# AMMONIA PRODUCTION FROM A NON-GRID CONNECTED FLOATING OFFSHORE WINDFARM: A SYSTEM LEVEL TECHNO-ECONOMIC REVIEW

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## ABSTRACT

This paper investigates the technical and economic feasibility of a floating offshore wind driven ammonia production system with a capacity of 300 tons/day. The ammonia plant is located on a plantship and there is no connection to the grid. An analytical model (MATLAB based) for this system was based on an all-electric Ammonia plant and the use of 4.5 MW wind turbines.

## INSPIRATION

▪Recent trends in the offshore wind sector indicate a shift towards installment of windfarms further away from the shore [1].

▪Currently transmission through electric cables, but increasing distance leads to higher reactive power losses, thereby making it inefficient, and with addition of higher costs and engineering complexity, it is not a long-term solution.

▪This leads to investigation of ammonia as an energy storage medium for the offshore windfarms.

## BACKGROUND

- Dissertation by Morgan (2013) provides a techno-economic review of a 300 tons/day ammonia production system from a grid connected offshore windfarm [2].
- Connection to the grid allowed a uniform ammonia production despite variations in the wind.

## MODEL DESCRIPTION

The turbine model selected is Wind 2 Energy W2E-151-4.5MW turbine and enlarging its rotor diameter to 162m. The electrical energy from the wind farm will desalinate sea water and the distilled water produced will run through the electrolyzers which will produce hydrogen gas. To produce nitrogen, air separation method is used. Hydrogen is compressed at around 150 to 250 bars in compressors. The next step is to feed the produced hydrogen and nitrogen in an ammonia synthesis loop, which is a continuous cycle of gases that travel at high temperature and pressure through an adiabatic reactor. The ammonia plant is on a plant ship and there is no connection to the grid.

. This creates a challenge, as the ammonia synthesis plant must operate between 65-100% loads [3]. Thus, the concept of multiple mini-ammonia plants is used to address the scenario of wind energy production at less than rated power. This will allow operation of one or more mini- ammonia plant (corresponding to the available energy from offshore wind). In the event of wind speed lower than the cutoff wind speed for the turbine, the ammonia plant will use the produced ammonia as fuel to power a gas turbine engine in a Brayton or combined cycle configuration in order to keep the plant idling.

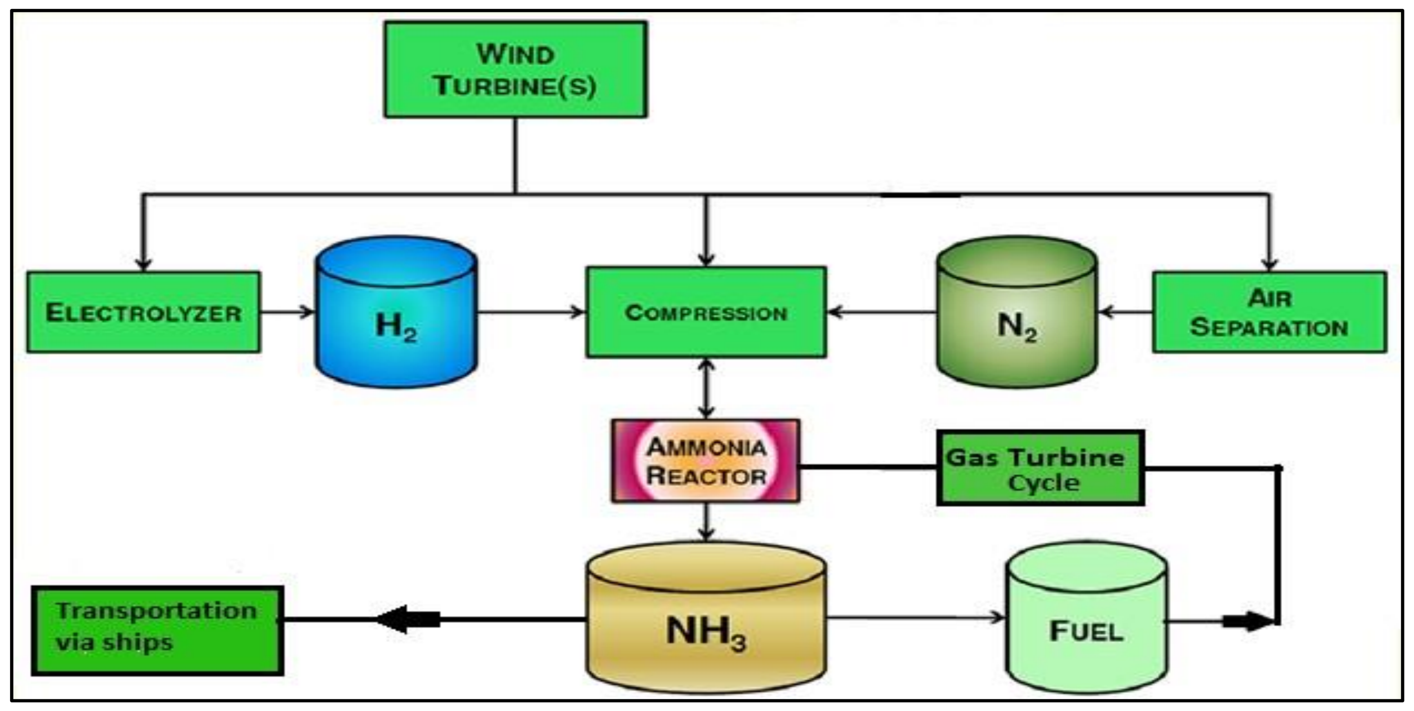


Figure 1: Flow-chart of offshore wind ammonia production system [4]

During this time, it will maintain the reaction conditions of the synthesis chamber and will not produce any ammonia. This step is necessary because it will take days to restart the plant because of time consumed in regenerating the catalyst used in the Haber-Bosch process [3], which in turn will make the project less economically viable. Thus, at any wind speed, a mini-ammonia plant would either idle or operate between 65-100% load.

## SYSTEM ECONOMICS

The economics of the proposed system were determined from estimates for the capital and operation and maintenance costs of the entire system [3]. The major subsystems included: 1) Offshore wind farm, 2) All-Electric Ammonia Plant, 3) Ammonia Powered Gas Turbine, and 4) Platform for the Ammonia Plant. Next, the economics model produced values for the Levelized Cost of Ammonia (LCOA) in $/ton. The LCOA is basically the ratio of total average lifetime capital costs and operation and maintenance costs over the lifetime ammonia production.

## SITE SELCTION AND WIND PROFILE

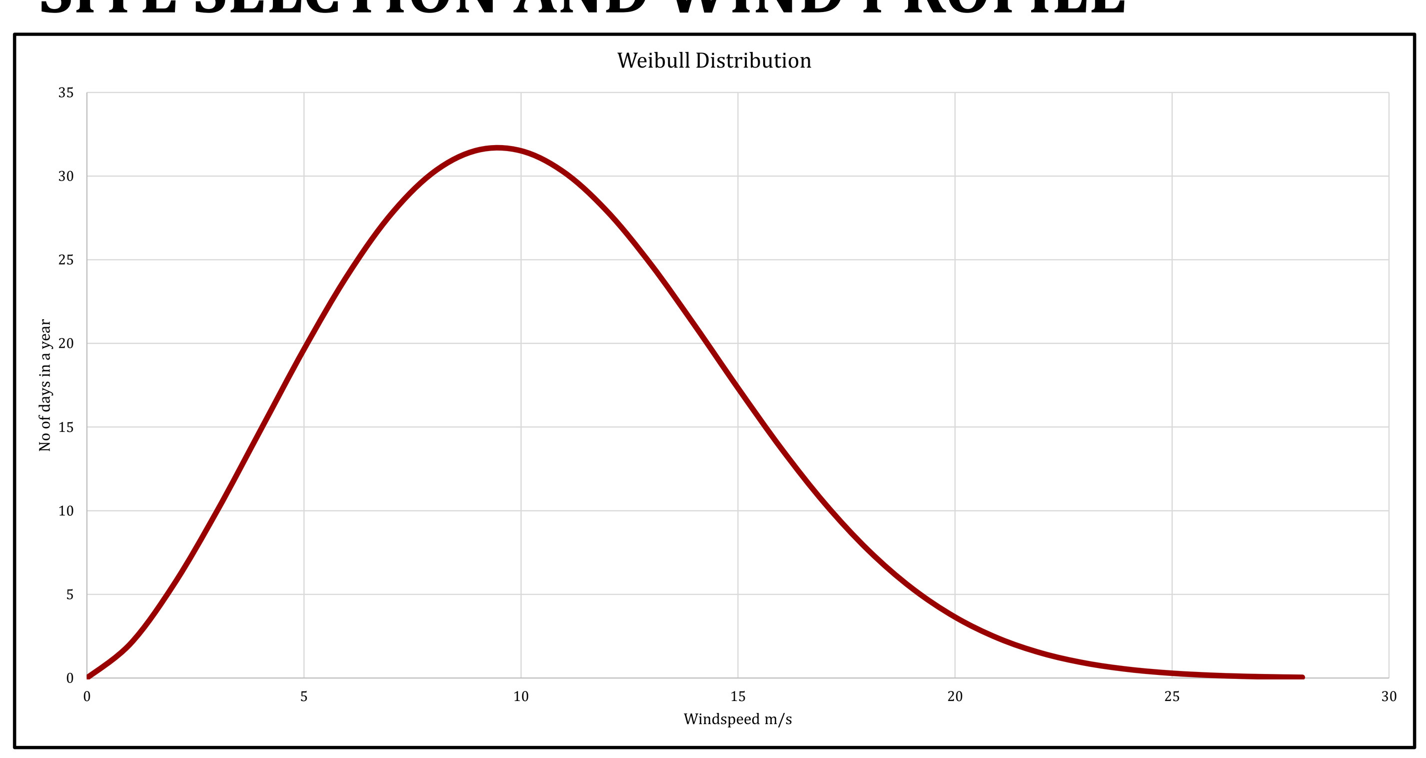


Figure 2: Weibull wind distribution for a year [4]

The wind speed at 90m above sea level is 10 m/s at a site which is 50 nautical miles from the shore of Massachusetts and has a depth of 60 meters [1]. In addition, the Weibull distribution is used to estimate annual wind distribution at hub height of 140m.

## RESULTS AND DISCUSSIONS

The divisions certainly help to increase the net annual production but with considerable increase in the LCOA as well. Here the term division implies the use of number mini-ammonia plants with the combined potential of rated ammonia production. The LCOA is lowest at almost ($1566/ton of NH3) when there are only 2 divisions as shown in figure 3. The LCOA for the baseline grid connected all-electric ammonia plant calculated by Morgan (2013) was $1224/ton of NH3 [2]. It is almost $350/ton of NH3 higher here.

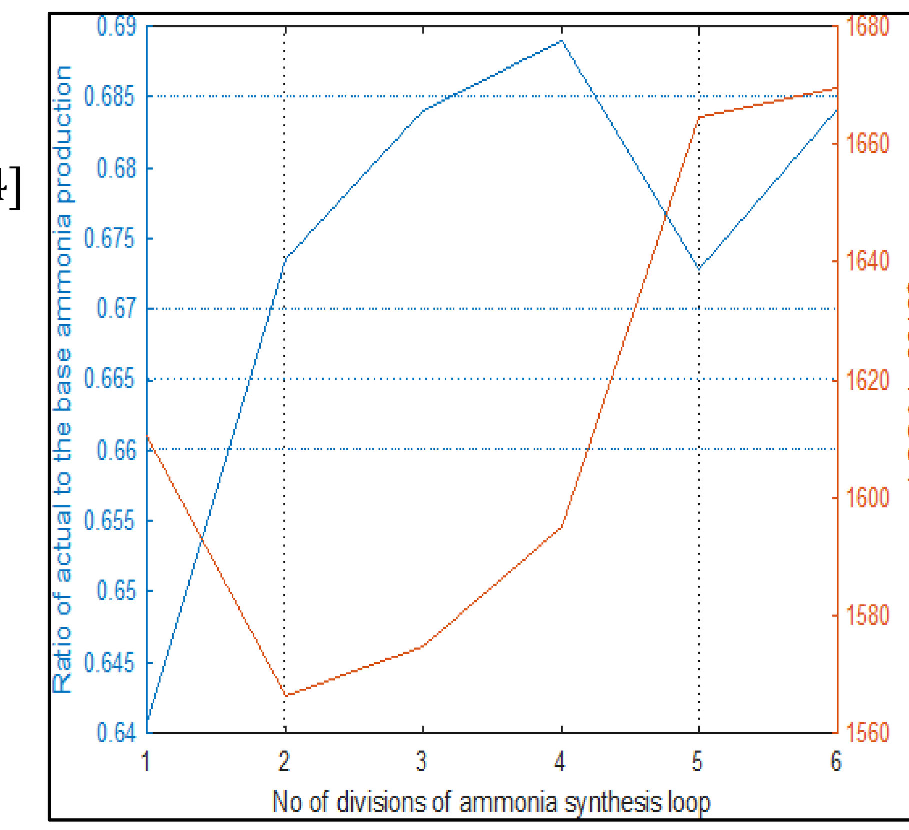


Figure 3: LCOA vs number of divisions of ammonia synthesis loop [4]

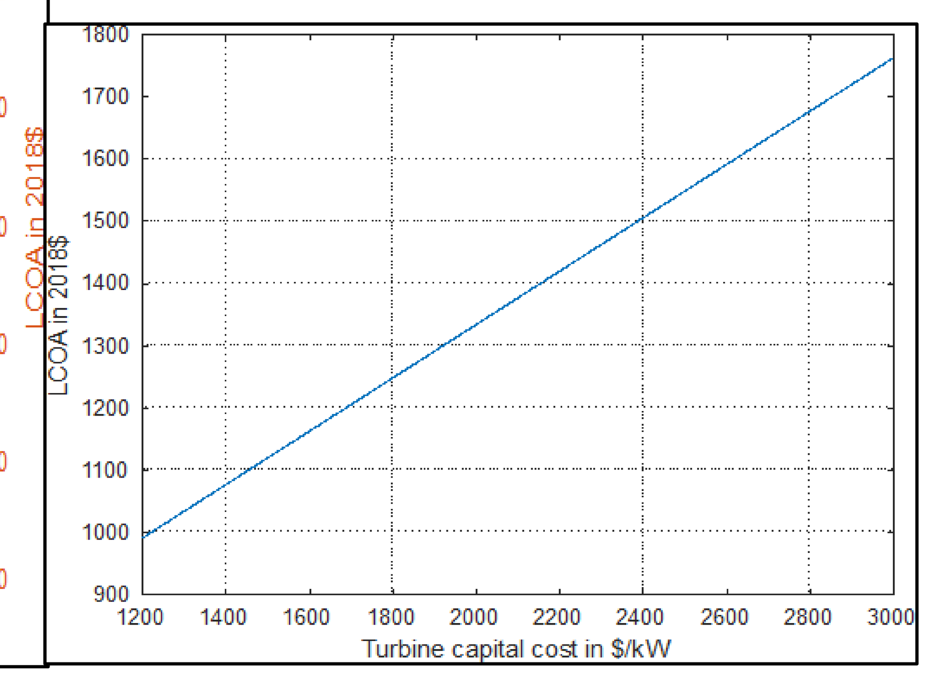


Figure 4: LCOA vs capital cost of the wind turbine [4]

LCOA linearly increases with increase in per kW cost of the turbine as shown in figure 4.

## FUTURE WORK

- Ammonia production calculation on 10 min wind data.
- Opportunities to optimize energy flow from windfarm to the ammonia plant.
- Possible to produce ammonia throughout the year.
- Estimation of accurate wind turbine prices. Any reductions or additions in the capital expenditure of wind turbine prices will have an amplified effect on the LCOA.
- Accurate estimation of the efficiency and capital expenditure of an ammonia powered gas turbine cycle.

## REFERENCES

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