***commercial cost-benefit analysis Of Dogger Bank WindFarm***

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## Overview

Transition from an energy mix dominated by fossil-fuel based energy generation to an energy mix with larger proportions of renewable energy, is on the agenda for many countries. The motivation is related to combatting climate change issues and to assure energy supply security. Renewable energy is capital intensive. If we are to reach the climate change goals within stated timeframes, investments from private companies are arguably a necessity. In particular, oil and gas companies have capital and competence needed to undertake large, renewable energy project. The decision-making of private companies, however, are not primarily driven by economics arguments but rather by financial arguments. In other words, the projects must be profitable from the companies’ perspective when using financial criteria such as net present value, internal rate of return and payback period (Osmundsen et al., 2021). Interestingly, as argued by Jaraite and Kazukauskas (2013) and Aguirre and Ibikunle (2014), there is a gap in the literature pertaining the business economics of renewable energy projects. We aim to fill some of this gap by undertaking a case study on Dogger Bank Windfarm.

Dogger Bank Windfarm is scheduled to be the largest offshore wind farm in the world by the time of its completion. The development site is located more than 130 km to the east of the coast of Yorkshire in the UK part of the North Sea. The water depth ranges from 20 to 35 metres. Dogger Bank consists of three projects: DBA, DBB and DBC. It was initially planned to have 100 12MW wind turbine generator of the Haliade-X series. The wind farm will have a capacity of 3.6GW, enough to provide 4.5 million British homes with electricity. This corresponds to roughly 5% of the energy consumption in UK. The projects are a joint venture between Equinor, SSE Renewable and ENI. Cost estimates suggest an investment cost of GBP 9 billion, which is to be invested between 2020 and 2026. The lifespan of Dogger Bank Windfarm is expected to be 25 years.

## Methods

There are two key objectives of our paper. First, we aim to develop a baseline scenario where we estimate the expected net present value (NPV) of the Dogger Bank Windfarm projects. Second, we address the uncertainty of the baseline estimate by conducting sensitivity analysis and Monte Carlo simulations. With our analysis, we elucidate which factors, constituting the NPV calculation, are the most uncertain and have the greatest impact. Given a set of inputs, the net present value is straightforward to calculate. See Equation (1).

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|  | $$\begin{matrix}Net\\Present\\Value\end{matrix}=\sum\_{t=1}^{T}\frac{\begin{matrix}Cash\\Flow\end{matrix}\_{t}}{\left(1+\begin{matrix}Discount\\rate\end{matrix}\right)^{t}}-\begin{matrix}Investment\\cost\end{matrix}$$ | (1) |

However, considerably more effort is required to estimate the various inputs. Based on information from Equinor’s press release, we know the estimated capex. With empirical analysis of past projects (Dahl et. Al., 2017; Lorentzen et. Al., 2017, Sovacool, 2017), a probability density function can be inferred for cost overruns. The discount rate calculated with the weighted average cost of capital (WACC) equation. See Equation (2).

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|  | $$WACC=\frac{Debt}{Debt+Equity}⋅\begin{matrix}Cost of\\Debt\end{matrix}⋅\left(1-\begin{matrix}corporate\\tax rate\end{matrix}\right)+\frac{Equity}{Debt+Equity}⋅\begin{matrix}Cost of\\Equity\end{matrix}$$ | (2) |

Further estimation is required to establish the cost of equity. In our case, we apply the capital asset pricing model. See Equation (3).

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|  | $$\begin{matrix}Cost of\\Equity\end{matrix}=\begin{matrix}risk free\\interest rate\end{matrix}+β\left(\begin{matrix}return on\\market\\portfolio\end{matrix}-\begin{matrix}risk fee\\interest rate\end{matrix}\right)$$ | (3) |

The most challenging input to estimate is the cash flows throughout the 25 years of expected lifespan. The annual cash flow, throughout operations, is the difference between income and operational expenditure (Opex). The latter is calculated based on parametric cost estimation using empirical data from past wind farm projects. Specifically, lifetime Opex is typically found to be equal to around 90% of nominal Capex or 25-35% of Levelized Cost of Energy (LCoE). We use a similar approach for the decommissioning cost. The annual income is given as specified in Equation (4).

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|  | $$Income=\left(Capacity⋅\left(24 hours⋅365 days\right)⋅\begin{matrix}capacity\\factor\end{matrix}⋅price\right)$$ | (4) |

Capacity and number of hours in a year, are well-known quantities. An idealized capacity factor is provided by GE, the producers of the Haliade-X wind turbine generators. The capacity factor is defined as the ratio between actual production and the theoretical maximum production. We conduct an extensive literature review and conduct various subject-matter expert interviews to establish a more realistic capacity factor. For the initial 15 years of operation, the windfarm will be subject to a fixed price, which is specified in the contract for difference (CfD). For the final decade of operation, the wind farm will be operating under market prices. Arguably, the market price is the most uncertain. Any estimate would come with a high degree of uncertainty. Again, we rely on an extensive literature review and consultation with experts from both the academic and industry domain.

Once a baseline for the net present value has been established, we conduct both a sensitivity analysis and simple Monte Carlo simulation. In accordance with best practice in project management, we utilize a PERT distribution for each of the stochastic input variables. The parameters of the PERT distribution are specified using expert judgment. Orthogonality is assumed between the stochastic variables.

## Results

Overall, the results suggest that the wind farm will be marginally profitable if everything goes according to plan. The payback period is beyond the initial 15 years of fixed price. The net present value is highly sensitive to the choice of discount rate. If we are to apply a discount rate that is commonly applied to petroleum projects, then the Dogger Bank Windfarm will have a negative net present value. In other words, the projects would be value destroying. As previously established, Dogger Bank Windfarm will be operating under a fixed price regime for the initial 15 years of operation. As such, it is reasonable to operate with a considerably lower discount rate. We argue for using two different regimes of discount rate – one for the fixed price period and another for when the wind farm is subjected to market prices. Even when the wind farm is operating under market prices, we argue for a lower discount rate compared to conventional petroleum projects. Both petroleum and electricity prices are volatile. The former is nonstationary while the latter is stationary. Given the two different discount rates, we cannot conduct a standard internal rate of return analysis. Results from the Monte Carlo simulation showcase that the probability of the profitability tipping into the negative is substantial. In short, whether the projects will be profitable, in terms of net present value, will largely depend on beliefs regarding the market price of electricity 15 years from now and how low the company is willing to go regarding the hurdle rate.

## Conclusions

Our analysis elucidates important aspects of the business economics of offshore wind farm project by using Dogger Bank as a case study. Based on the established baseline, the projects will be marginally profitability. Chances of the project turning out to be unprofitable is large. With our analysis, we have revealed a knowledge gap in regard to the capacity factor and the future market price. More research is needed on these two topics. To ensure the continued participation of oil and gas companies in the shift toward a greener energy mix, we argue that continued support from governments in terms of the CfD is needed. Continued innovation is also needed to ensure cost reduction.

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