



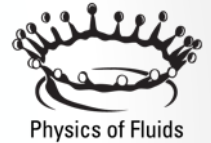
PROGRAMA
**ANÁLISIS OPERATIVO
DE PARQUES EÓLICOS**

HOTEL MELIÁ AVENIDA AMÉRICA
4 OCTUBRE 2022
EVENTO PRESENCIAL

Concentrated Wind Power:
An innovative solution to increase
production in existing and future
wind farms.



UNIVERSITY
OF TWENTE.



Manuel Alcocer
Managing Director

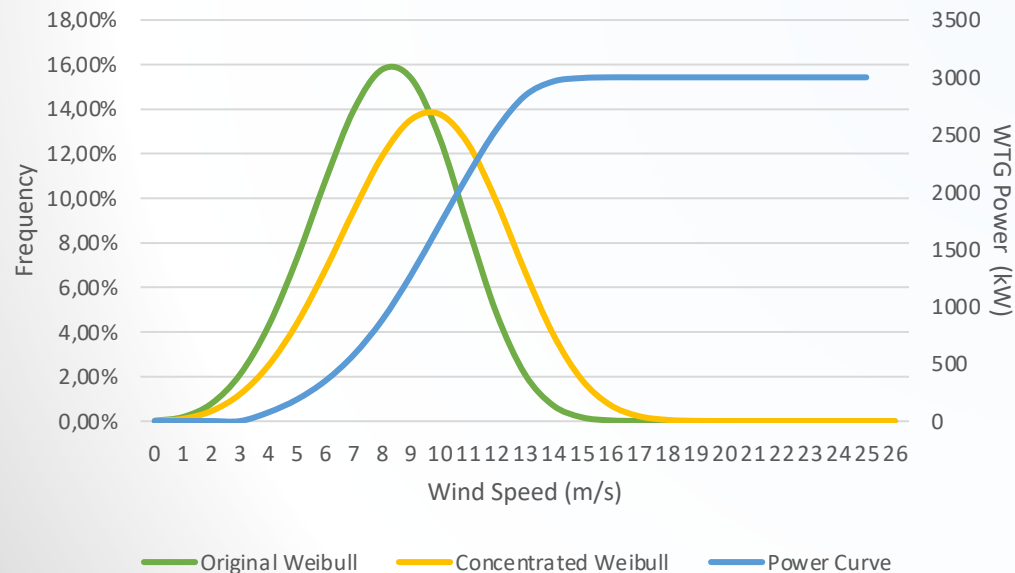


Dr Richard Stevens
Associate Professor

Concentrated Wind Power

- Independent entities.
- We both do R&D in a common topic.
- W'wave also commercializes products and services.

Common research topic: **Improving wind in wind farms**



Why?

1. To **increase clean energy production at lower LCoE.**
2. To **increase the number of turbines** that developers can fit in a given wind farm (i.e.: **the power of the wind farm**).

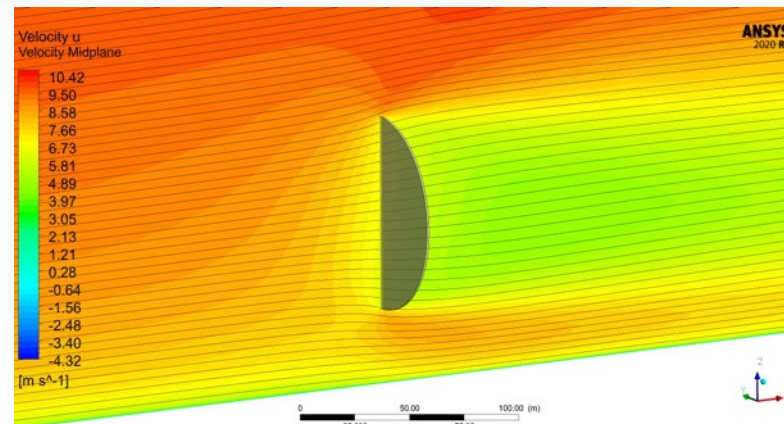
Basic technical principles



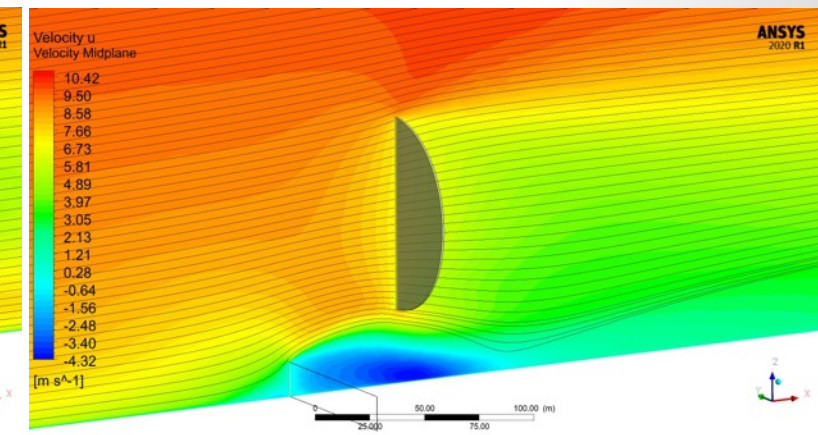
How do we optimize wind? **With Concentrators:**

- ... at the **right location** from the turbine,...
- ... generating a **flow detachment**, which reduces the necessary height of the Concentrator,...
- ... leading to a new wind profile through the rotor with **higher speed, lower turbulence intensity and lower wind shear.**

Wind profile through the wind turbine rotor **WITHOUT** the Concentrator



Wind profile through the wind turbine rotor **WITH** the Concentrator



Experimentation & Data Analysis

1.- Modification of the wind profile:
Measurement of the new wind profile &
comparison with our own CFD tools:

In collaboration with:



2.- Turbine production measurement
and production comparison with
inhouse CFD tools:

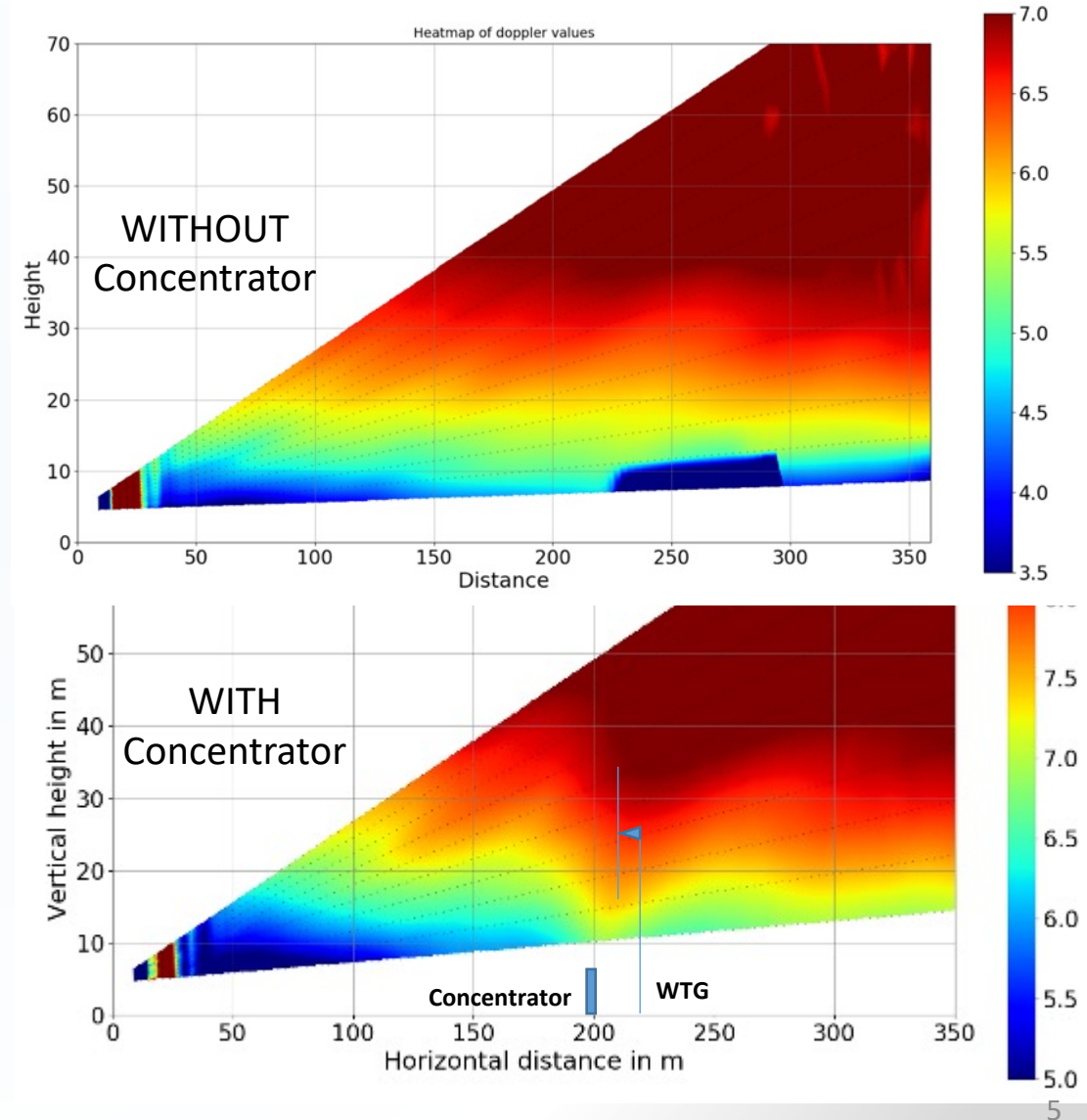


3.- Load and turbine lifetime analysis using certified aeroelastic models

Experimentation & Data Analysis

1.- Modification of the wind profile:
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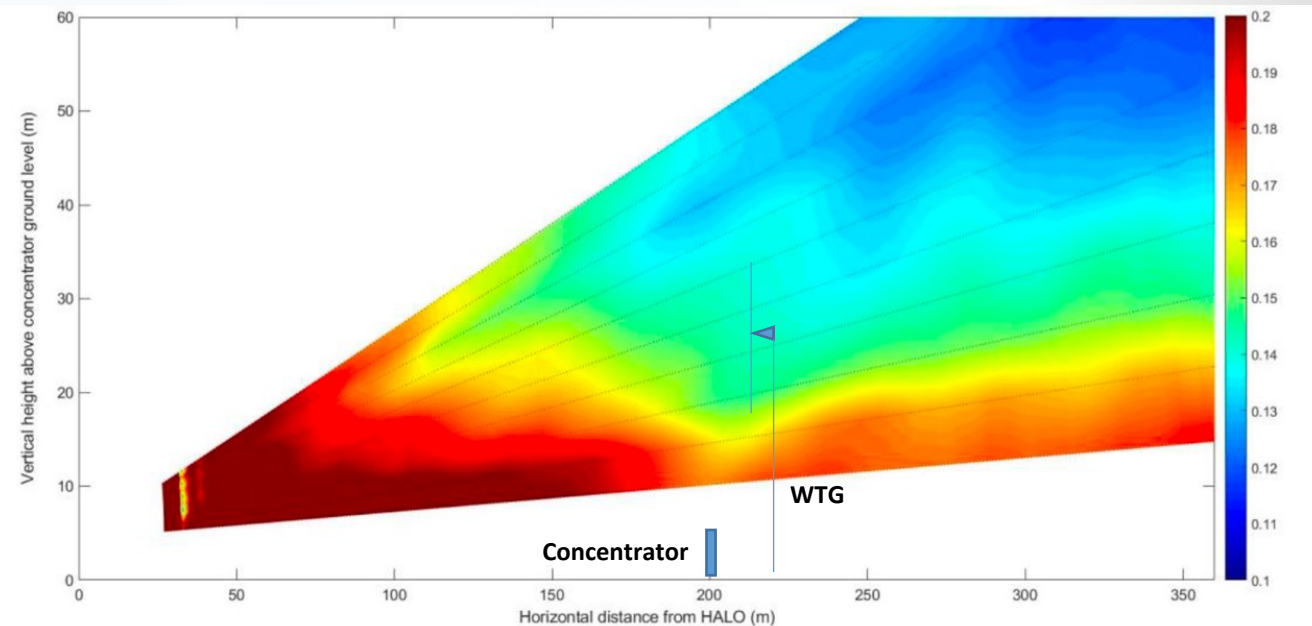
In collaboration with:



Experimentation & Data Analysis

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In collaboration with:

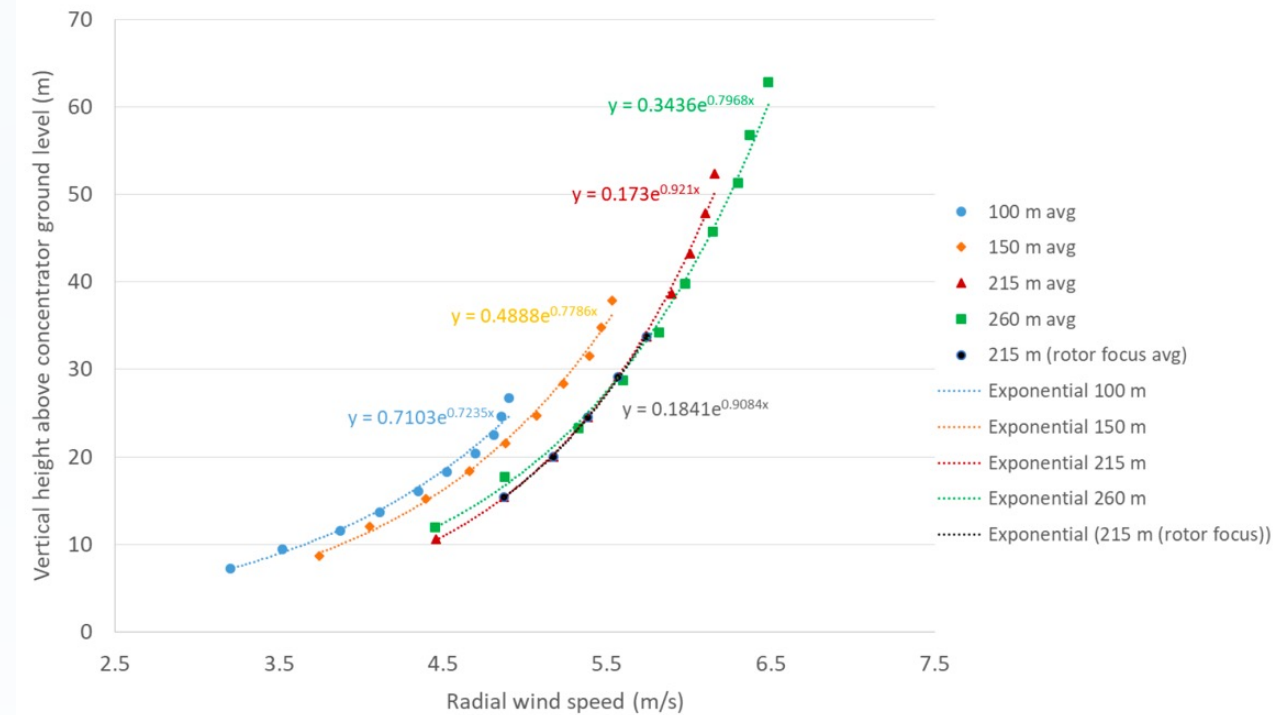


Measured wind turbulence intensity profile WITH Concentrator

Experimentation & Data Analysis

1.- Modification of the wind profile:
Measurement of the new wind profile &
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In collaboration with:

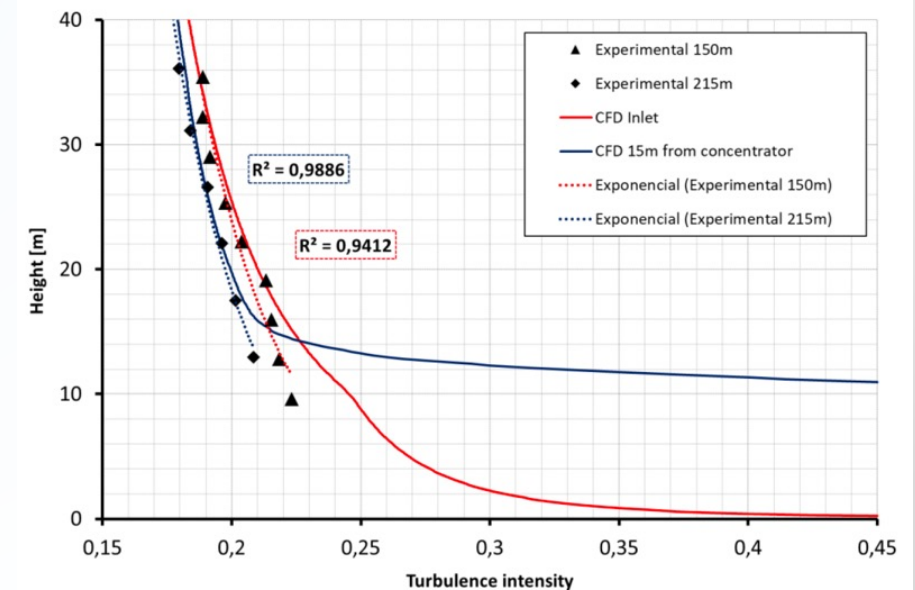
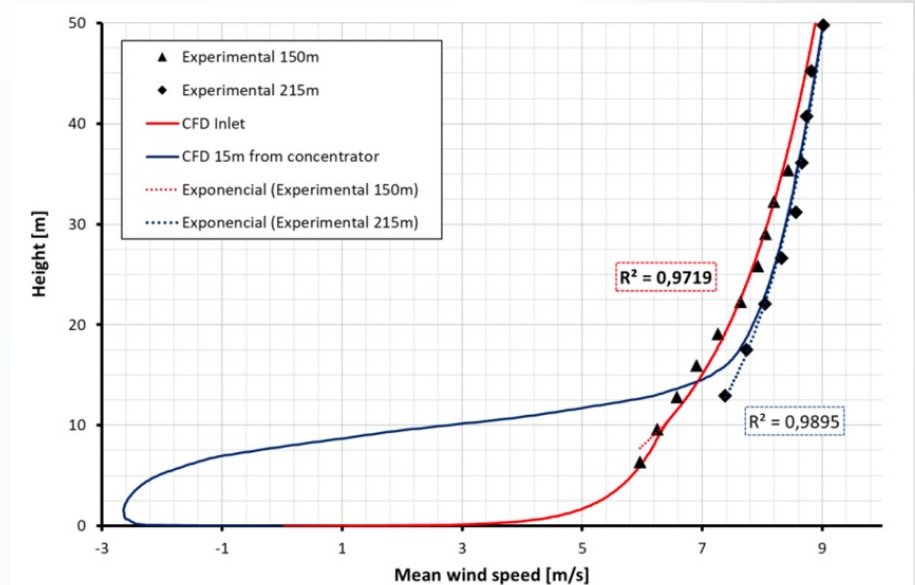


Concentrator @ 200m distance from Lidar
Virtual rotor position @215m distance from Lidar

Experimentation & Data Analysis

1.- Modification of the wind profile:
Measurement of the new wind profile &
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In collaboration with:



Experimentation & Data Analysis

In collaboration with:



2.- Turbine production measurement
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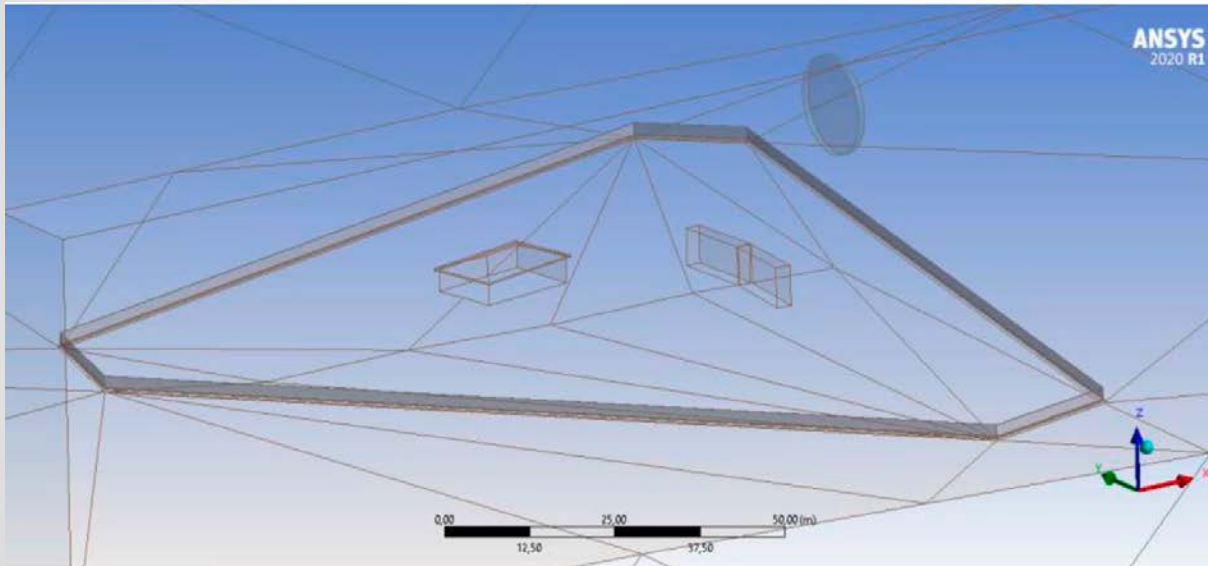


Experimentation & Data Analysis

In collaboration with:



2.- Turbine production measurement
and production comparison with
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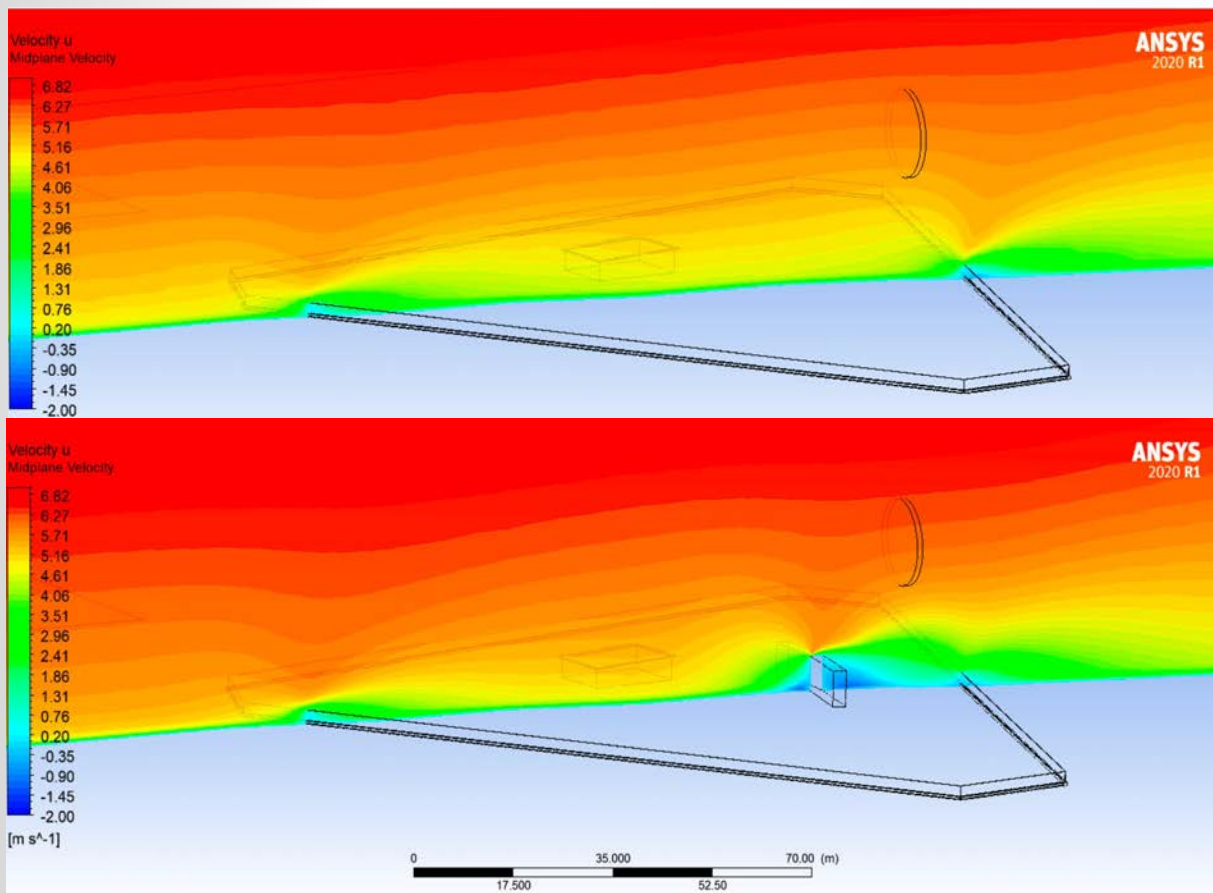


Experimentation & Data Analysis

In collaboration with:



2.- Turbine production measurement and production comparison with inhouse CFD tools:



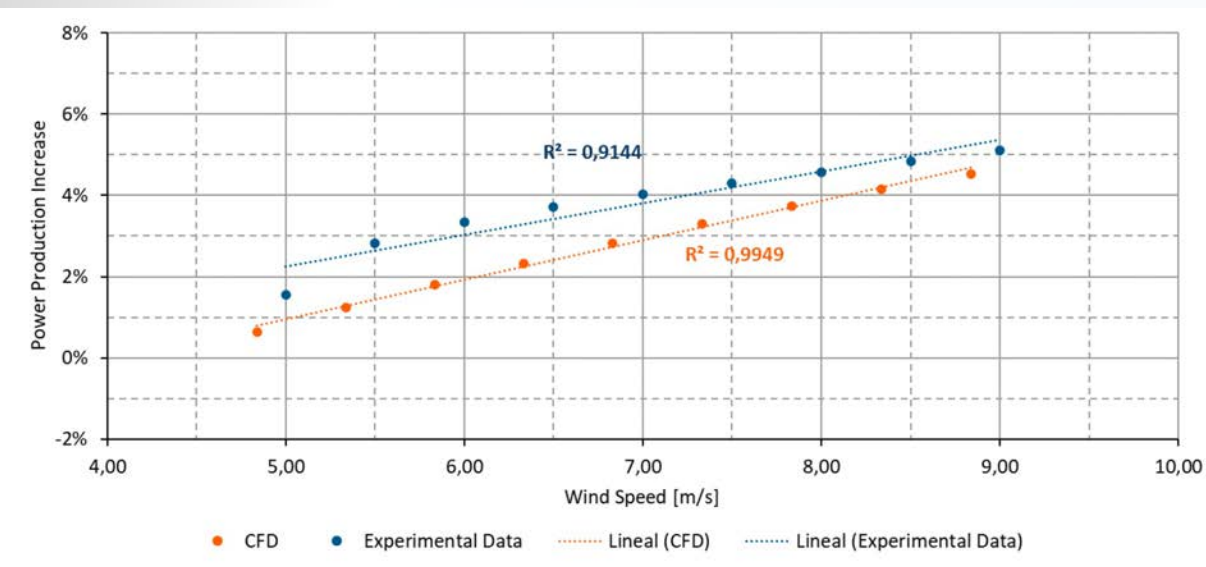
- Very complex site. High roughness due to fence.

Experimentation & Data Analysis

In collaboration with:



2.- Turbine production measurement and production comparison with inhouse CFD tools:



- Very complex site. High roughness due to fence.
- CFD model able to come close to experimental results

Experimentation & Data Analysis

3.- Load and turbine lifetime analysis using certified aeroelastic models

- WTG: 90m-rotor-3MW-HH80
- For a discreet Concentrator, lower wind shear balances higher wind speed, **resulting in the same critical expected operational lifetime.**
- Conservative, as the observed reduction in Turbulence Intensity has not been considered in the analysis.

Table 3.1: Considered scenarios and wind conditions

Parameter	Initial	Conc.
Wind condition description [-]	Similar to Class I	Similar to Class I
V_{ave} [m/s]	9	9.5
Weibull shape factor k [-]	2	2
Weibull scale factor A [m/s]	10.16	10.71
TI Subclass [-]	A	A
Wind Shear factor [-]	0.10	0.05
Inflow angle [deg]	0	2
Density [kg/m ³]	1.225	1.225

Table 7.1: Lifetime expectancies [years] considering design loads as reference

Component	Similar to Class I	
	Initial	WES ²
Blade composite 29m	26.9	25.3
Blade composite 19m	24.0	22.7
Blade composite 11m	22.0	20.0
Blade composite 7m	20.0 ³	20.0 ³
Blade root composite 1m	21.0	21.0
Blade root joint 1m	37.9	36.9
Hub	54.1	48.5
Hub-GBX Joint	47.4	40.6
Main Frame, Casting	35.7	27.6
Main Frame, Welded	29.3	24.5
Main Frame, Tower joint	27.4	23.0
Tower top 80m	27.4	23.0
Tower top 40m	24.3	20.8
Tower top 20m	24.0	20.7
Tower bottom	24.5	20.9

How much can we optimize wind?



- **Wind speed increase:**

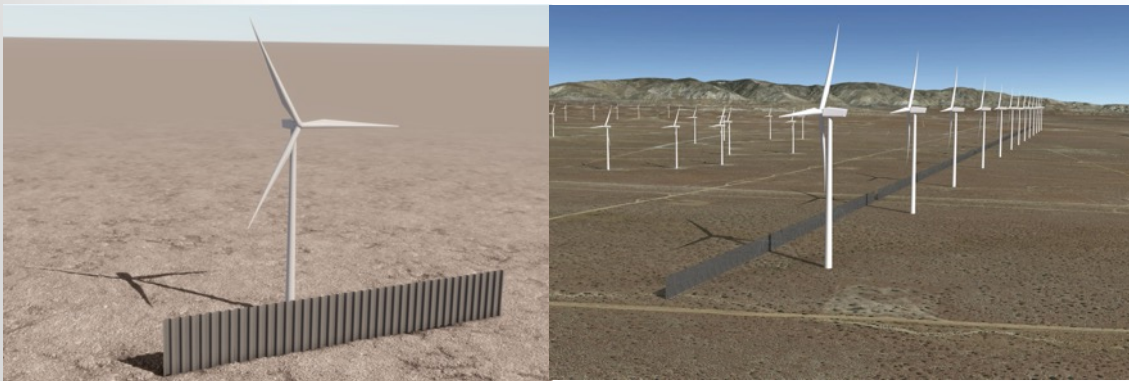
- **We can increase from 4% to more than 15% the average wind speed in the predominant direction.**

Increase in wind speed and its subsequent wind energy extra production depends on the specific Concentrator, the turbine and the site characteristics (orography & layout).

Concentrator Size

Individual Discreet
Concentrator

Continuous Concentrator
(or Multiple Discreet)

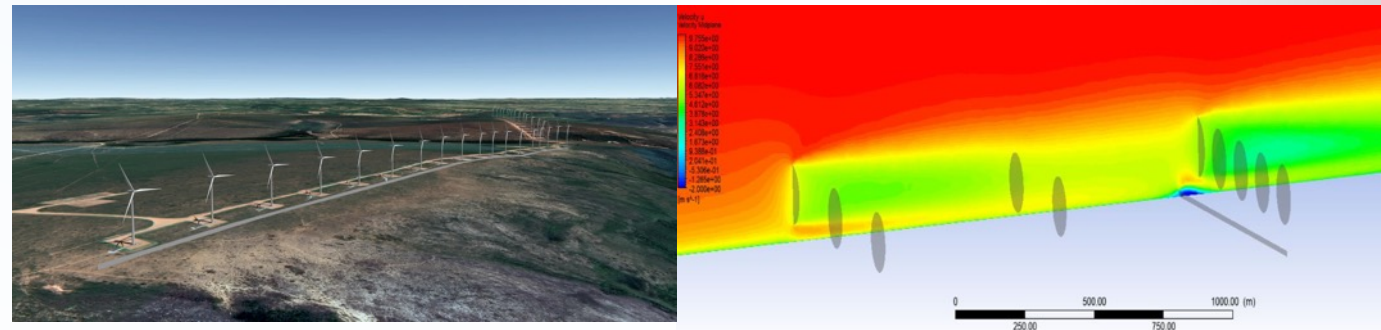


Less losses by the sides

Concentrator Siting in the wind farm

One-row wind farm

Last-row wind farm



High wake correction effect

How much can we optimize wind?



- **Wind speed increase:**

- **We can increase from 4% to more than 15% the average wind speed** in the predominant direction.

Wind Power equation:

$$P = \frac{1}{2} \times \rho \times A \times C_p \times V^3$$

However, due to several factors (WTG Power Curve, Weibull curve, etc.) wind production to expect is lower:

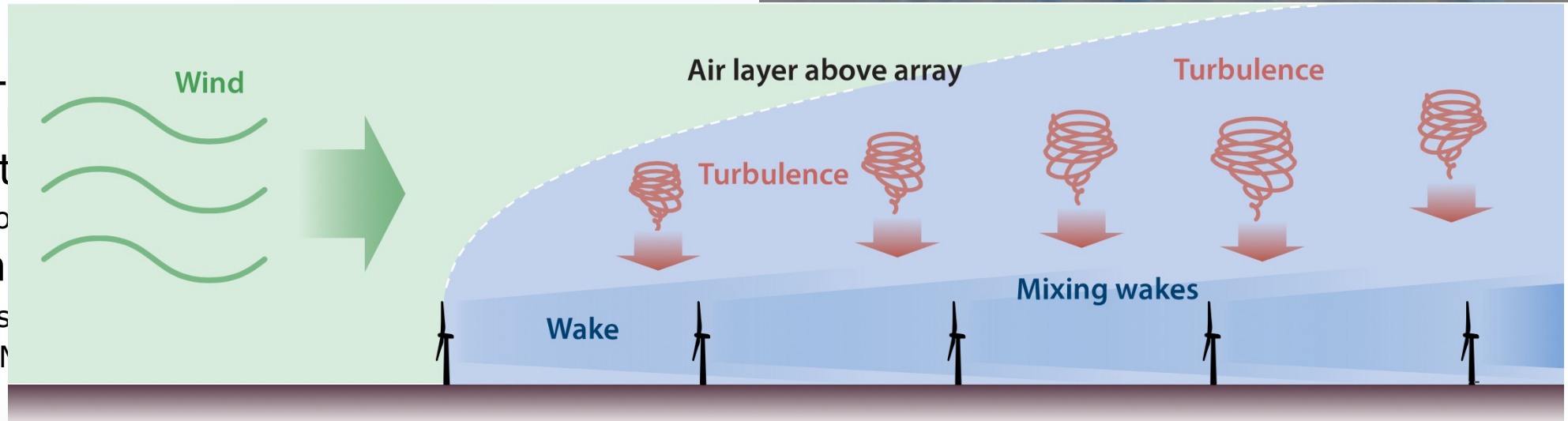
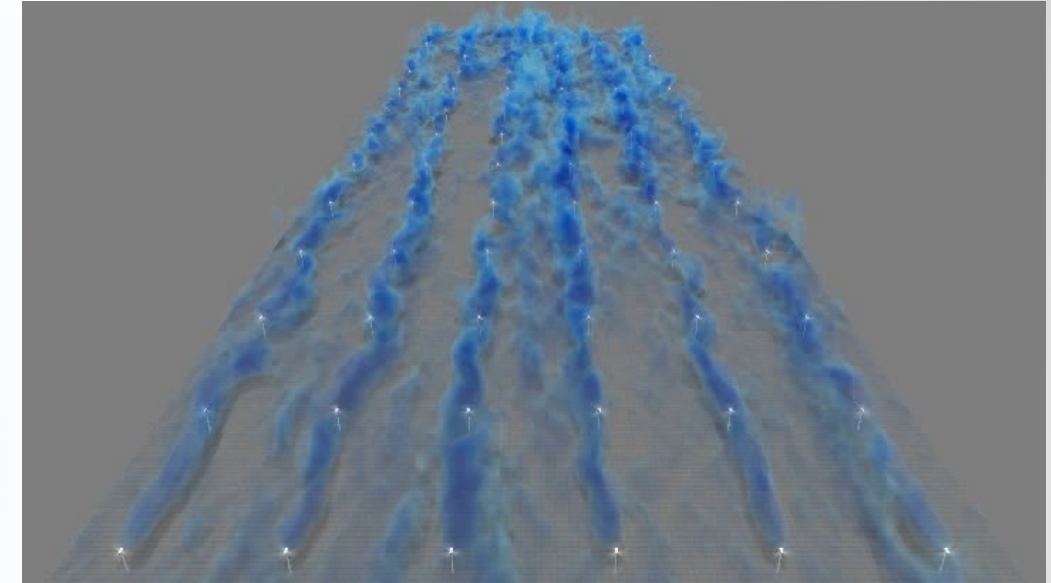
Concentrator Catalogue	Wind Speed ¹ increase	Wind Power ¹ Increase	Production ¹ Increase		
			k*=2		k*=4
Individual Discreet Concentrator ->	5%	15%	[7%	-	11%]
Continuous Concentrator ->	8%	26%	[12%	-	21%]
Continuous Concentrator in last wind farm row ->	15%	52%	[25%	-	37%]
Continuous Concentrator in last row and short distance from previous row ->	18%	64%	[29%	-	43%]

¹Indicative. Depends on site-specific wind conditions and WTG (reference is for 90m-3MW-HH80)

*K = Weibull wind frequency distribution shape factor

LES of wind farms

- Spectral-finite difference solver
 - Albertson 1999, Stevens et al., JFM 2014
- Different advanced sub-grid models
 - Bou-Zeid et al., PoF 2005, Gadde et al., BLM 2020
- Logarithmic law-of-the-wall
 - Moeng, J. Atmos. Sci. 1984
- Atmospheric inflow generator
 - Stevens et al. Renewable Energy, 2014
- Atmospheric thermal stability, baroclinicity
 - Gadde et al. BLM
- ADM, ADMR, ALM
 - Calaf et al. Phys. Rev. Fluids
- Wind concentration
 - Tobin & Chamorro
- High-performance computing
 - $>>10^9$ grid points
 - Stevens et al., JFM

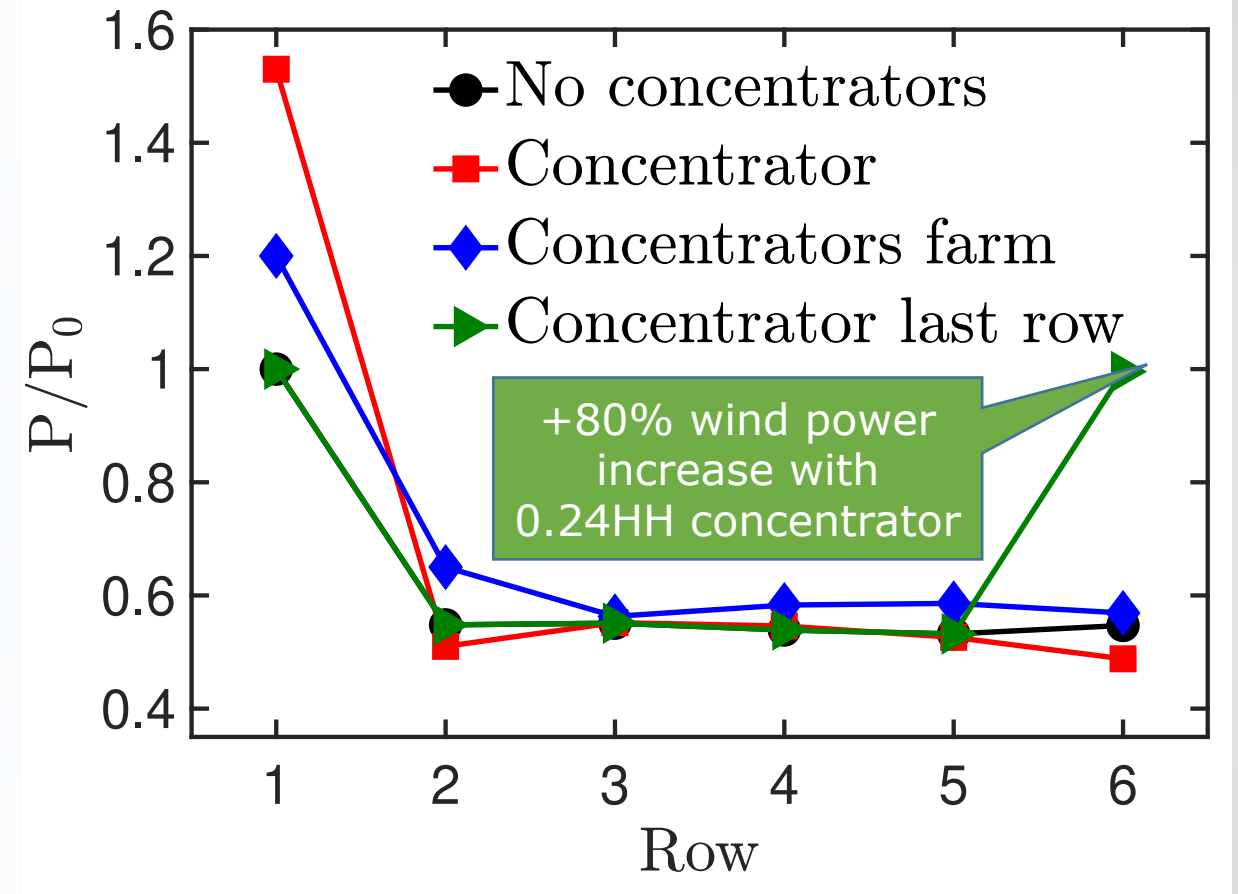
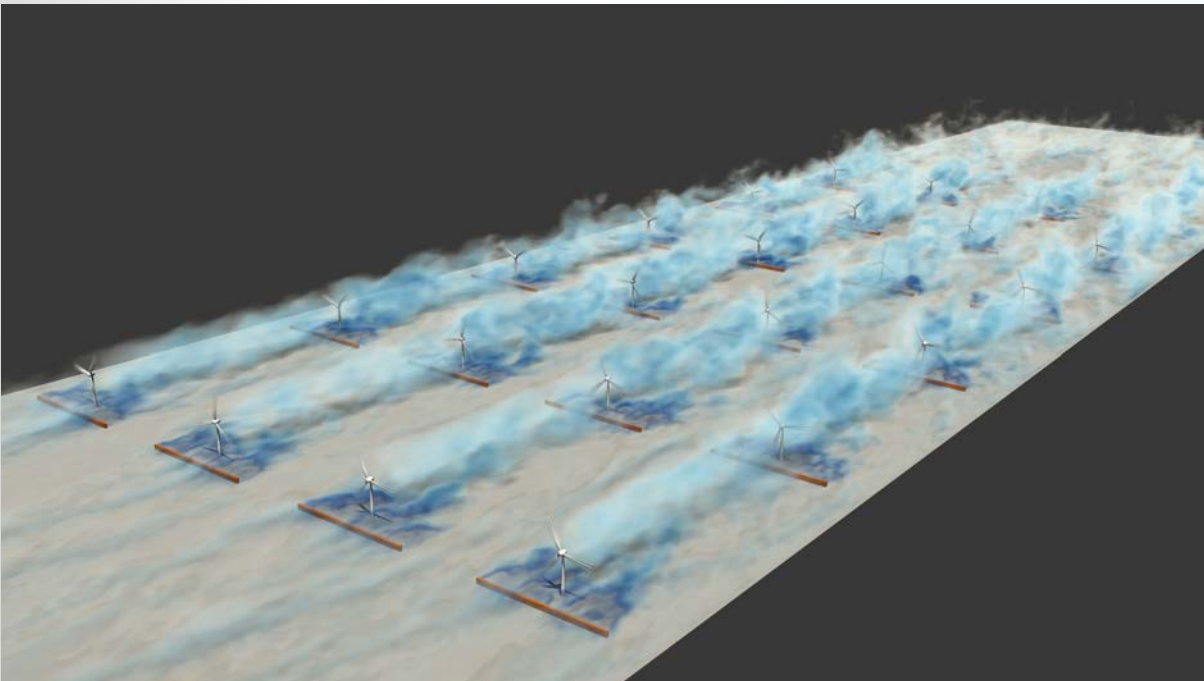


Concentrators in wind farms

Conventional wisdom:

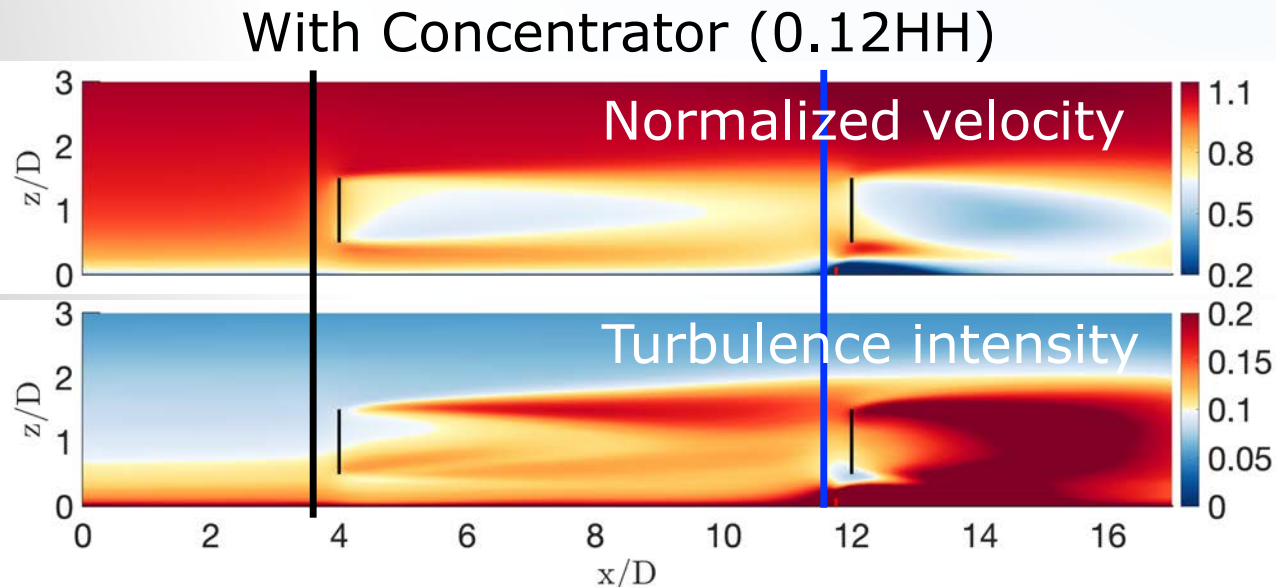
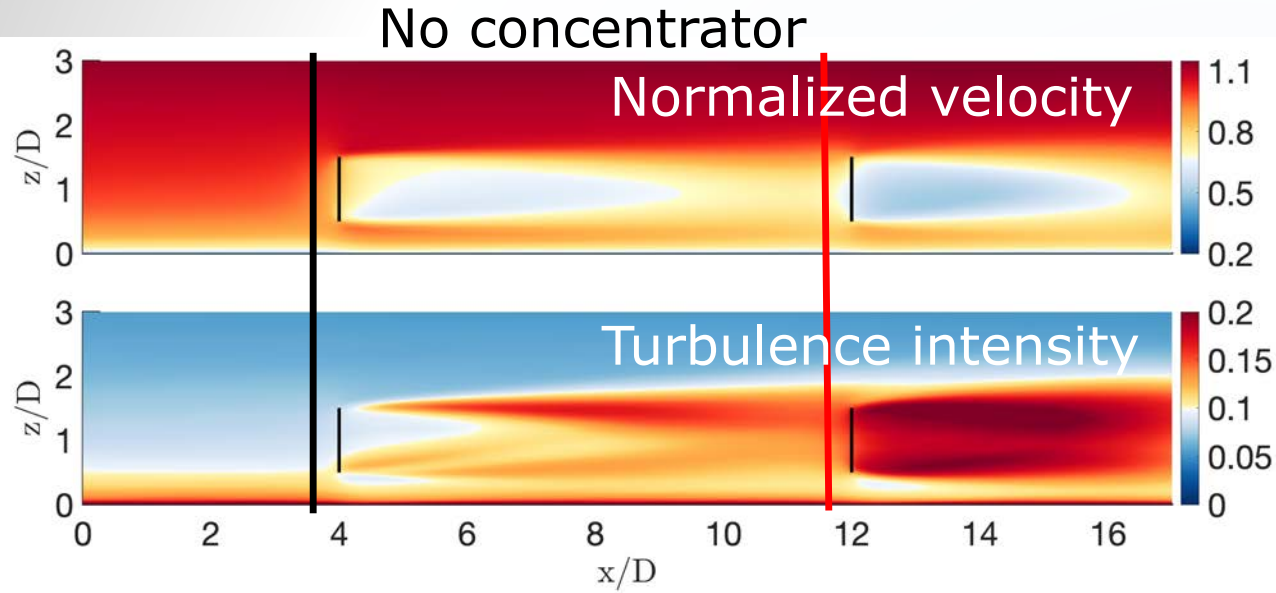
Obstacles in a wind farm can be unfavourable.

Finding: Using concentrators appropriately in wind farms can greatly improve their efficiency. Optimal concentrators for farms are lower than for isolated turbines.

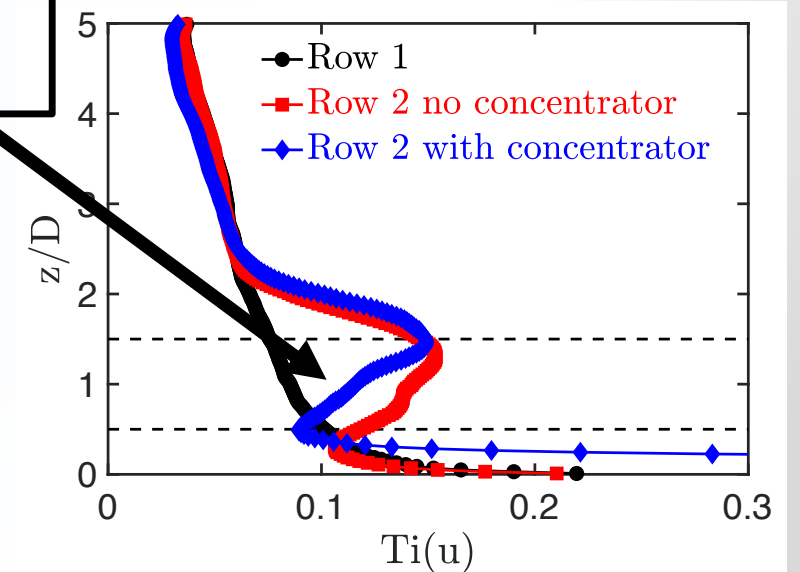
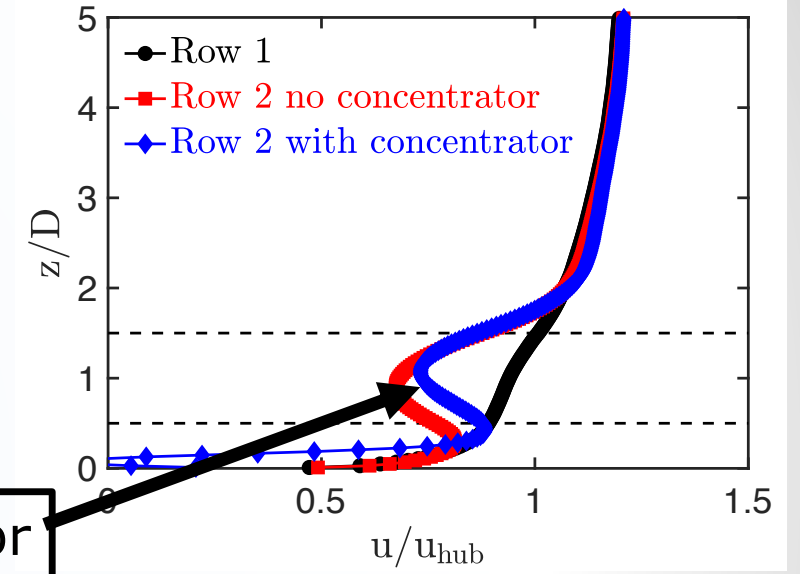


Better: Only using a Concentrator in the last row in predominant direction can greatly improve performance with few Concentrators.

Concentrators correct wake

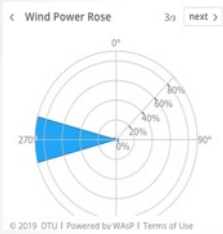


Concentrator
Improves
wake

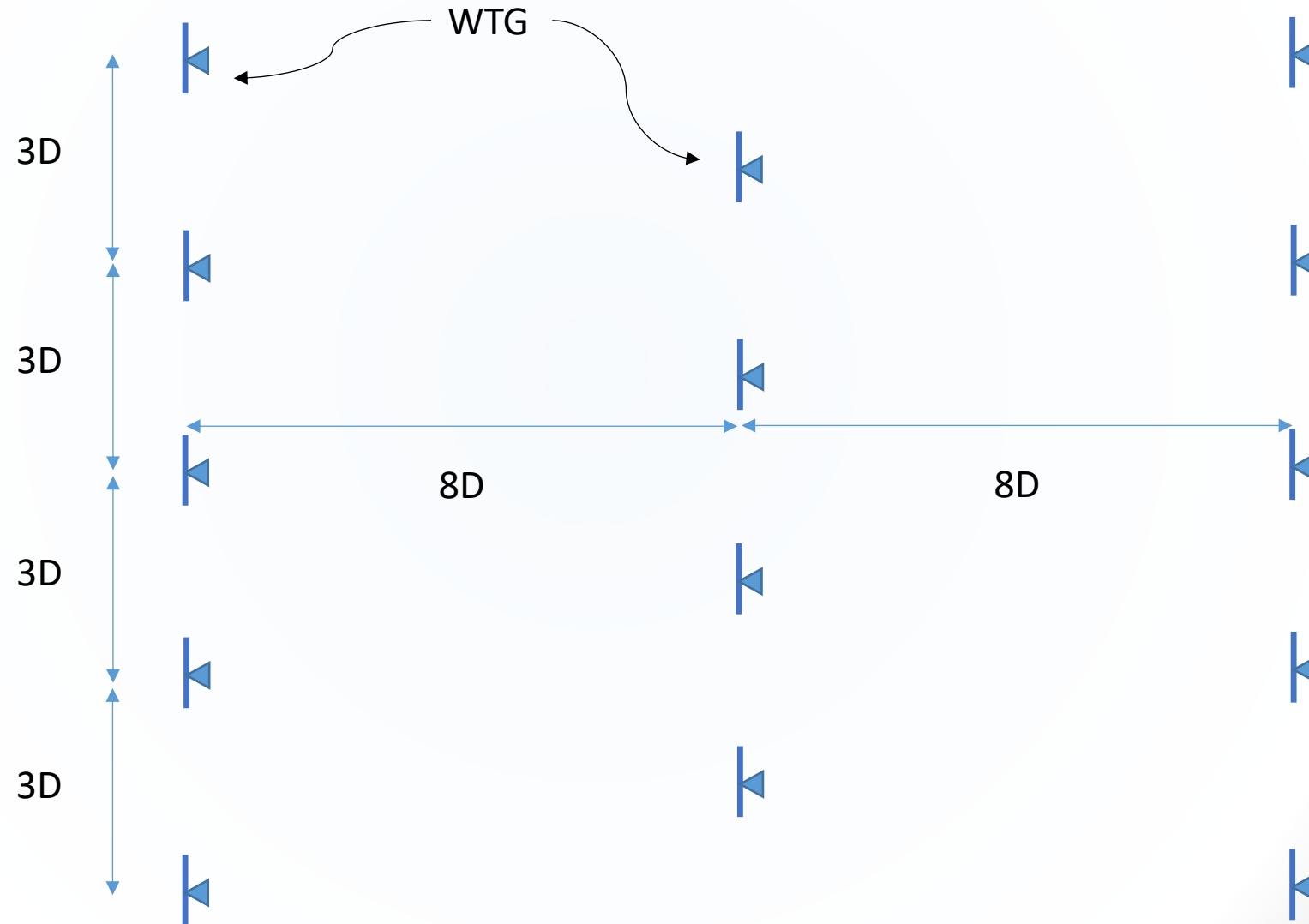


Use Cases CWP in last rows

Original

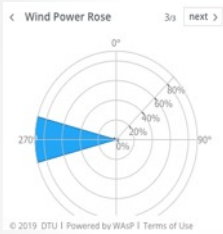


**OPTIMIZATION
OF LAST ROW**

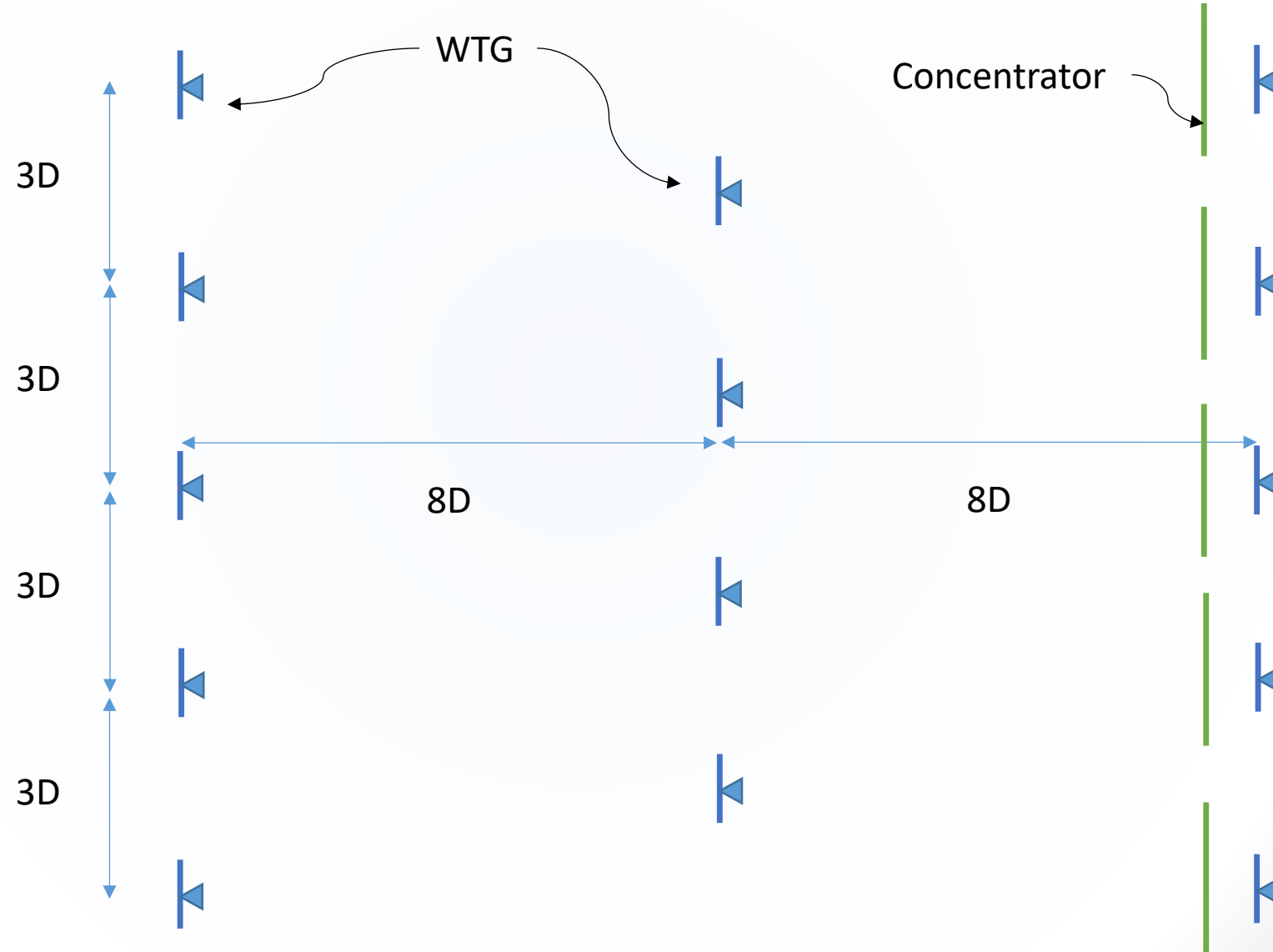


Use Cases CWP in last rows

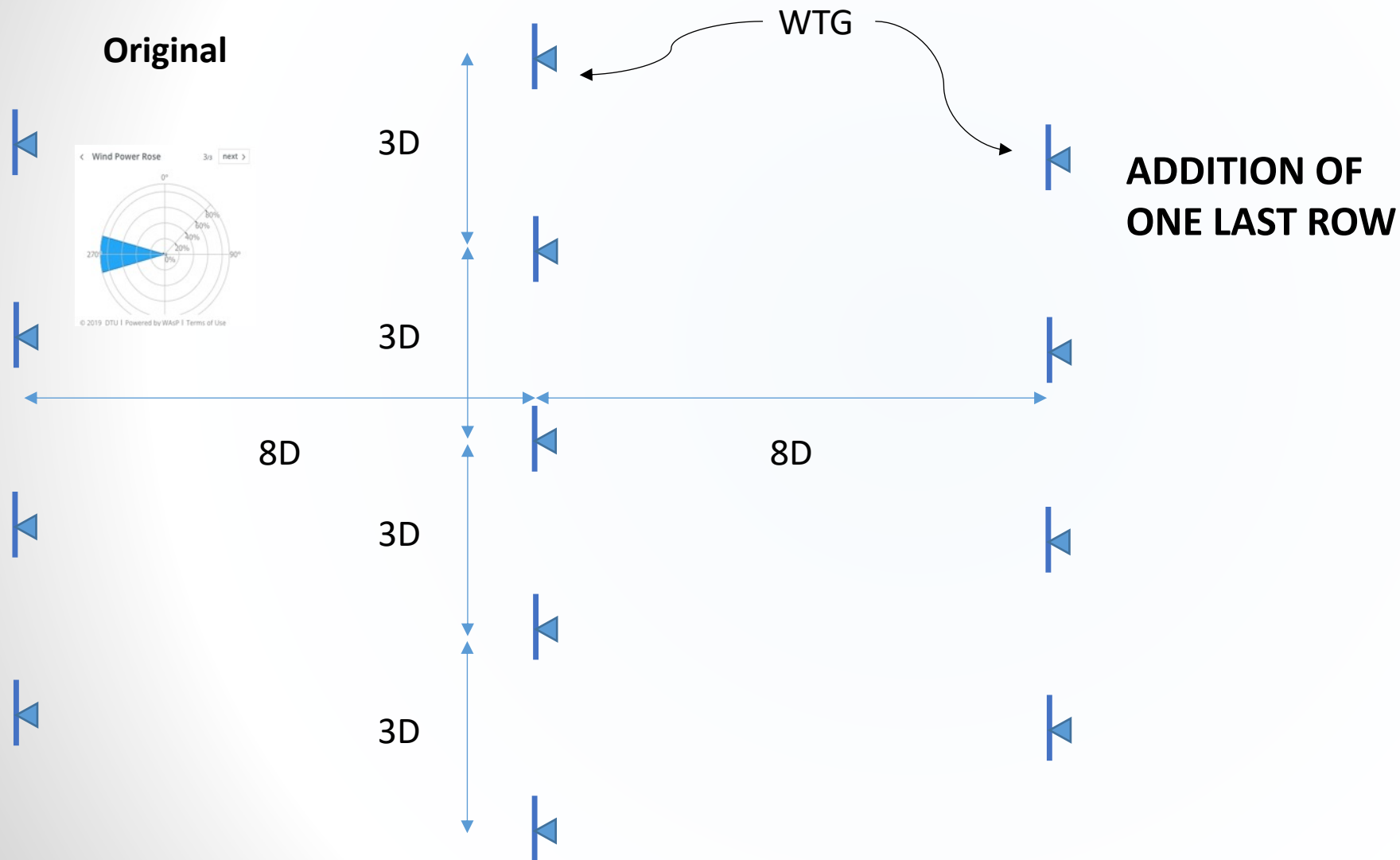
Concentrated



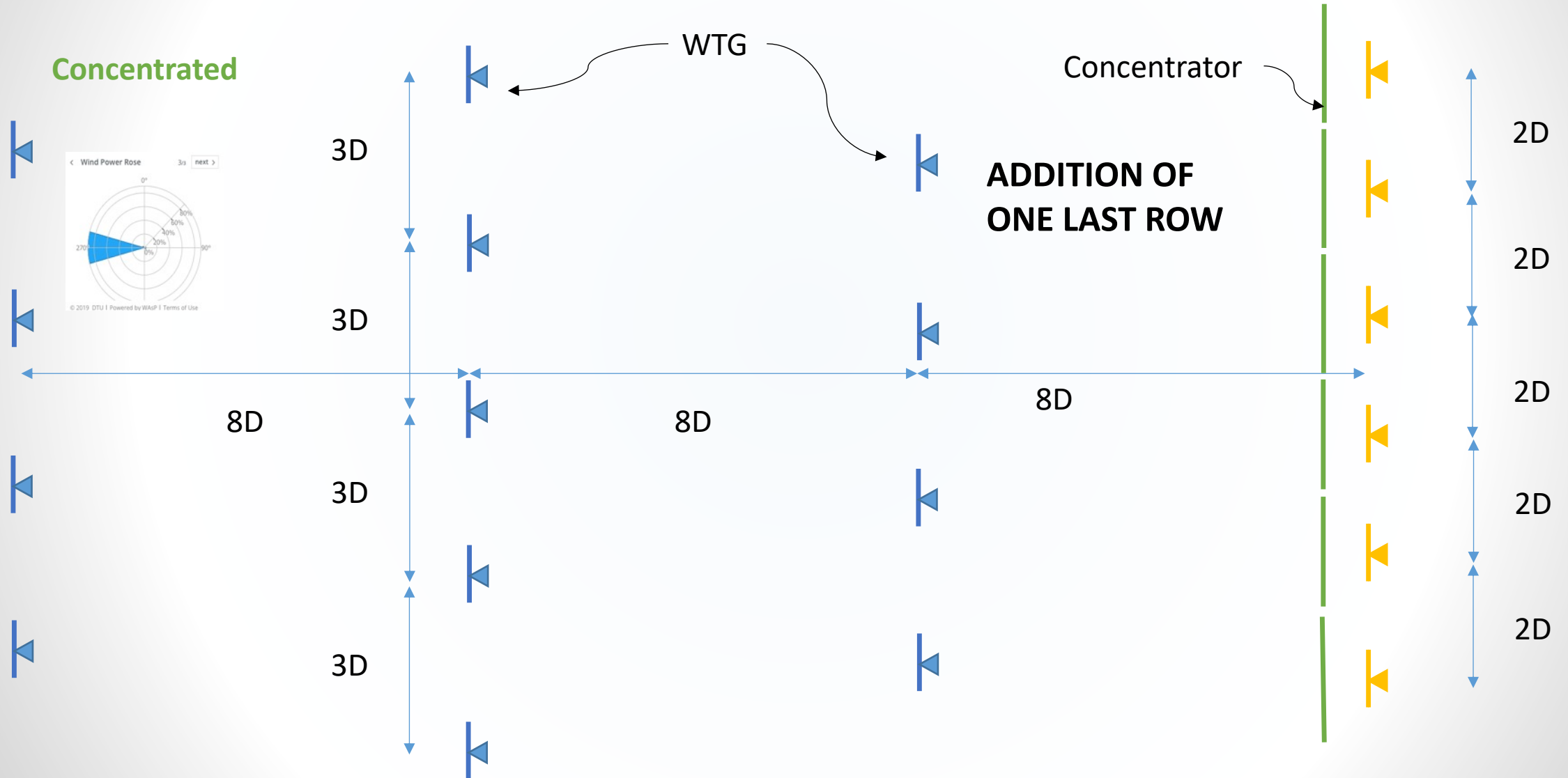
OPTIMIZATION
OF LAST ROW



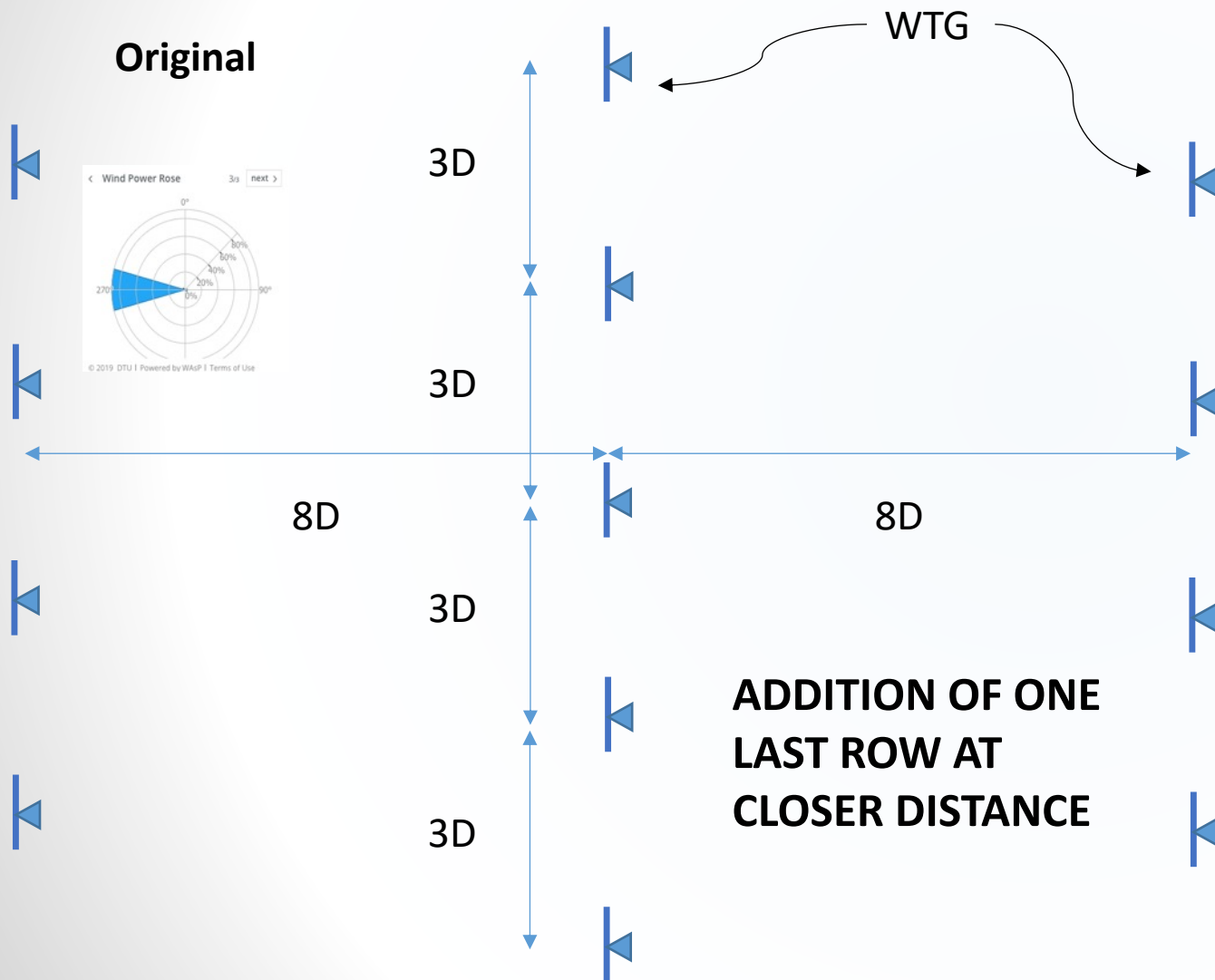
Use Cases CWP in last rows



Use Cases CWP in last rows

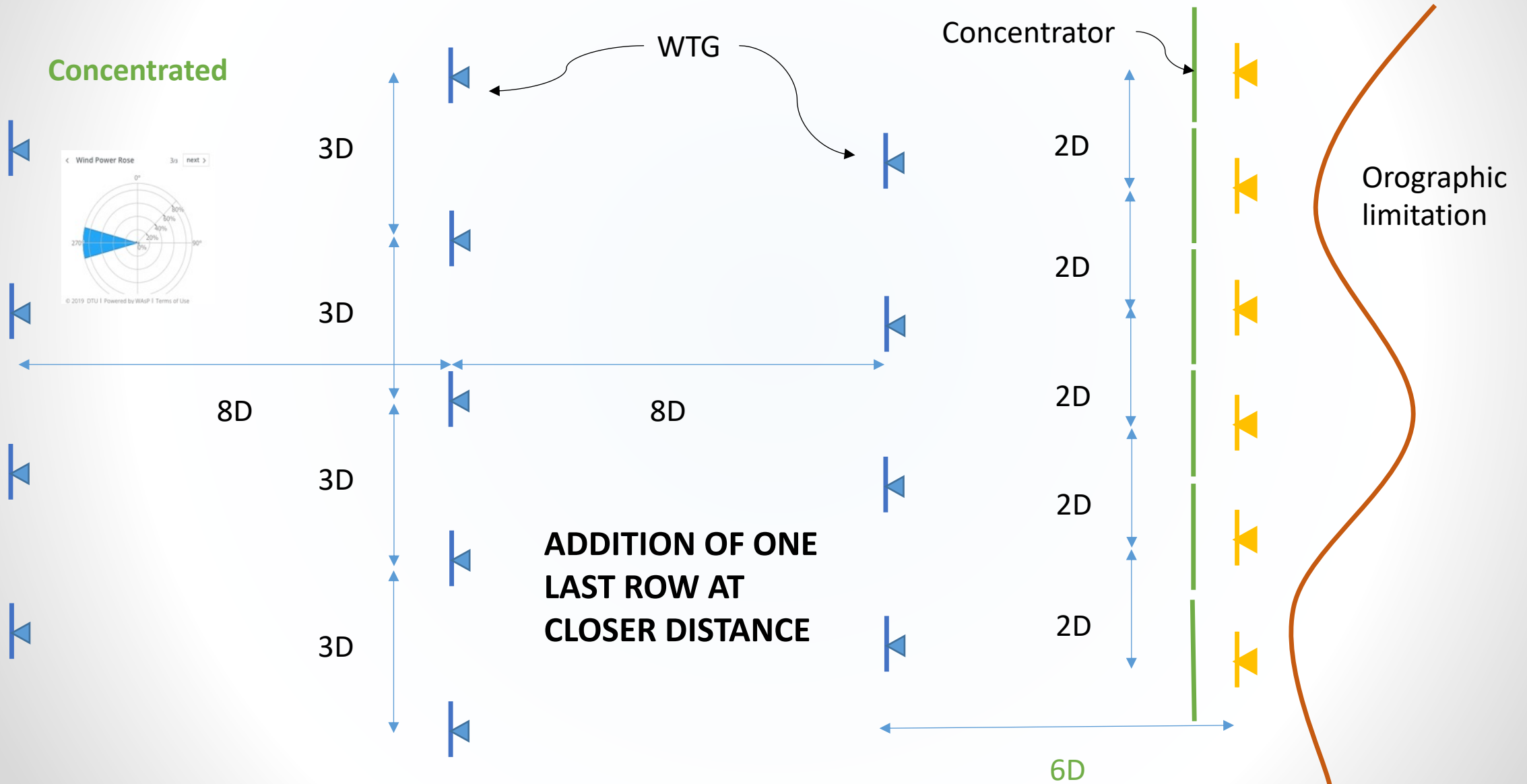


Use Cases CWP in last rows



Orographic
limitation

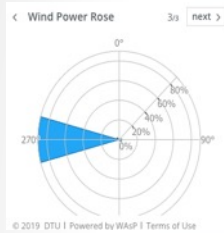
Use Cases CWP in last rows



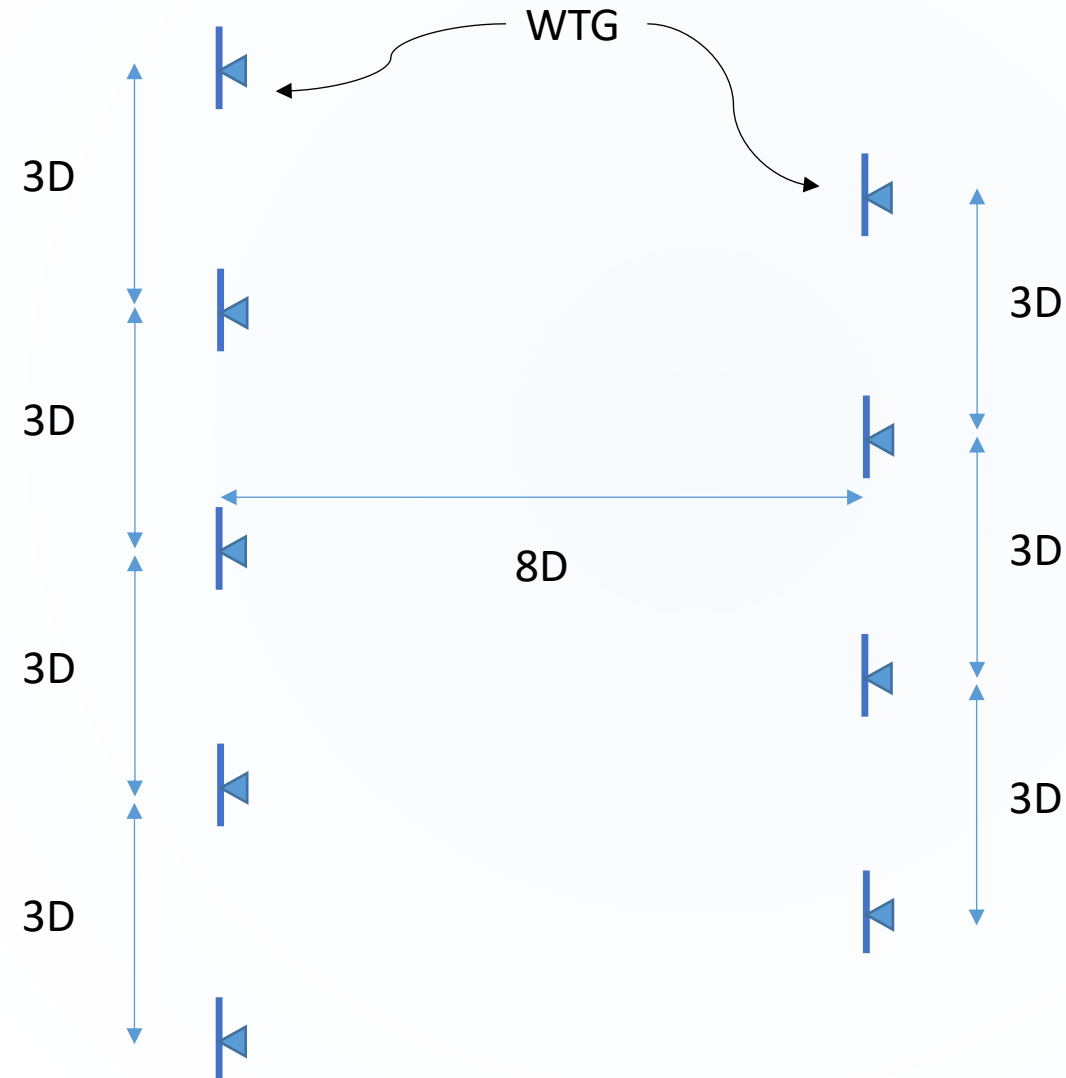
Use Cases CWP in last rows

Original design

9 WTGs



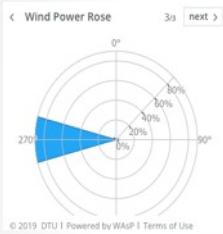
**DESIGN OF WIND
FARMS WITH MORE
TURBINES**



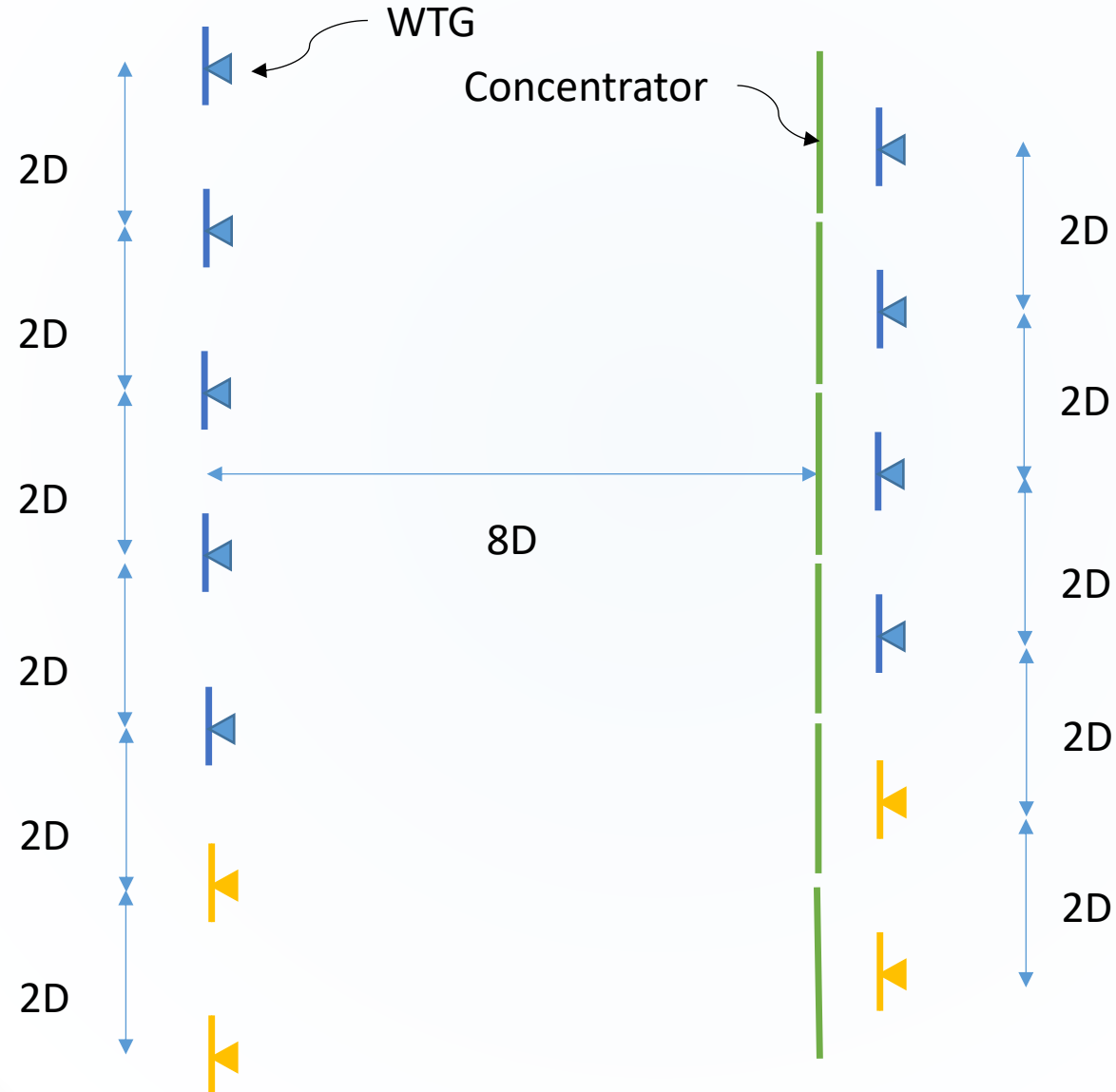
Use Cases CWP in last rows

Concentrated design

13 WTGs

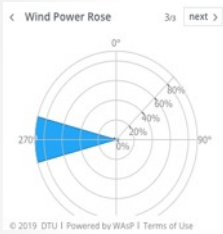


DESIGN OF WIND FARMS WITH MORE TURBINES

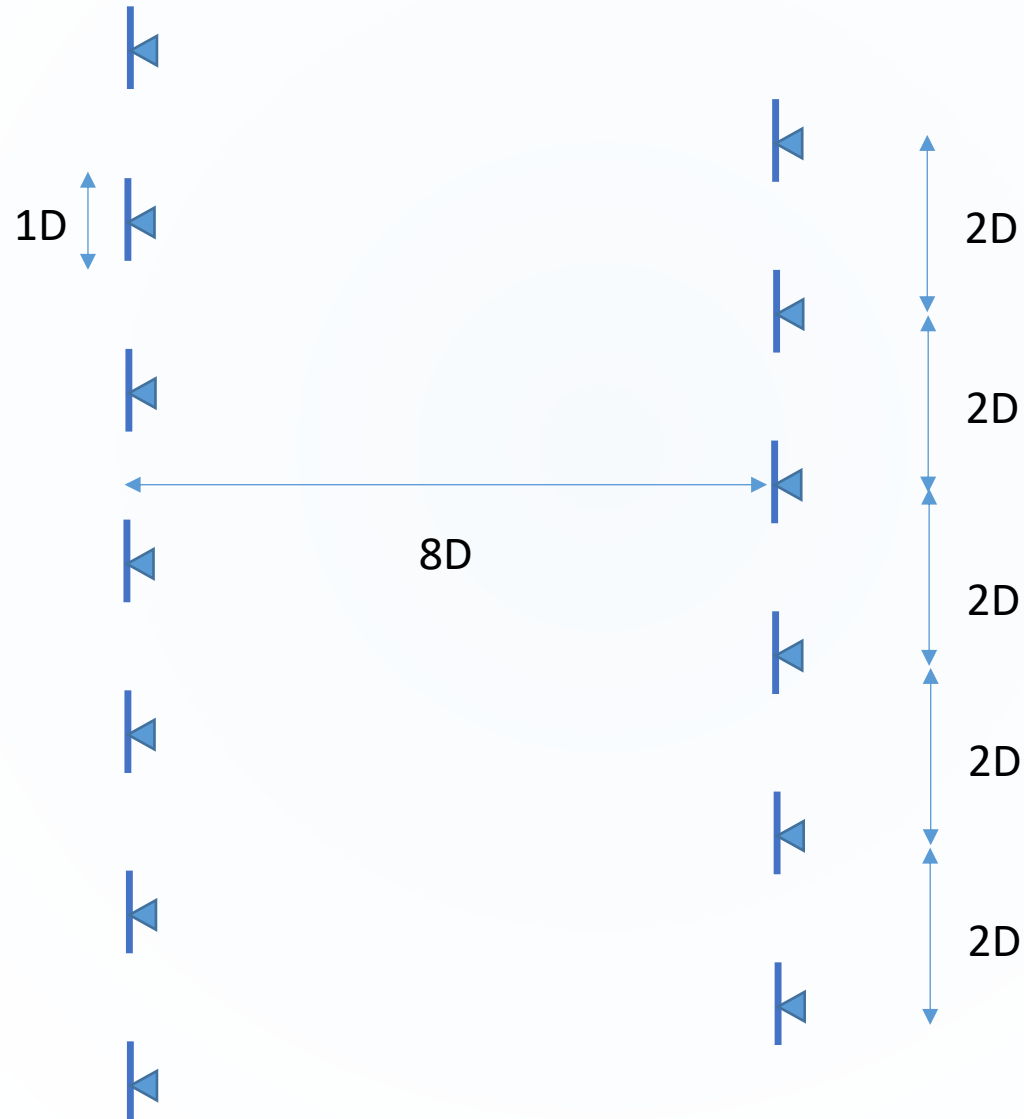


Use Cases CWP in last rows

Original

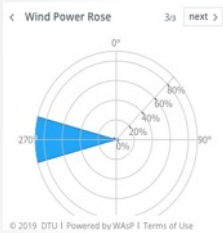


**CONSTRUCTION (OR
REPOWERING) OF
WIND FARMS IN
FRONT OF EXISTING
WIND FARMS.**

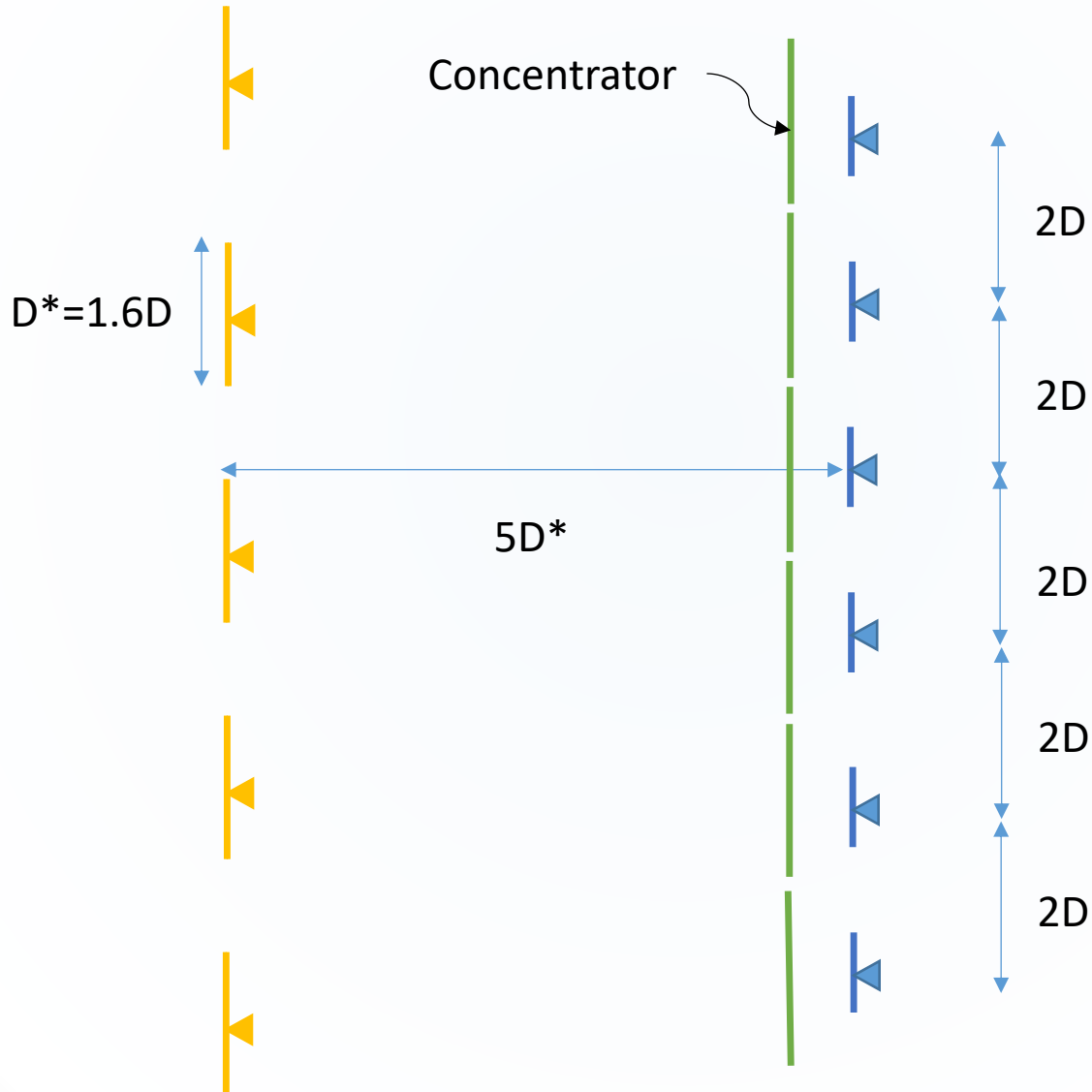


Use Cases CWP in last rows

Repower



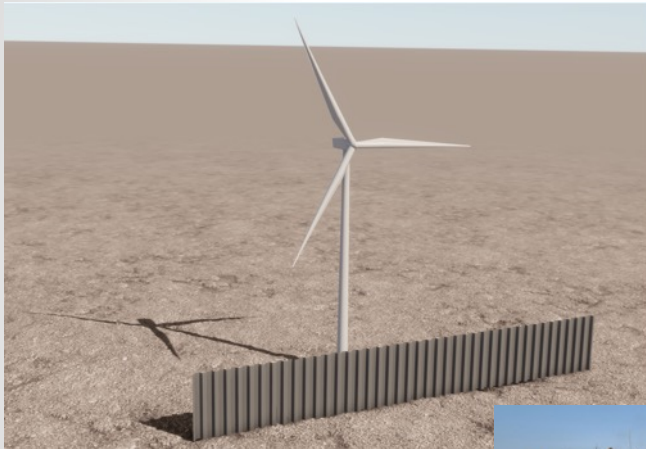
**CONSTRUCTION (OR
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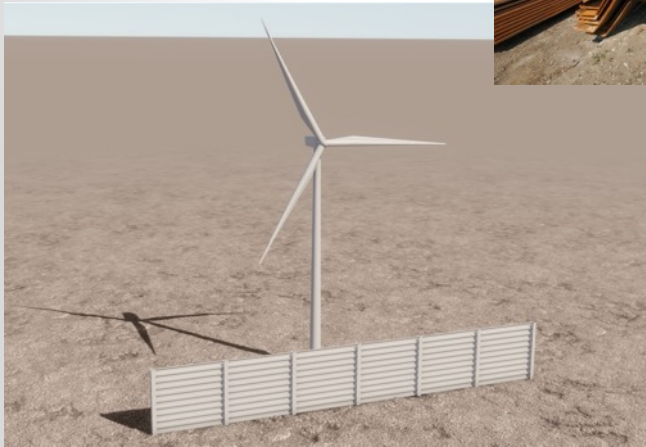
The Product

W'WAVE® Concentrators: Minimum Viable Designs

Steel-Sheet-Pile Concentrator



King-Post Concentrator



Priorities:

- Safety & Compliance (building codes).
- Long, high, but thin (materials economy).
- Universality for all types of soils.
- Low land use. Respect to original surrounding land use.
- High lifetime (>50 years). Low O&M.
- Recyclable and Reusable.
- Low CO₂ footprint: potential sourcing from low-carbon manufacturing processes.

Coming Next: More sophisticated designs.



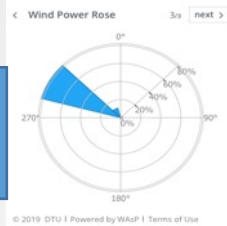
Hybridation Concentrated Wind Power – Solar PV:

- Maximize benefits of hybridation and social benefits respecting original land use.

Next Steps

Regions with clear predominant direction (just some examples. Non limitative. There are many more)

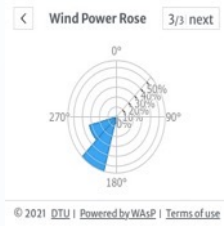
North America



California



Oregon



Washington



Montana



Wyoming

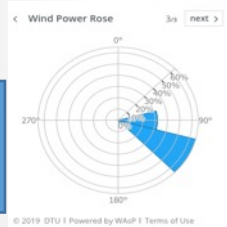


Alberta

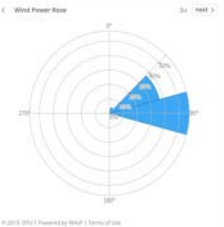


Mexico

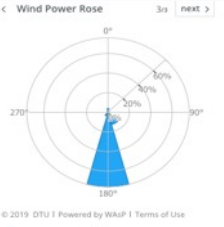
South America



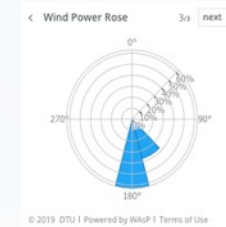
Brazil



Colombia

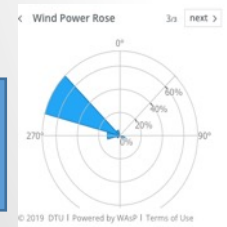


Chile



Perú

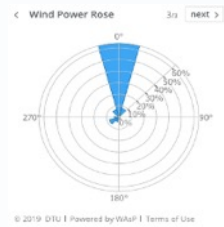
Europe



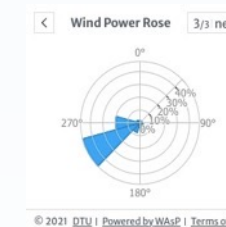
Ebro Valley
(Spain)



Occitanie
(France)

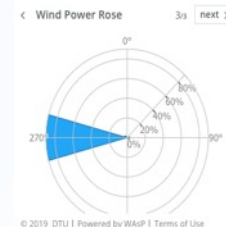


Viotia
(Greece)

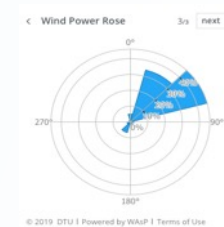


Northeast UK

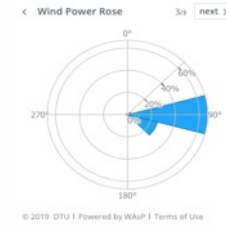
Asia, Middle East & Africa



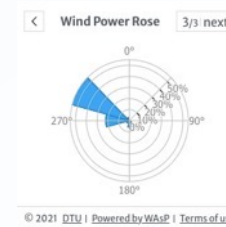
India



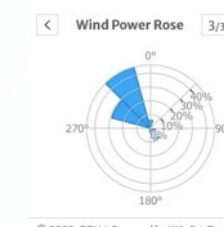
China
(SouthEast)



North
Australia



Japan



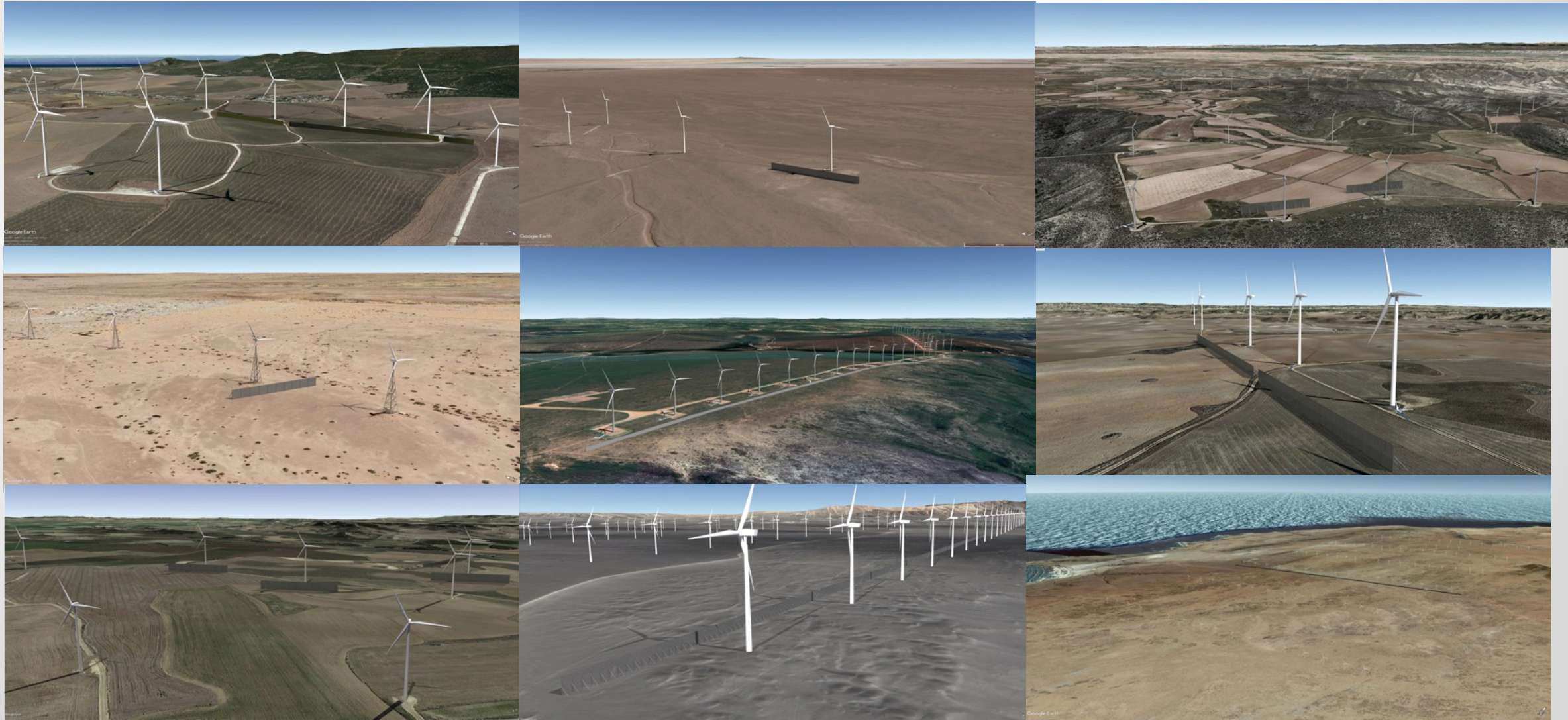
Kuwait



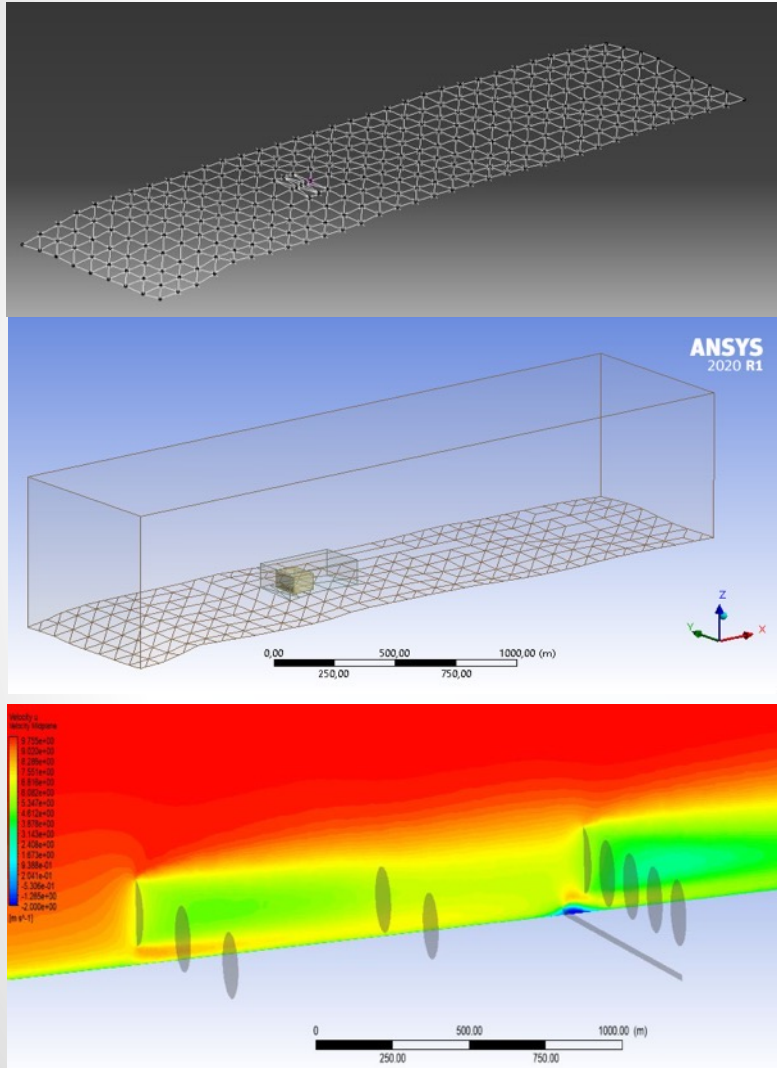
Kenya

Next Steps

Development and data-acquisition in large-scale pilot projects



Next Steps



W'wave's Concentrated Wind Power Assessments

W'wave can provide wind operators and developers **an assessment of the hidden value of their wind farms** that can be unleashed **with Concentrated Wind Power**.

We can produce:

- **Technical reports** using advanced Computerised Fluid Dynamic tools with proprietary tools, validated with 3rd-party and our own field experiments. Our reports show the optimised wind conditions (increased wind speed, decreased turbulence intensity, decreased wind shear) which drive the assessment of the expected wind energy production increase.
- **Financial reports** with the Business Case analysis, considering the increased production and construction price of our Concentrators.

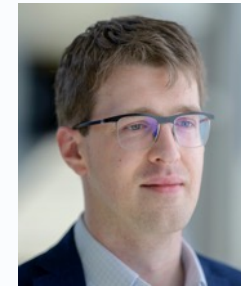
Our reports will enable our Customers' to assess the total value of an asset and guide their O&M and investment decisions.

Thank you for your attention.
Questions?



Manuel Alcocer

Manuel.Alcocer@wwavenet.com



Dr Richard Stevens

r.j.a.m.stevens@utwente.nl