

Burying Climate Change



University
of Victoria

Capturing and Solidifying Carbon Dioxide with Wind Turbines

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Introduction

Carbon emissions - a concerning topic within the battle against climate change. Typically, the methods that combat carbon emissions are almost exclusively to mitigate the discharge of carbon dioxide. Some of the most attractive methods are driving electric cars and limiting beef consumption. Although effective, those methods alone are not sufficient in producing a substantial change.

Instead of reducing carbon emissions, we reverse the process by capturing carbon dioxide from the air and converting it into carbon rock - a more tangible and disposable substance.

The foundation of the carbon capture process is an offshore wind farm consisting of hundreds of wind turbines that operate to collect air (figure 1). It then goes through a filtration system where CO₂ is extracted and injected (figure 2) into ocean basalt on the seabed, converting it into basalt rock (figure 3). Over time, the wind farm needs maintenance or repairs for continual operation.

The purpose of this study is to develop and implement an efficient strategy for the operations and maintenance of the wind farm.



Figure 1. Offshore Wind Farm



Figure 2. CO₂ Injection

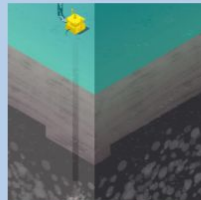


Figure 3. Basalt Rock Conversion

Methods

The implementation of the operations and maintenance strategies was driven by an open-sourced software called WOMBAT (Windfarm Operations and Maintenance cost-Benefit Analysis Tool). The software simulated how the wind farm would react to typical offshore conditions such as wind speed and sea wave height (figure 4). Based on these reactions, the simulation calculated failure rates and repair maintenance needs alongside the corresponding costs and production delays.

Using Python, WOMBAT's functions were deconstructed and remodelled to optimize costs and increase overall efficiency specific to our wind farm. Software testing using unit tests was followed subsequent to every change, ensuring simulation accuracy and consistency.

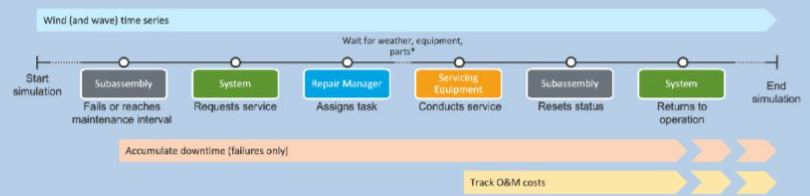


Figure 4. WOMBAT simulation process modelling a discrete event simulation

Results

At its initial capabilities, WOMBAT was calculating its metrics with a fixed distance of 50km between the shore and the wind farm. We formulated a new function to calculate variable distances within a range of anywhere between 50km to 200km offshore. As the distance from shore increased, the productivity of the wind farm declined and maintenance labour costs increased linearly.

A Direct Air Capture (DAC) unit is essentially a filtration unit that separates the CO₂ from the air (figure 6). This fundamental component in the wind farm was lacking in WOMBAT's software. We implemented the necessary components of the DAC unit into the software (compressor, heat-pump, flowline, etc) and established metrics for each of these components. These metrics were the amount of CO₂ produced with and without considering variable wind speeds and wave heights.

In the event of a component failure, the simulation will determine the corresponding costs and production losses for the DAC unit. This implementation increased overall wind farm maintenance costs and labour hours in the simulation.

Additional features were added such as the ability to input a desired maintenance duration or repair frequency for CO₂ production and maintenance cost analysis.

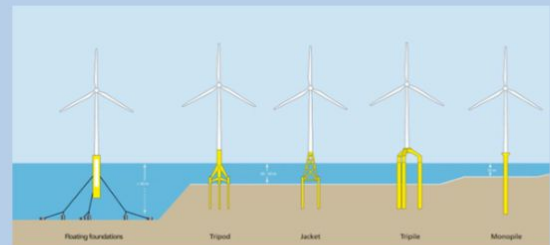


Figure 5. Examples of different types of wind turbines

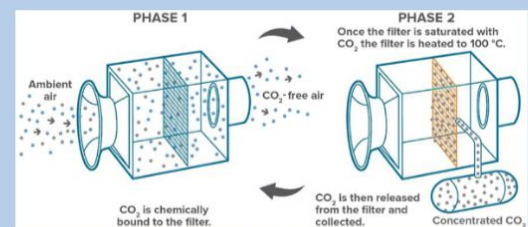


Figure 6. Direct Air Capture unit filtration cycle

Discussion

There are a plethora of moving parts within the operations and management of a wind farm, and more to be discovered. As strategies are still in development, the new functionalities to WOMBAT are not concrete and are subject to change as more research is conducted. WOMBAT is at a stage where it has been integrated into the research's code base and adheres to the code that was previously written by my colleagues. Further operations and maintenance research must be done on hydrogen generation, floating offshore wind turbines, and carbon injection.

Moreover, three primary vessels are considered in the operations and management strategies - Crew Transfer Vessel (CTV), Field Support Vessel (FSV), and Heavy-Lift Vessel (HLV). With the addition of variable distances from the wind farm to the shore, labour, maintenance, and oil costs for these vessels become variable as well. Further analysis of these vessels or other transportation methods is required to optimize costs.

Wind speed and wave height were critical factors in increasing CO₂ production in the wind farm. When neglecting offshore sea conditions, CO₂ production significantly increased compared to when the conditions were accounted for. This is an indicator that sea conditions must be mitigated to increase wind farm efficiency.

References

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