CARBON IMPLICATIONS OF ENERGY STORAGE IN GRIDS WITH EXPANDED WIND ENERGY

Is energy arbitrage inherently green?

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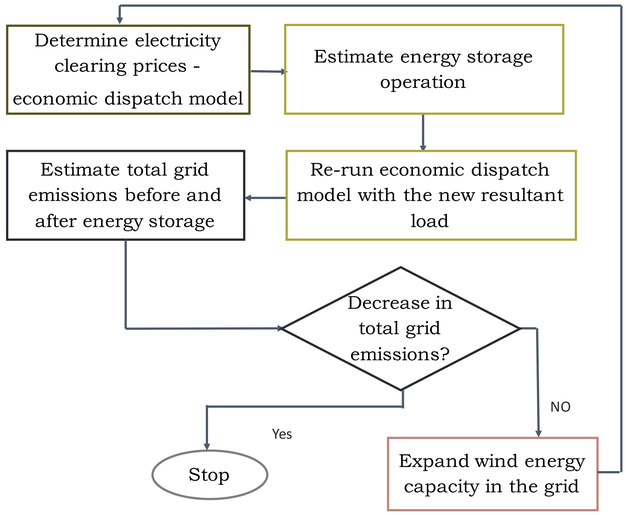
OBJECTIVES

1. Investigate the effect of economic arbitrage operations of large energy storage systems on total grid emissions.
2. If storage increases total grid emissions, find additional wind energy needed for storage to reduce emissions.
3. Compare the effects of bulk energy storage between NYISO and MISO.

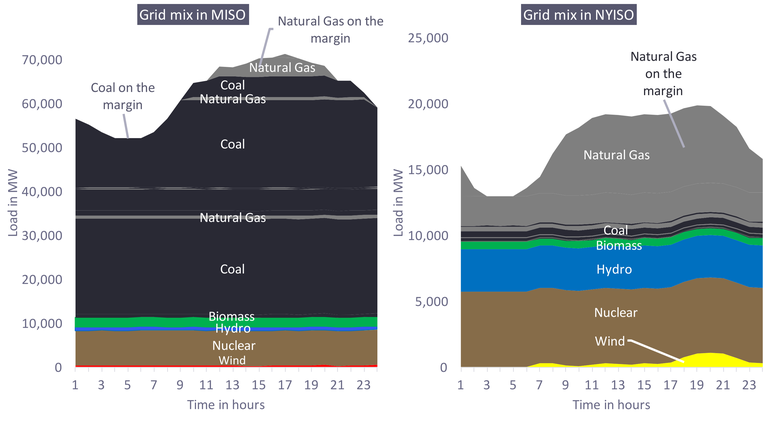
METHODOLOGY

Hypothesis: With increased wind generation, economic operation of storage will lead to decrease in systems emissions



ECONOMIC DISPATCH

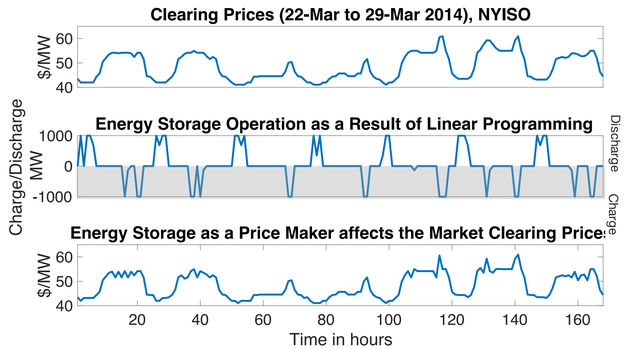
Additional load because of energy storage is usually supplied by generator on the margin at that given time



ENERGY ARBITRAGE METHOD

- The objective of the energy storage operation is **maximization of revenue**
- Clearing prices are **not exogenous** for the bulk storage operation
- Perfect information is assumed
- Optimal storage operation provides an upper bound to estimate the maximum emissions from storage

LIMITATION OF LINEAR PROGRAMMING FOR OPTMIZED BULK ENERGY STORAGE OPERATION AS A PRICE TAKER

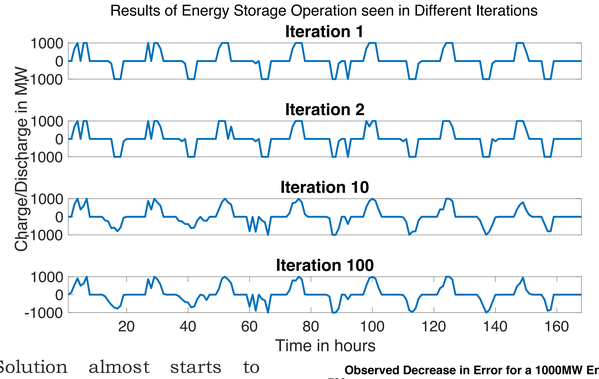


Energy storage operator expects to make: $110,000.

Energy storage operator makes only $ 90,000 as a price maker.

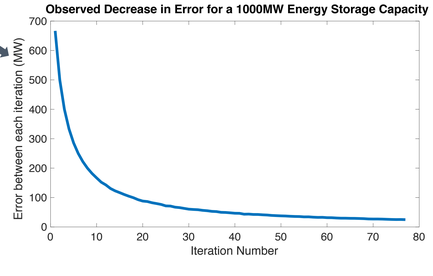
SOLUTION FOR ENERGY STORAGE OPERATION

Linear programming method is iteratively used to estimate storage operation and moving average of the storage values is considered in each iteration till the solution converges

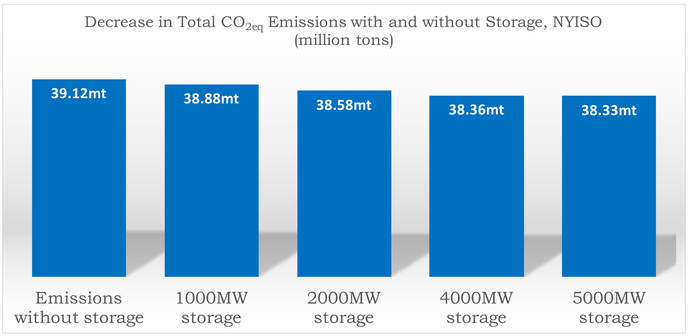


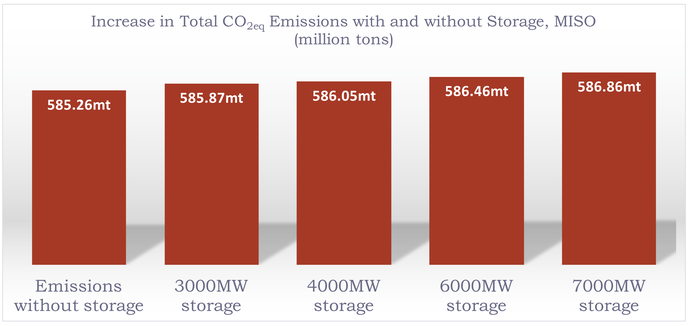
Solution almost starts to converge after 100 iterations.

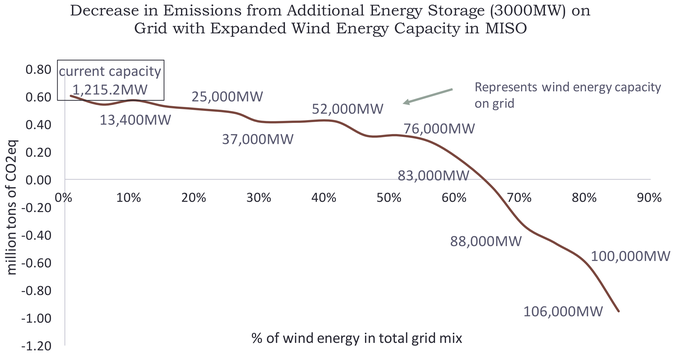
Note: +ve represents discharge and -ve represents charge of storage operation in the adjacent graph.



RESULTS







CONCLUSIONS

- Bulk energy storage could lead to increased emissions especially when the grid mix is dominated by coal power plants.
- In MISO, significantly greater penetration of wind energy which is about 65% of the grid mix is required before energy storage reduces carbon emissions.

ACKNOWLEDGEMENTS

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