Calculation of the optimal location of the wind turbines

Highlights

- A novel two-fold framework for optimal wind farm placement.
- A long-term wind speed model according to wind directions.
- Optimal wind farm siting and sizing to maximize wind power generation.

1. Introduction

- Wind energy will play an important role in achieving the energy targets. Both small and industrial sized wind turbine systems have the maturity to be considered economically effective. The small wind turbine market is still developing and could see major growth in the near future.

- Taking into account this scenario, it is important to improve energy production from the wind by means of either more efficient wind turbines or enhanced planning of wind farms in terms of wind turbine placement within wind parks and/or location selection. As is obvious, wind turbines are a mature technology and few margins are possible. For high-power wind farms, energy production needs to be optimised to be financially competitive with conventional forms of energy production.

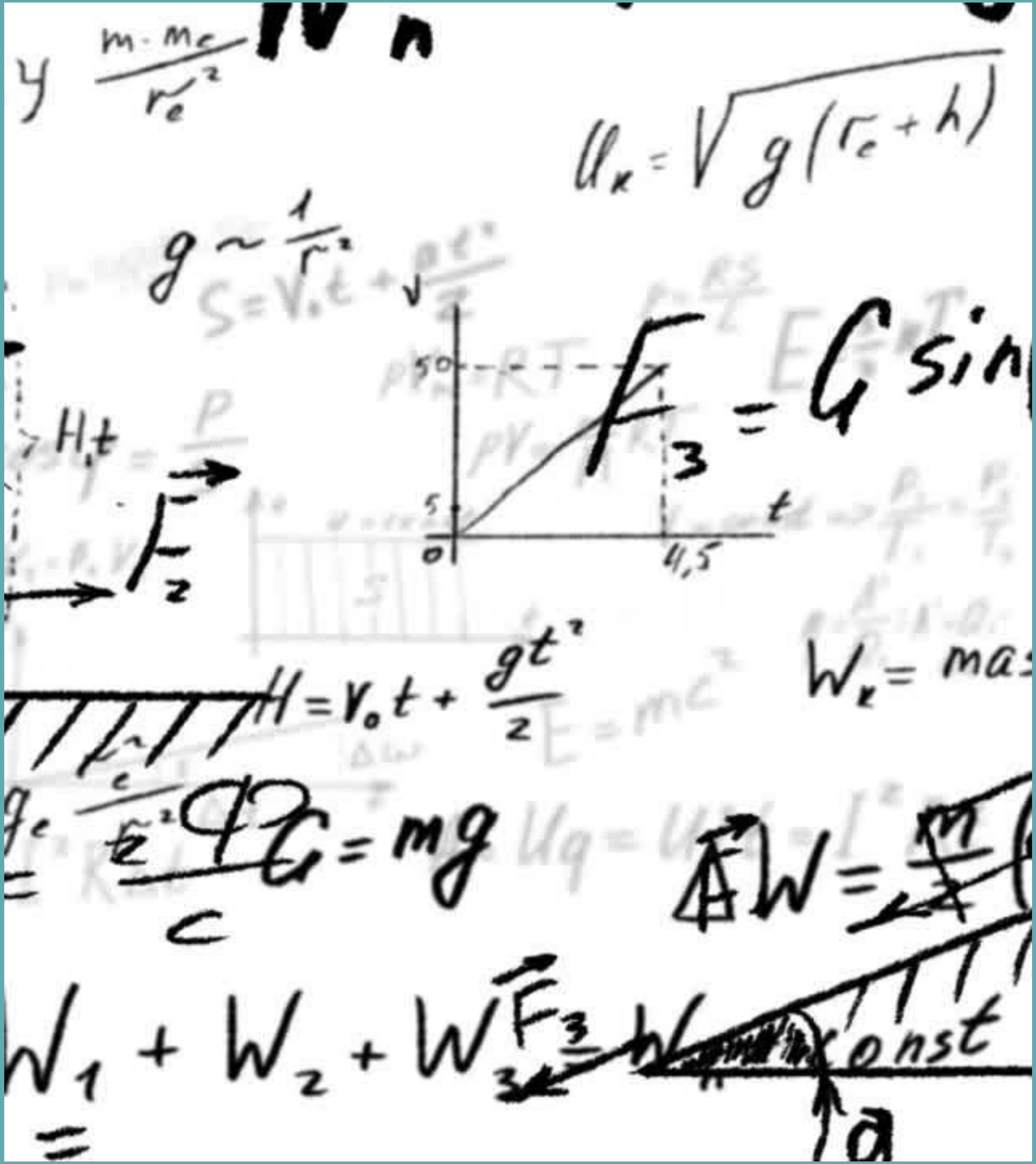
- This paper implements a new mathematical optimization procedure for wind turbine positioning within a wind farm. In this study, multicriteria optimization takes into account maximum energy production and minimum cost. The central factors are wind turbine number and their positioning within the farm based on the criteria above. In this study, a new approach was carried out by using the Monte Carlo simulation. Wind turbine interaction and wind speed intensity, as well as wind direction, were taken into account. A MATLAB program code was implemented to run the optimization method. Moreover, this study focused on the Monte Carlo optimization method's effectiveness evaluation to identify the best wind turbine positioning.

2. SCENARIO

Wind turbines work by converting the kinetic energy in the wind first into rotational kinetic energy in the turbine and then electrical energy that can be supplied, via the national grid, for any purpose around the UK. The energy available for conversion mainly depends on the wind speed and the swept area of the turbine. When planning a wind farm it is important to know the expected power and energy output of each wind turbine to be able to calculate its economic viability.

3. PROBLEM STATEMENT

With the knowledge that it is of critical economic importance to know the power and therefore energy produced by different types of wind turbine in different conditions, in this exemplar we will calculate the rotational kinetic power produced in a wind turbine at its rated wind speed. This is the minimum wind speed at which a wind turbine produces its rated power.



MATHEMATICAL MODEL

The following table shows the definition of various variables used in this model:

E = Kinetic Energy(J)

ρ = Density(kg/m3)

m = Mass (kg) A = Swept Area(m2) v = Wind Speed(m/s)

Cp = Power Coefficient

P = Power (W) r = Radius (m)dt dm = Mass flow rate(kg/s)

x = distance (m)dt

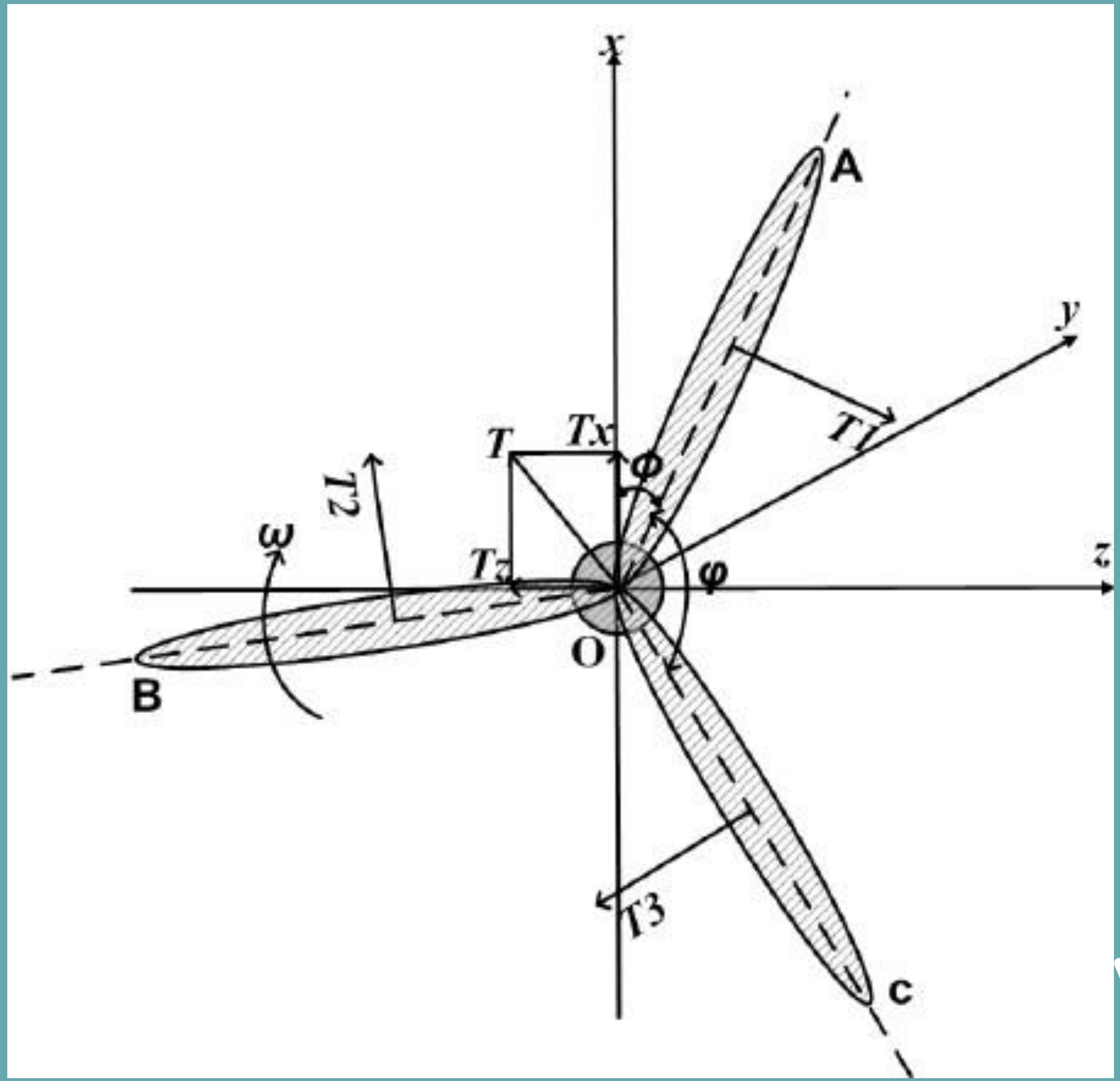
dE = Energy Flow Rate (J/s)

t = time (s)

Under constant acceleration, the kinetic energy of an object having mass m and velocity v is equal to the work done W in displacing that object from rest to a distance s under a force F ,

i.e.: E = W = Fs

According to Newton's Law, we



The swept area of the turbine can be calculated from the length of the turbine blades using the equation for the area of a circle:

A = πr^2 …

CALCULATIONS WITH GIVEN DATA

We are given the following data:

Blade length, l = 52 m

Wind speed, v = 12 m/sec

Air density, ρ = 1.23 kg/m^3 Power Coefficient, Cp = 0.4

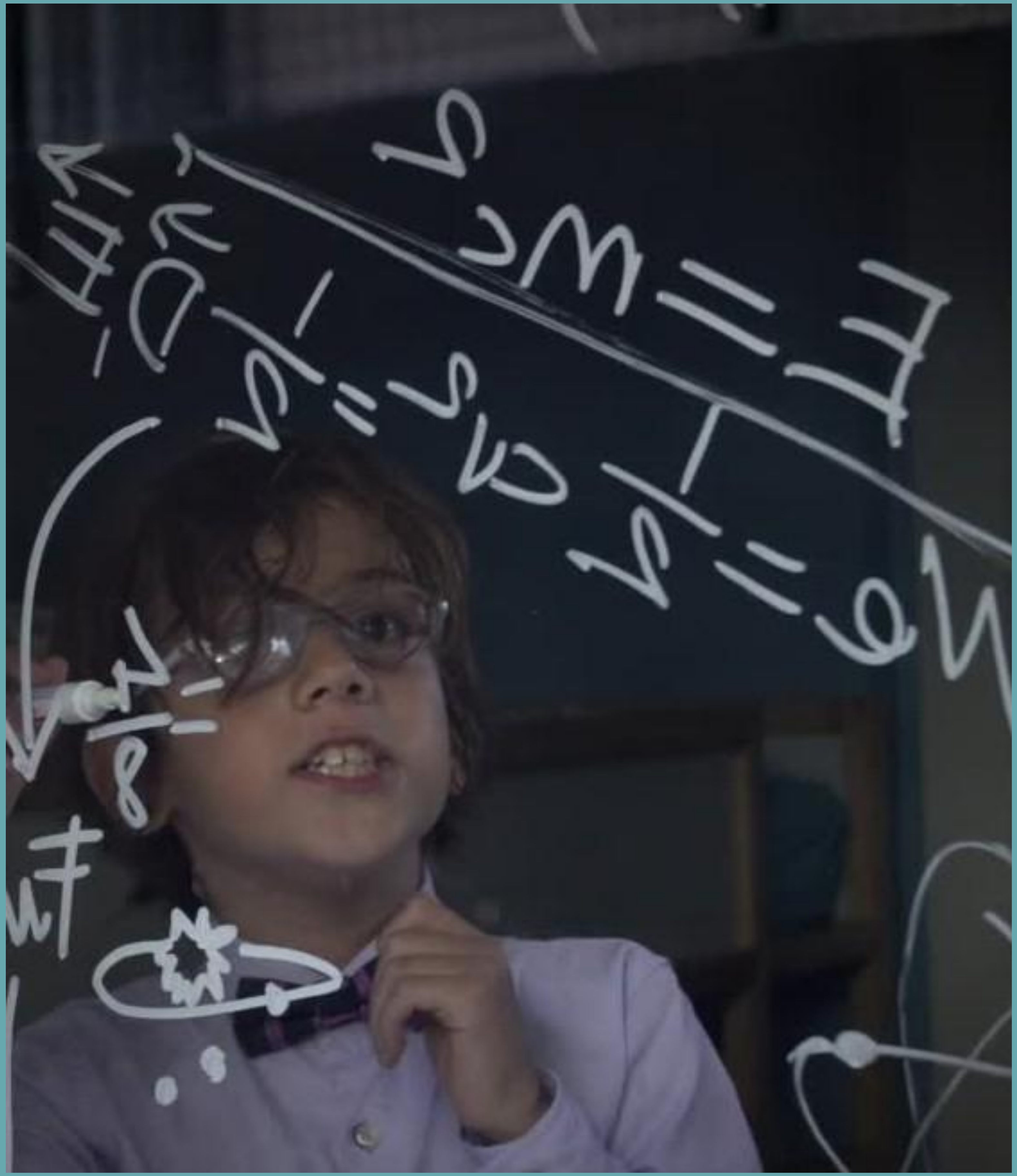
Inserting the value for blade length as the radius of the swept area into equation we have:

l=r=52m

A=πr^2=π*52^2=8495m^2

We can then calculate the power converted from the wind into rotational energy in the turbine using equation:

P=0.5*pAv^3C=0.5*1.23*8495*12^3*0.4=3.6MW



CONCLUSION

This value is normally defined by the turbine designers but it is important to understand the relationship between all of these factors and to use this equation to calculate the power at wind speeds other than the rated wind speed.Having knowledge of how a turbine behaves in different wind speeds is critical to understand the income lost by any down time of the turbine. It is also useful to understand what power a turbine should be producing so that if there is a problem with the turbine this can be picked up on due to lower than estimated energy values.

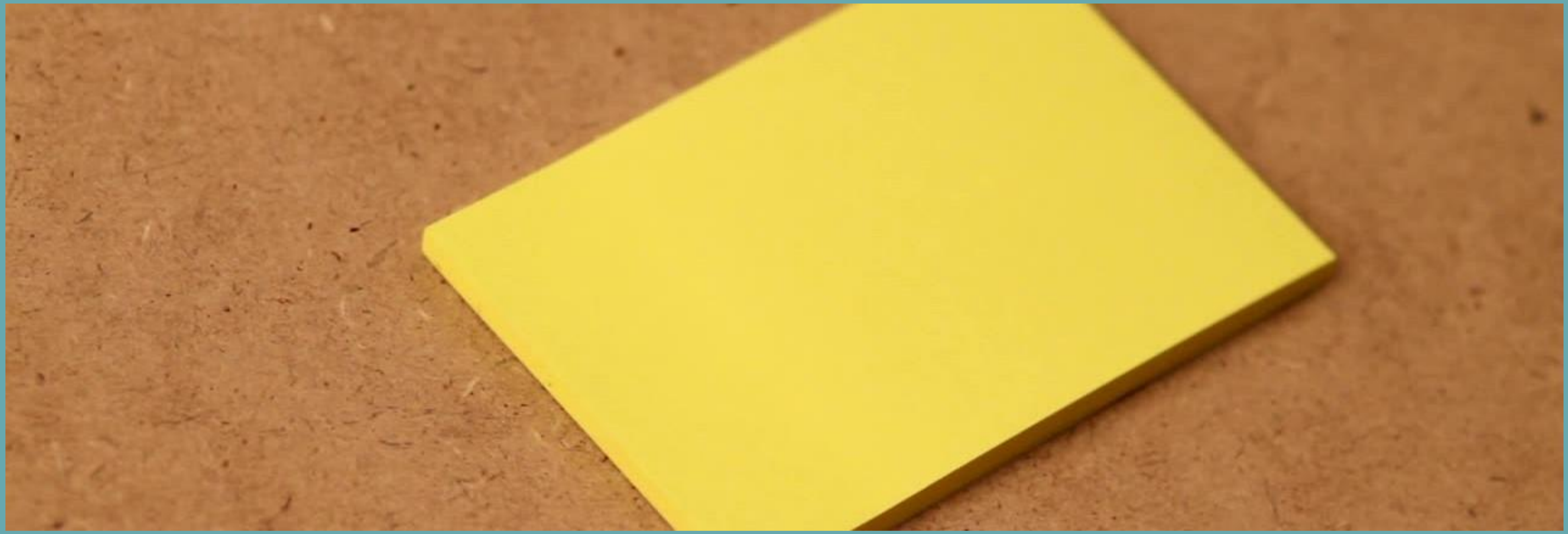
The capacity factor of a wind turbine is defined as the ratio of actual power generation over a period of time, to the potential power generation if it were possible to operate at full capacity indefinitely:

Capacity Factor=Total Generation/Turbine Size*Operating Hours

For the proposed model, the annual capacity factor η of a wind turbine at a site can be calculated using the expected annual power generation   in the definition of capacity factor.

- The optimal placement of wind farms under grid constraints

The integration of wind farms and their power outputs into the electrical grid affects the operation of the transmission system. Therefore, grid operators demand that newly integrated wind power plants into the electrical grid do not violate the transmission system constraints.The ineligible geographical areas for wind farms due to the economic and environmental criteria contain urban areas, natural parks, airports, etc. and areas at an altitude higher than 2000 m.



Conclusions

In this paper, two main studies were carried out and presented. The first study is based on the use of wind data in terms of direction and intensity per year. In the second, only dominant wind direction and intensity were used.

The results suggest that optimal wind turbine placement should take into account changing wind direction and intensity which can lead to a scattered wind turbine distribution on the ground, while placement using only the dominant wind data prevalently aligned with the dominant wind direction. In both cases, all the available terrain surface is taken up.

Moreover, using dominant wind intensity tends to overestimate the annual energy production by about 9%. Thus, using all the wind data leads to a more precise annual energy evaluation and a more optimal placement of thanks

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