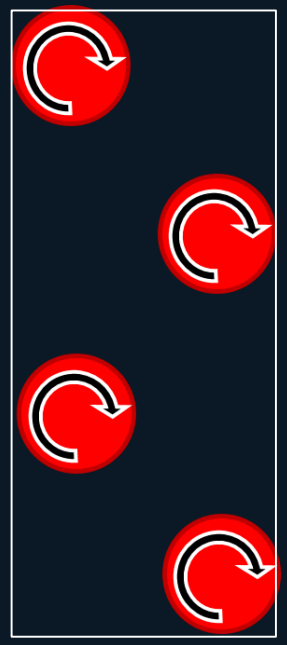
vertical

set 2



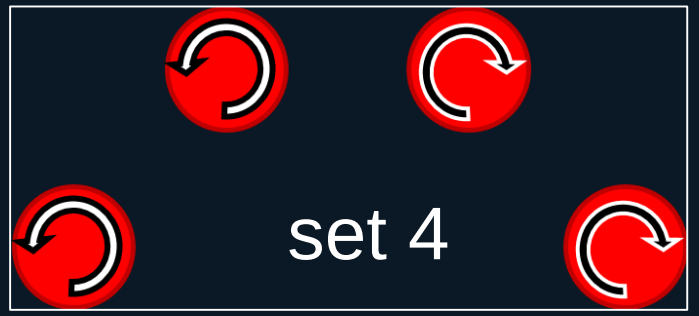
diagonal

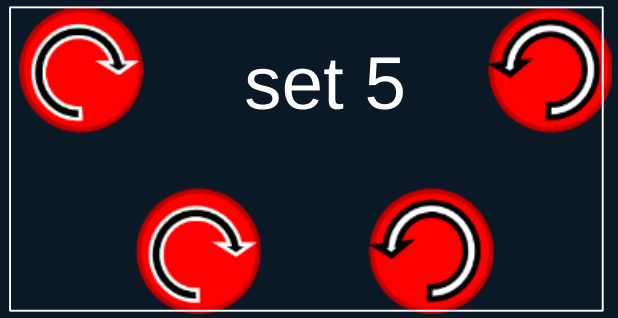
set 3



zig zag

V-shaped

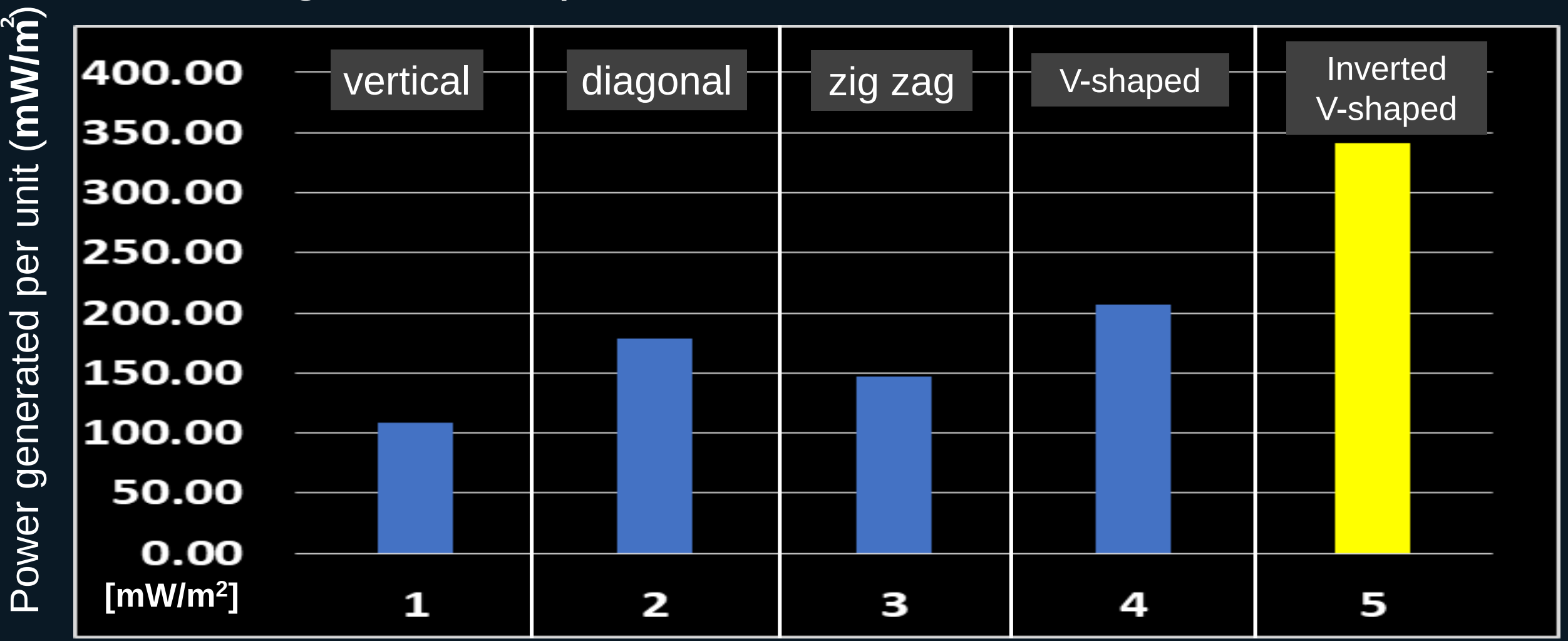




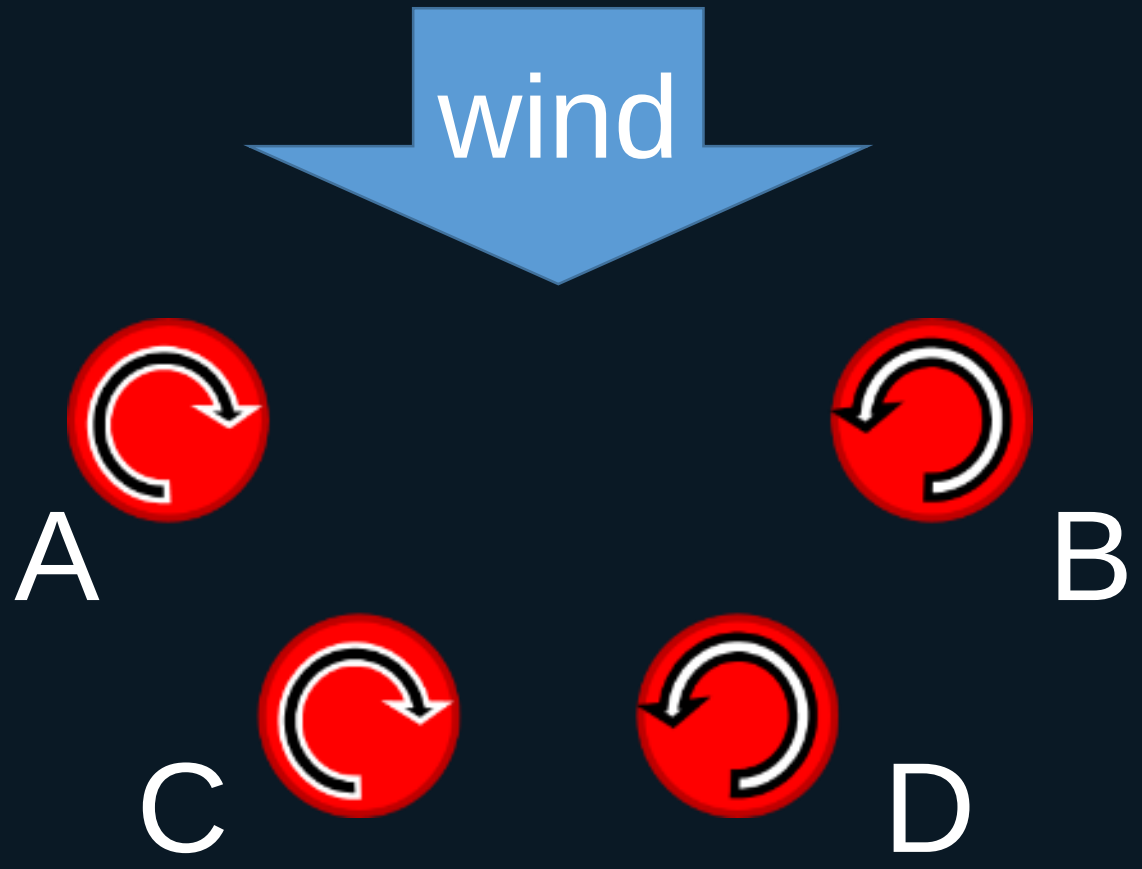
inverted V-shaped

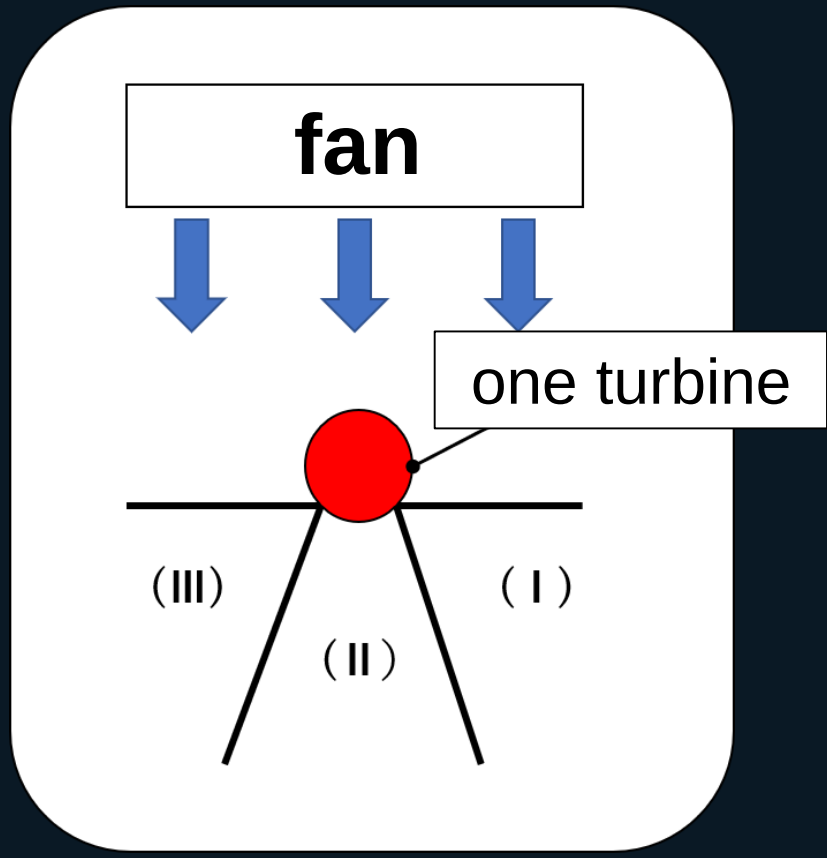
Experiment 1 5 sets of turbine arrangements

Power generation per unit area for each set of turbines



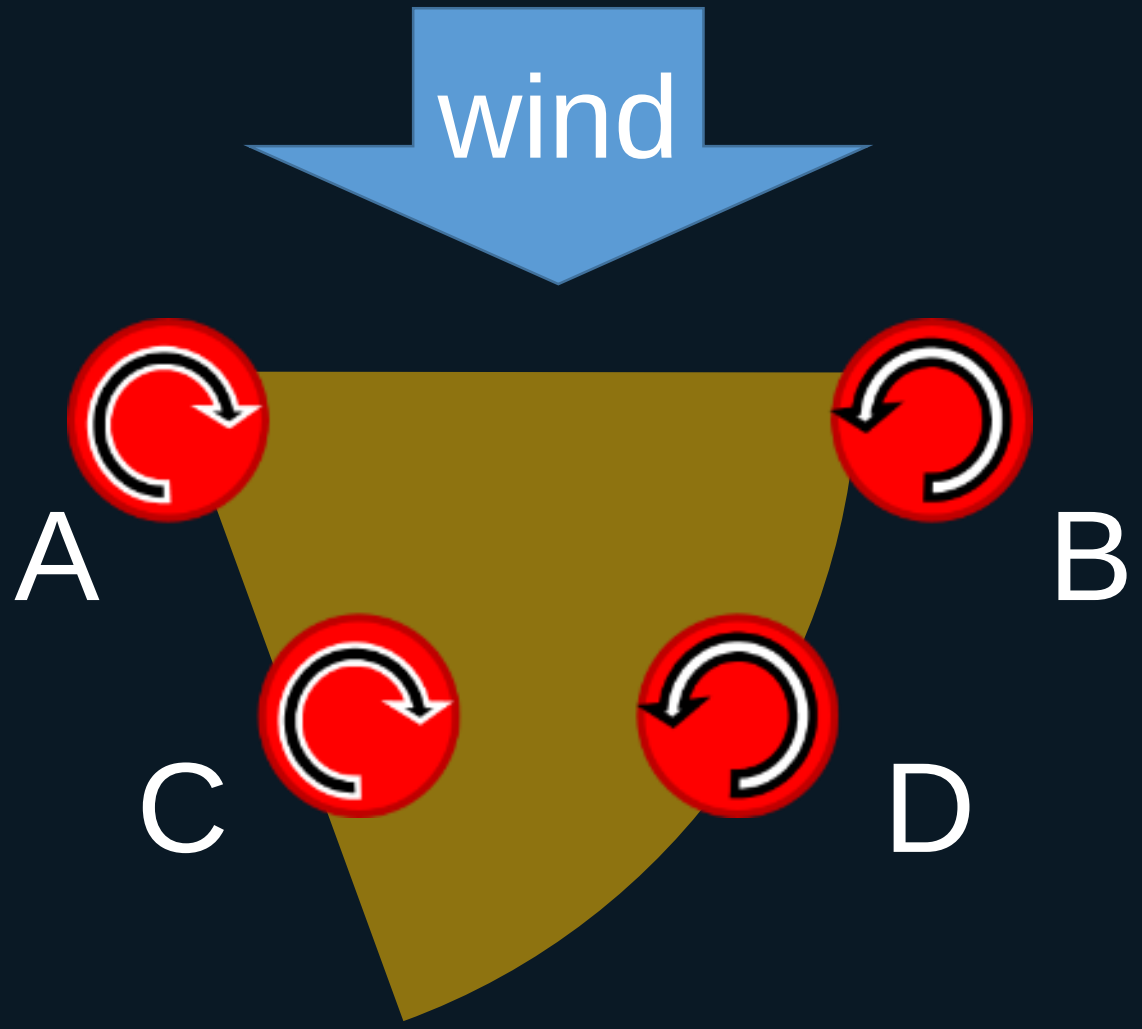
Experiment 1　5 sets of turbine arrangements

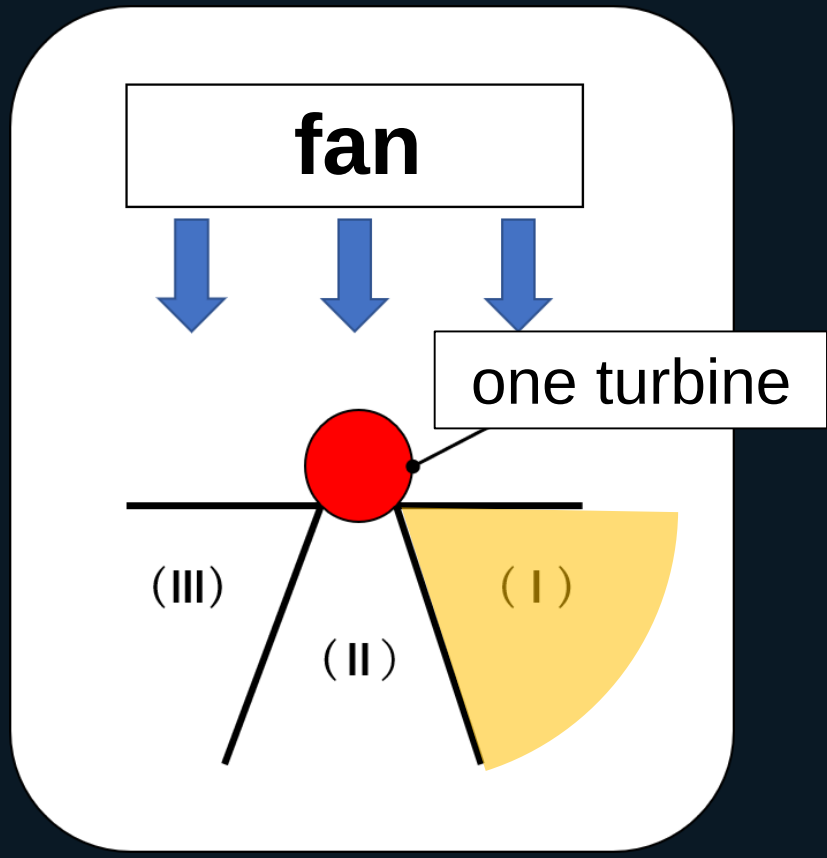




4 turbines per set

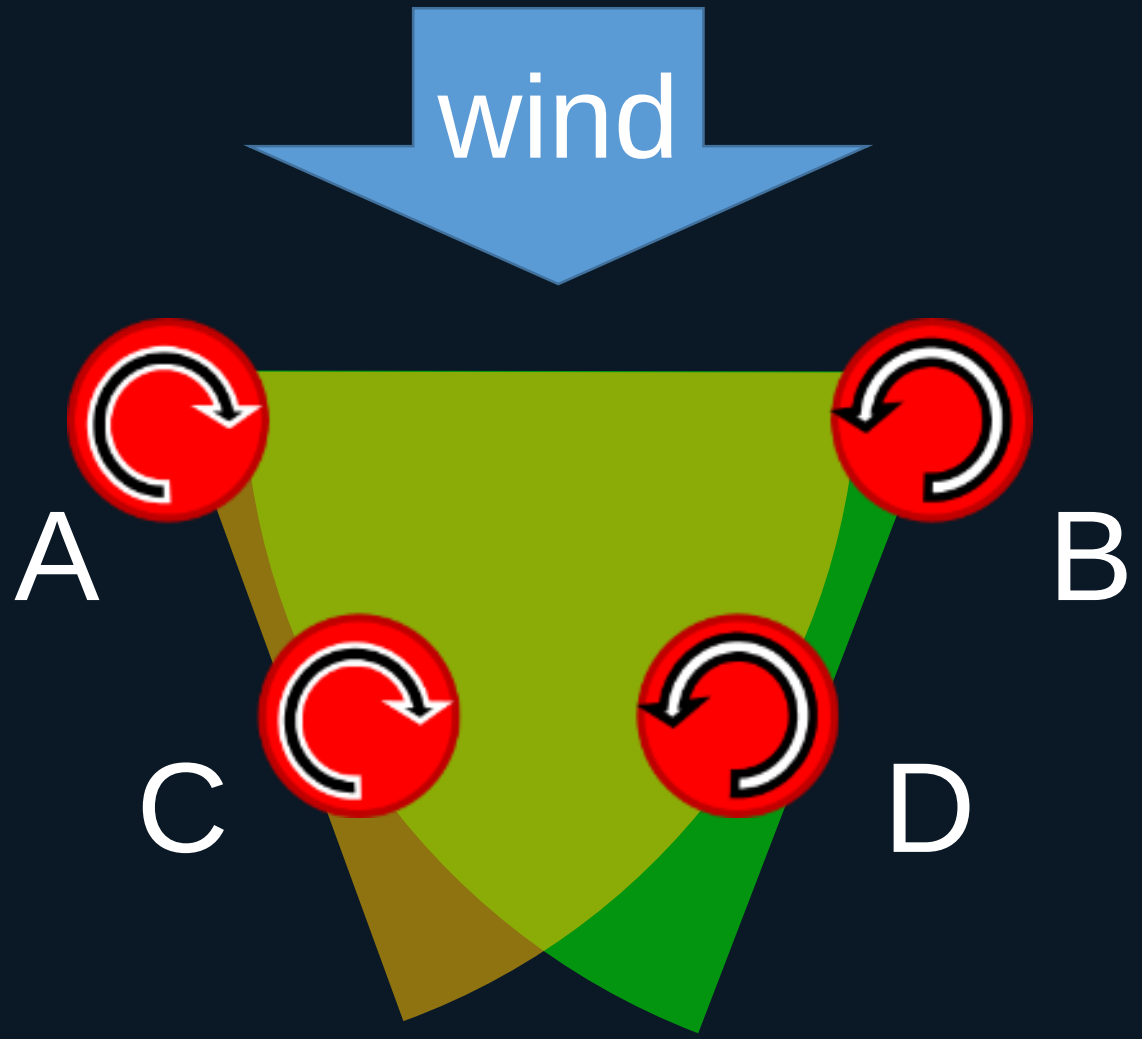
Experiment 1　5 sets of turbine arrangements

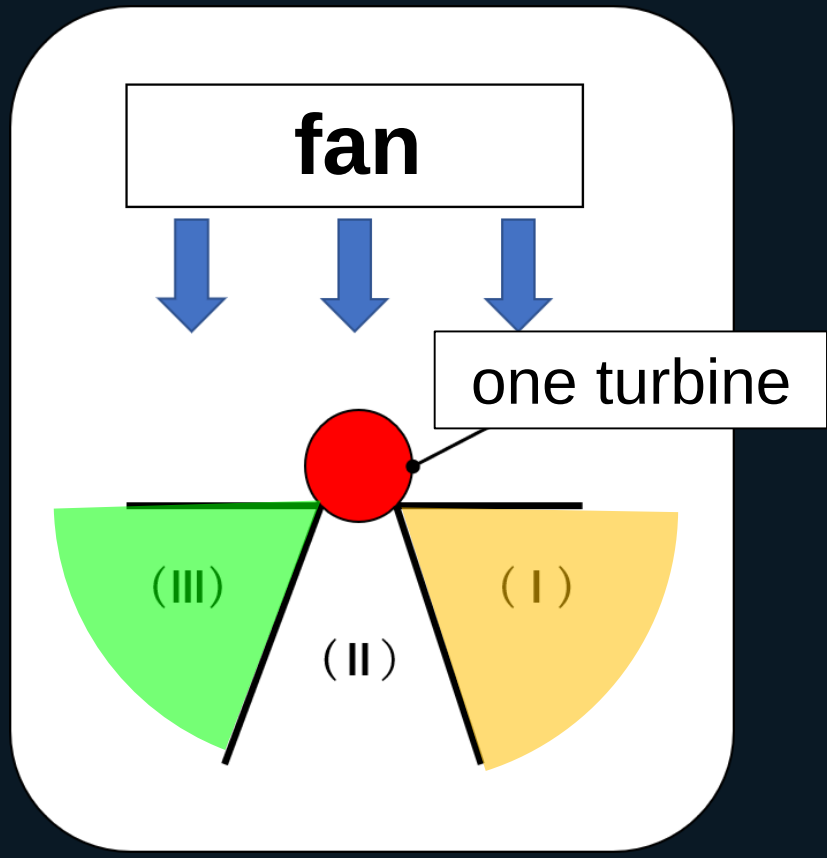




4 turbines per set

Experiment 1　5 sets of turbine arrangements





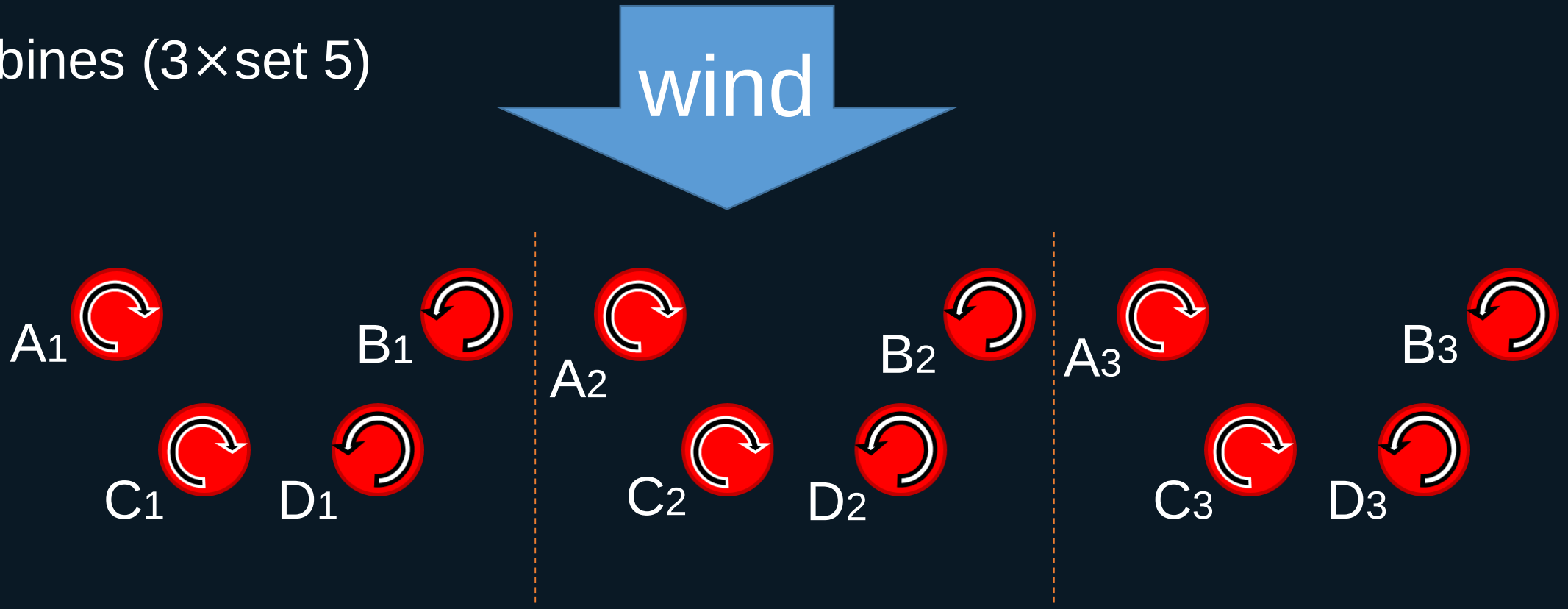
4 turbines per set

Experiment 2 Kawasaki Heavy Industries' wind tunnel

wind

Experiment 2 Horizontal formation of set 5

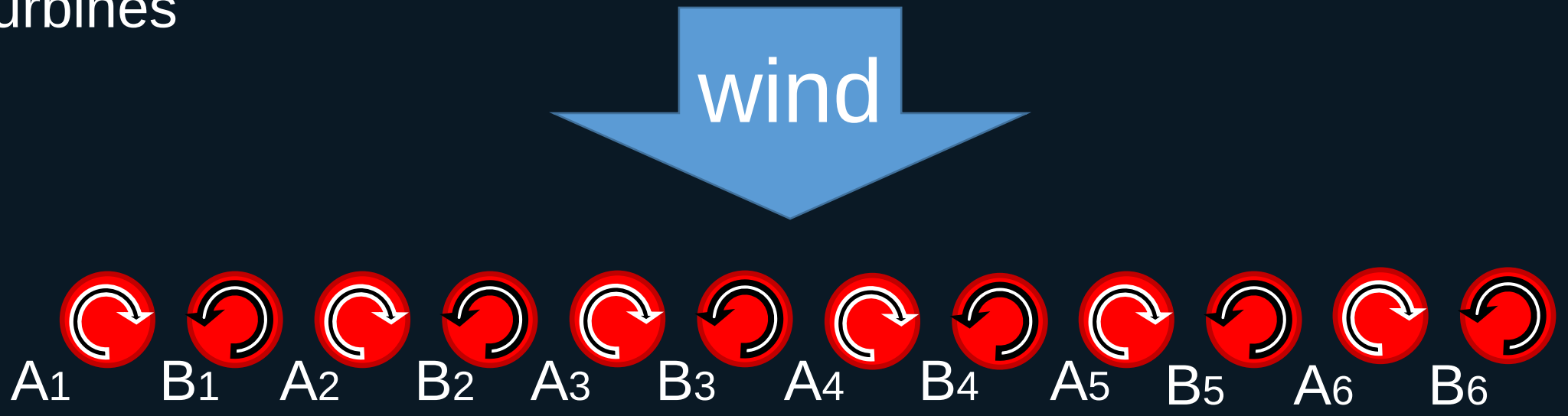
12 turbines (3×set 5)



Observed power generated by different types of separation distances between turbines

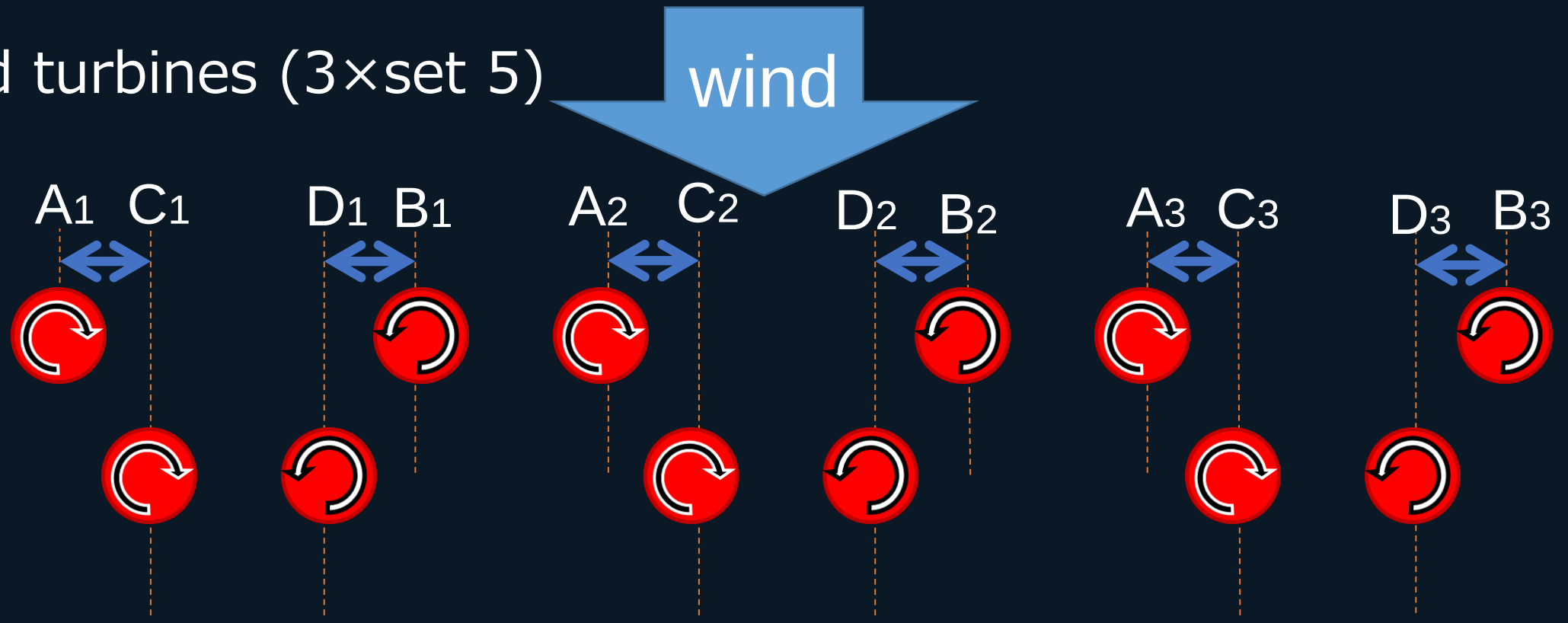
Experiment 2 Horizontal straight line formation

12 turbines



Experiment 2　separation type 1

12 wind turbines (3×set 5)

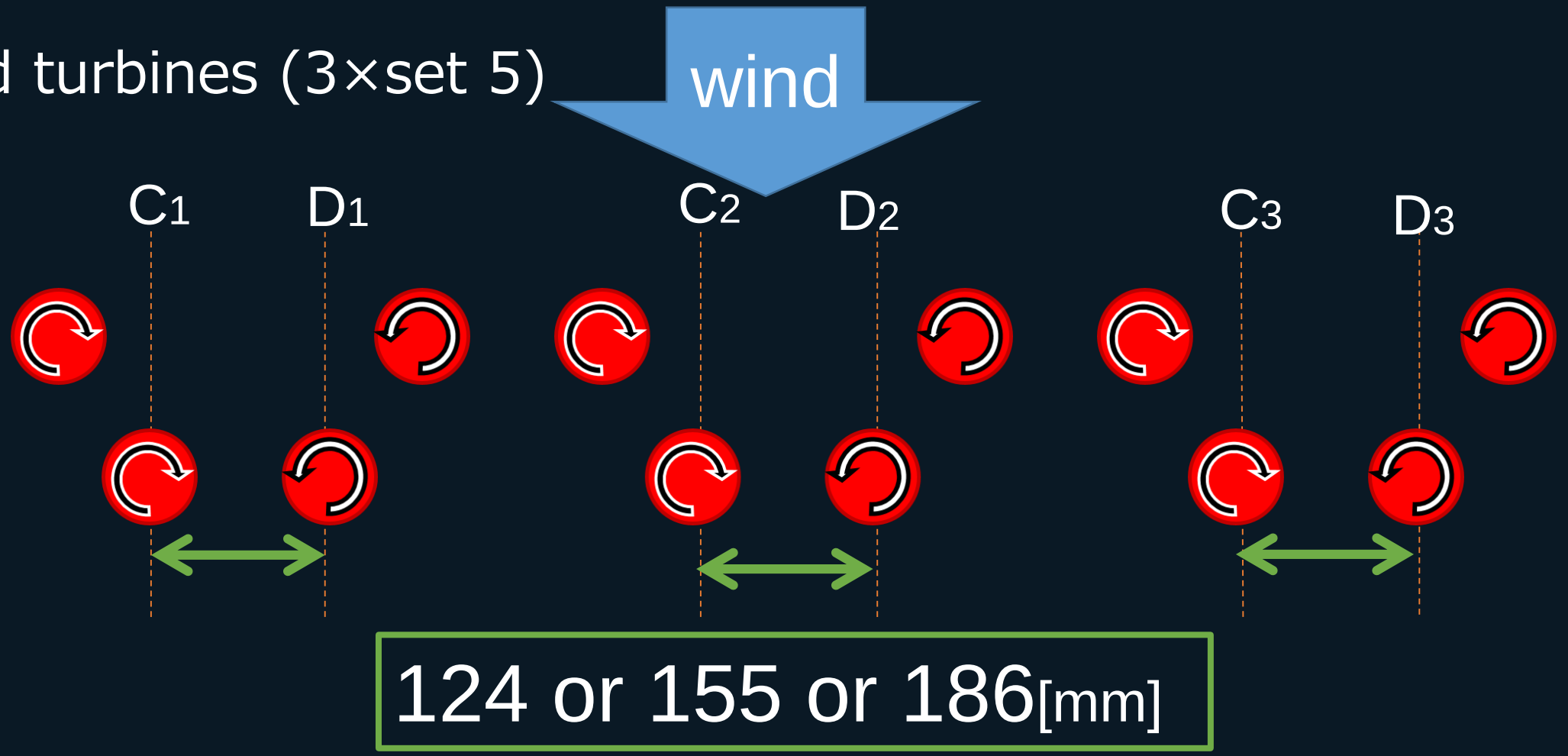


31 or 62 or 93[mm]

Type 1: horizontal separation distance between turbines
A-C and D-B within each set.

Experiment 2　separation type 2

12 wind turbines (3×set 5)



Type 2: horizontal separation distance between turbines C-D within each set.

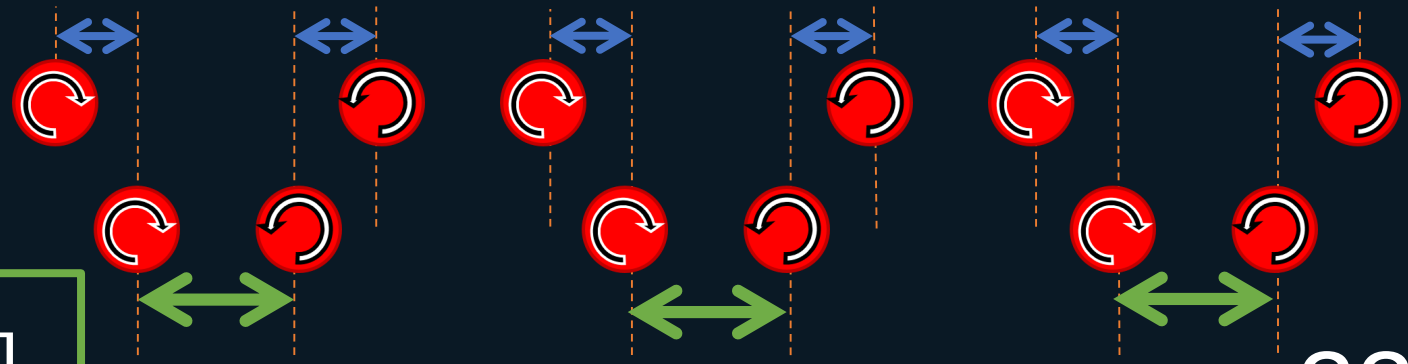
Experiment 2　Results

Electrical power generated per unit separation distance

[mW/m]			
↔ \ ↔	124mm	155mm	186mm
31mm	131.4	114.7	84.9
62mm	164.3	170.9	137.1
93mm	181.3	168.3	151.2
124mm	*1		

[mW/m]	
horizontal straight line	**one turbine**
173.5	185.6

*1: Unable to measure due to sensor malfunction
Data: Average of 100 measurements



31 or 62 or 93[mm]

124 or 155 or 186[mm]

Experiment 2　Analysis and discussion

・Wind Interference effects from nearby turbines lower the amount of electrical power generated.

・An inverted V-shape (set 5) is the best way to increase the amount of electrical power generated per total formation width.

Conclusion

- When multiple turbines are placed close together, the electrical power generated decreases.
- The inverted V-shape (set 5) formation generated the highest electrical power per unit separation distance.

Conclusion

- The inverted V-shape is the most suitable for electrical power generation using building air vortices, as it can generate more power from a smaller area.

Acknowledgements

Mr. Oota Masaya
Osaka Prefecture University College of Sustainable System Sciences School of Knowledge and Information Systems

Mr. Yoshitake Hideto and Mr. Hamada Shinji
Kawasaki Heavy Industries, Ltd. Engineering division

References

1. Shigetomi akinari, murai yuichi, tasaka yuji, takeda yasushi “mutual interference between each savonius wind turbines under the condition the arrangement of horizontally”, the latest speech & article of the power & energy technology：symposium 2009.14(0),45-46,2009 general incorporated association, the japan society of mechanical engineers

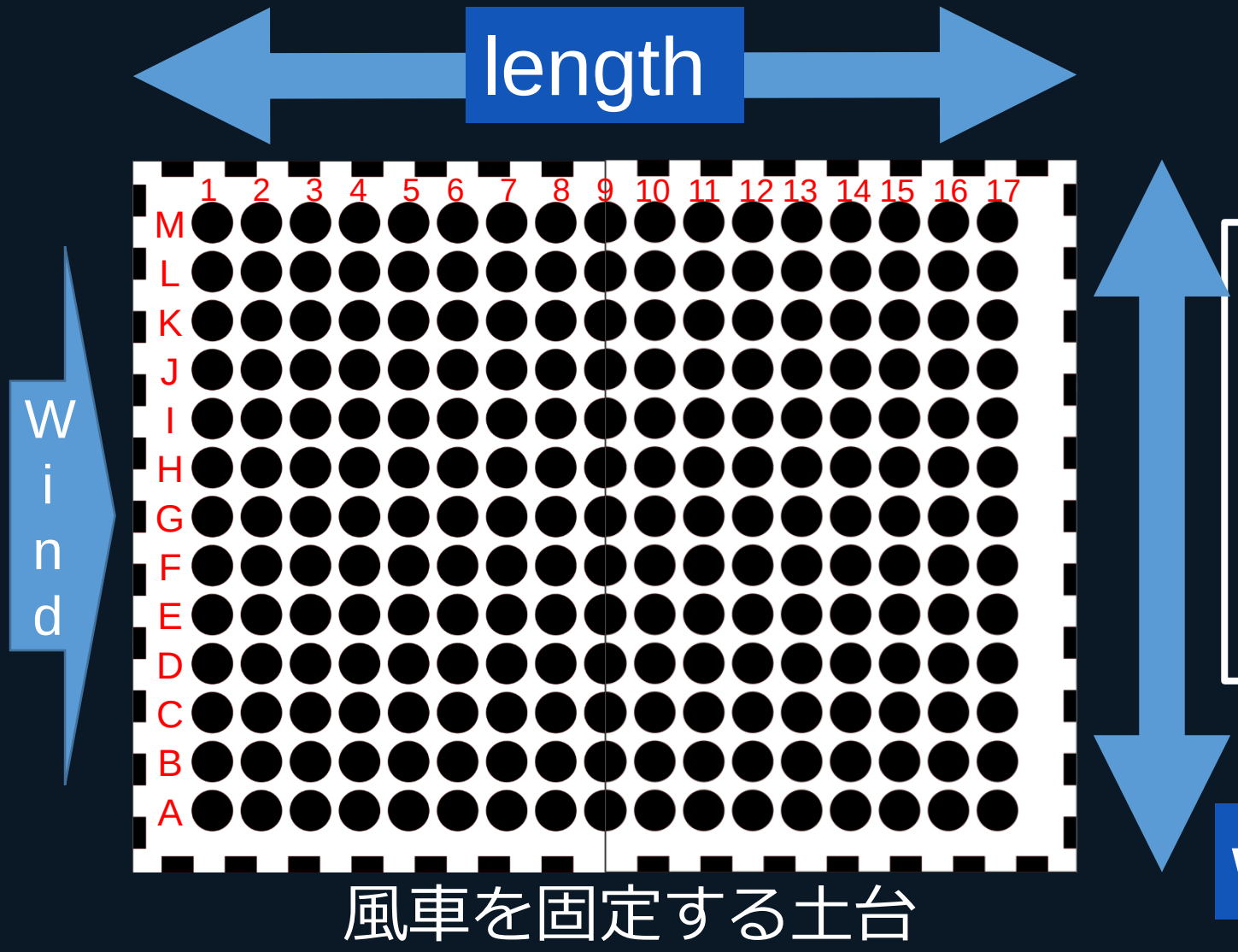
2. Murai yuichi, oda tomorou, oishi yoshihhiko, tasaka yuji ”wind tunnel model experiments on interaction among horizontally arranged VAWTs” the latest speech & article of the power & energy technology ：symposium 2013.18(0),29-30,2013 general incorporated association, the japan society of mechanical engineers

3. Kitai atsuya, shino hiroaki, tanaka yumi, fujimoto yudai, miura taishi　kakogawahigashi high school（2017）the efficiency of private wind turbines with different aspect ratios”Kajimoto syota, kono tomoki, tabe humiki, Tsuda shuto, miyamoto ken, yamawaki kaisei　kakogawahigashi high school（2019）”improving the efficiency of vertical axis wind turbines “

4. Robert W Whittlesey1, Sebastian Liska1 and John O Dabiri1,2 ”Fish schooling as a basis for vertical axis wind turbine farm design 1” Graduate Aeronautical Laboratories, California Institute of Technology, Pasadena CA 91125, USA 2 Option in Bioengineering, California Institute of Technology, Pasadena CA 91125, USA, October 29, 2018

Thank you for listening.

Instrument

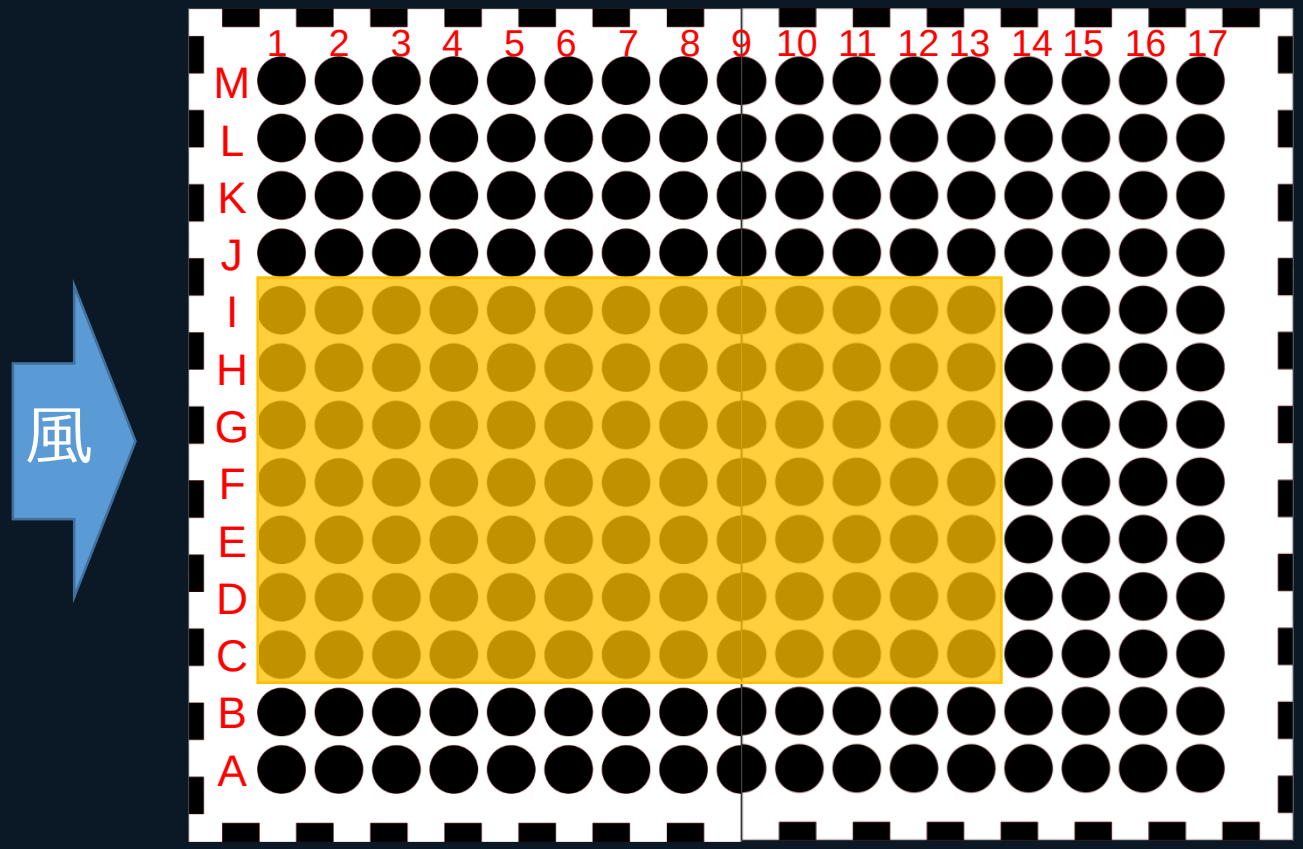


width：450mm
length：600mm
diameter：26mm
distance between
two holes：5mm

windspeed

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	3.71	3.76	4.08	4.28	4.51	4.95	4.63	4.78	4.10	3.42	3.26	2.67	2.04
9	4.48	4.46	4.66	4.88	4.81	4.91	4.93	4.80	4.68	4.51	4.17	3.53	3.36
17	3.84	3.85	3.96	4.00	4.16	4.21	4.24	4.23	4.23	4.10	3.63	3.33	2.96

windspeed



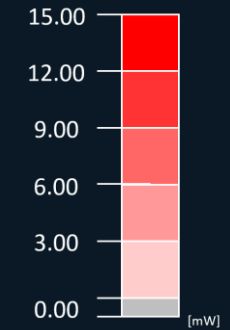
→1~13、C~I

Preliminary survey②

result

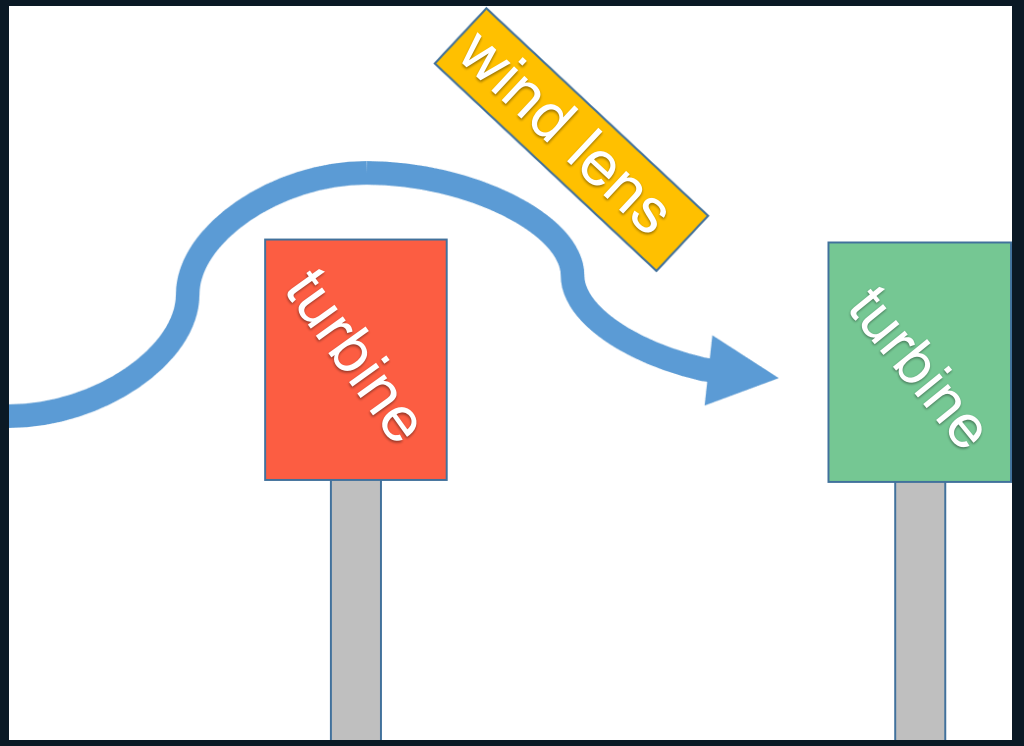
average of 150 data

（1） both spin in the same direction	（2） both spin inwards	（3） both spin outwards
5	1	3
31mm	31mm	31mm
6	2	7
62mm	62mm	62mm
8	4	9
93mm	93mm	93mm

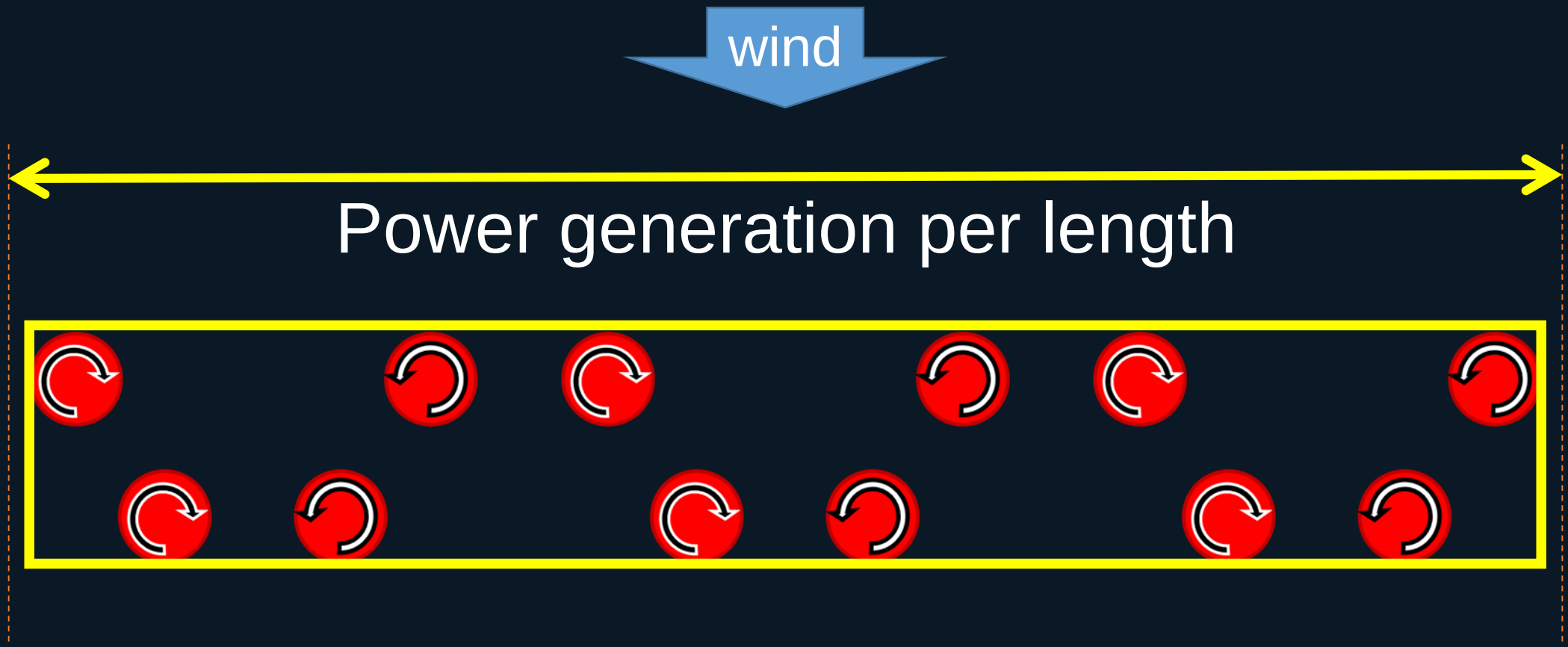


Future prospects

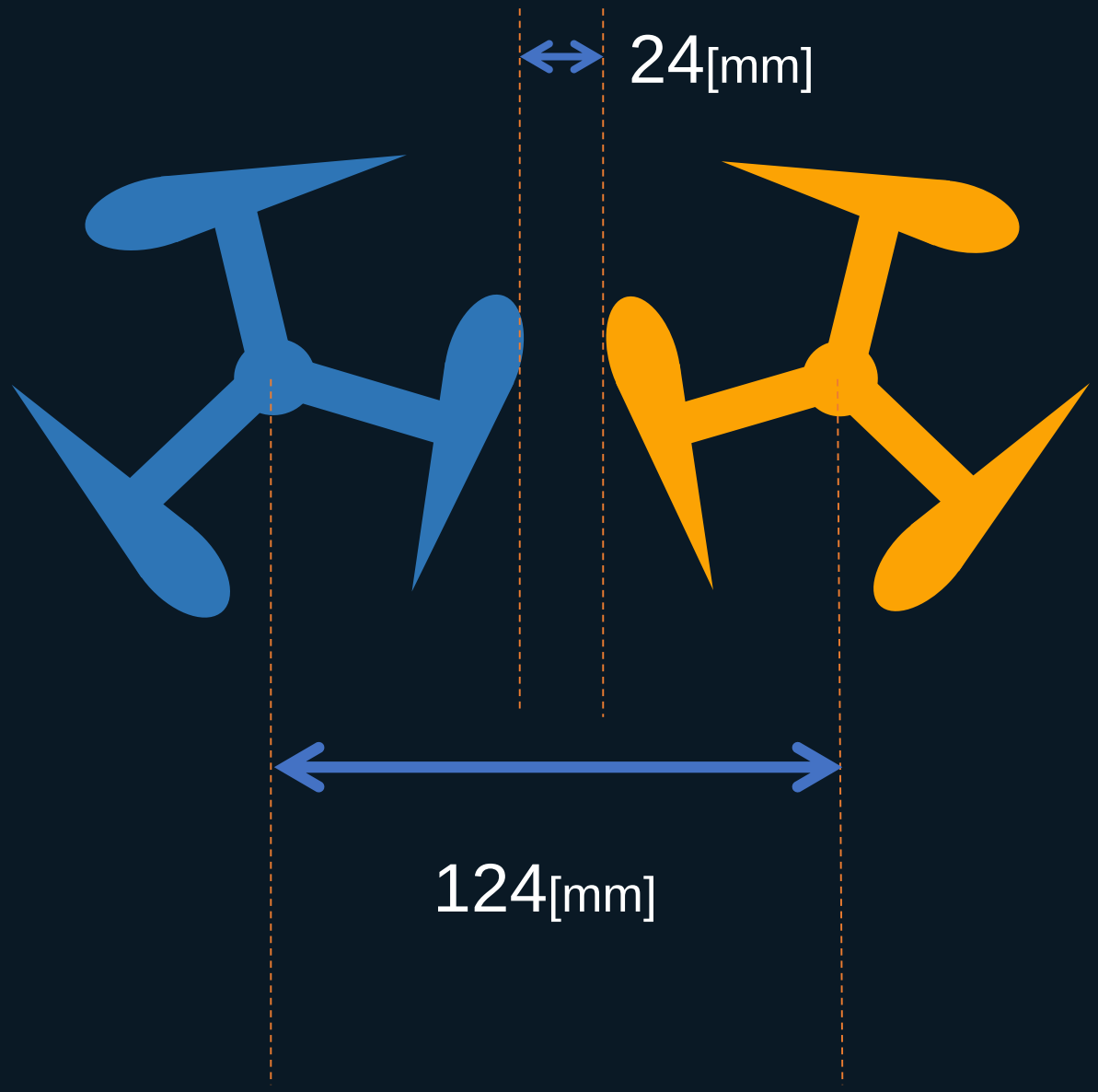
Future prospects



Evaluation Method

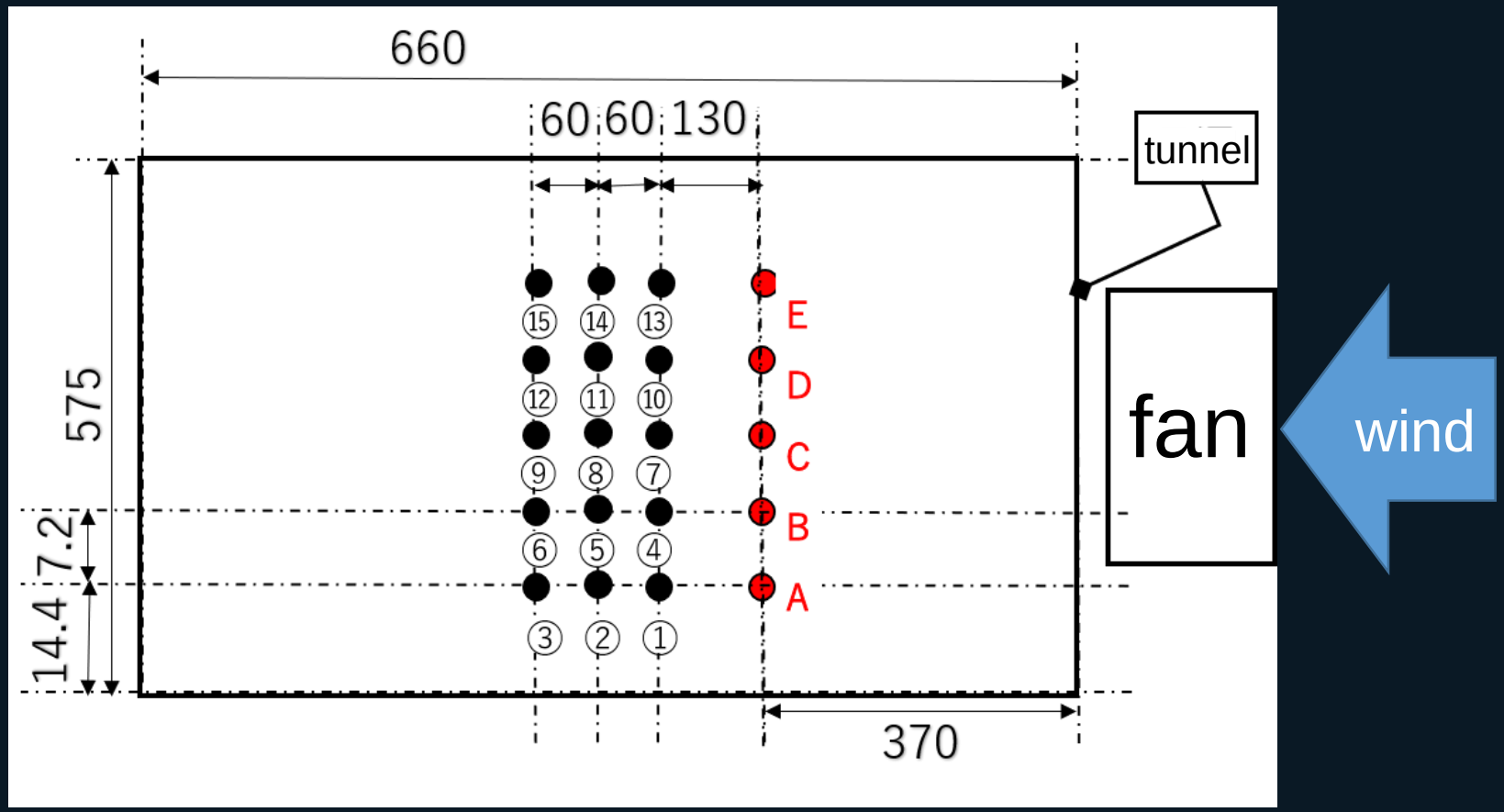


Evaluation Method



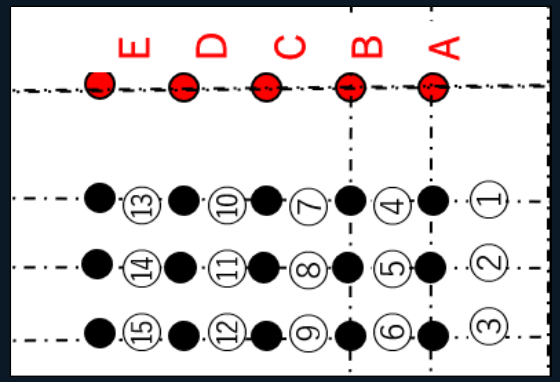
diameter:100[mm]

Preliminary experiment 1



unit:mm

Preliminary experiment 1



3.4	6.3	4.4	6.8	0.9
12.0	6.2		6.3	2.1
2.5	5.7		6.2	2.5

[m/s]

Preliminary experiment 1

same direction

wind

first：clockwise

0.0	13.7	20.0	19.8	0.0
0.0	17.0	18.6	19.6	0.0
1.8	18.8	20.4	16.0	0.0

wind

25.7	19.6	4.9	0.0	0.0
27.2	19.4	2.2	0.0	0.0
26.6	16.3	3.3	0.0	0.0

second：out clockwise

wind

3.6	25.8	20.3	17.8	0.0
5.4	26.2	21.9	14.4	0.0
14.2	24.9	23.3	15.3	0.0

wind

26.8	8.2	9.4	4.8	0.0
24.6	4.6	13.8	10.7	0.0
23.6	7.1	15.7	6.0	0.0

Preliminary experiment 1

opposite direction

wind

first：clockwise

22.4	4.5	19.4	24.0	0.0
17.0	10.9	20.3	20.5	0.0
20.2	18.8	21.8	18.8	0.0

wind

22.4	19.2	2.4	2.7	0.0
17.0	22.4	1.2	3.3	0.0
20.2	17.0	1.0	2.3	0.0

second：out clockwise

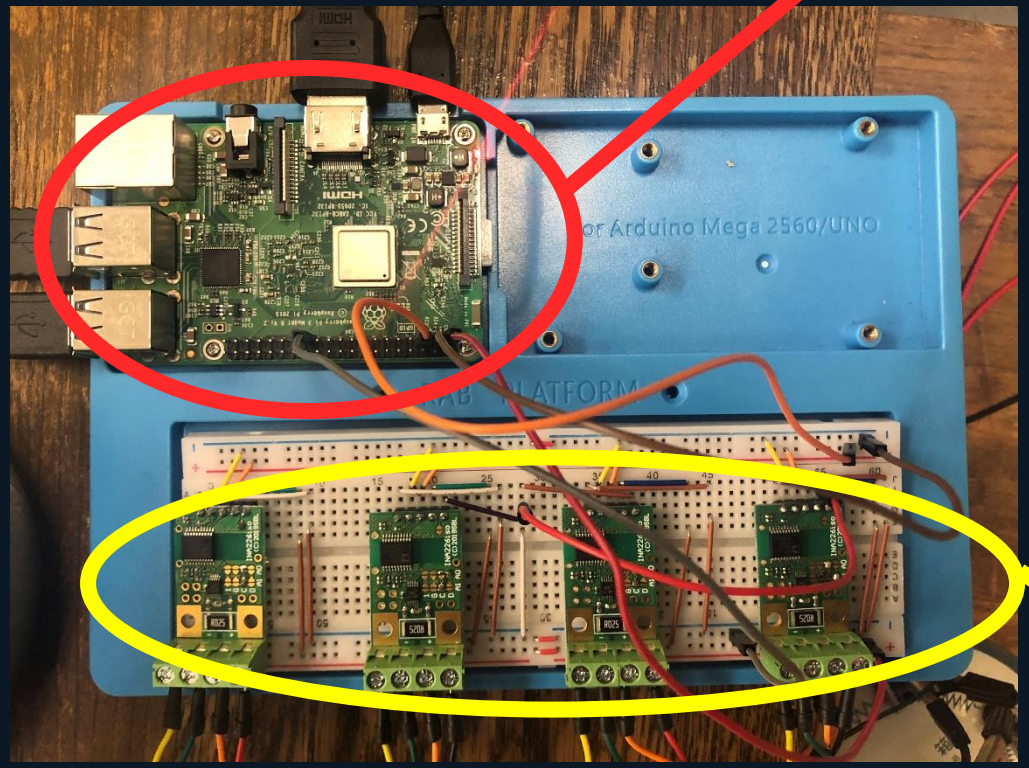
wind

0.0	27.7	17.5	25.6	0.0
0.0	26.6	17.9	19.0	0.0
2.6	25.7	20.5	16.4	0.0

wind

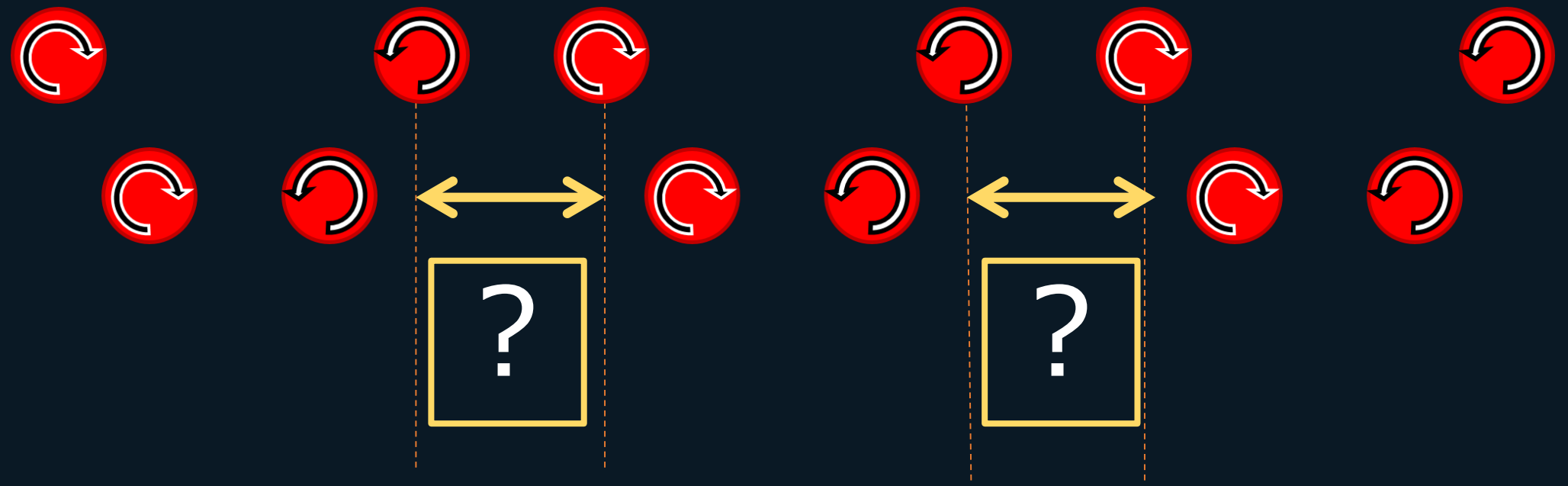
21.2	0.0	3.2	18.9	0.0
25.0	2.0	10.0	15.5	0.0
18.1	3.5	13.3	8.0	0.0

Single board computer and sensor



Future prospects

Research the most efficient formation length between each turbines



Wind lens

service-l02.jpg (205×444) (wind-hope.co.jp)

Preliminary survey②

Comparing inward with outward