In Silico Modelling of Energy Intensive Processes to Recover Nitrogen from Agricultural Fertilizer Streams

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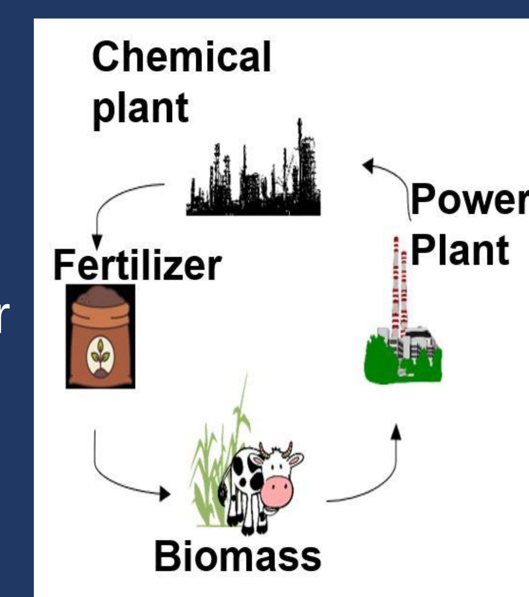
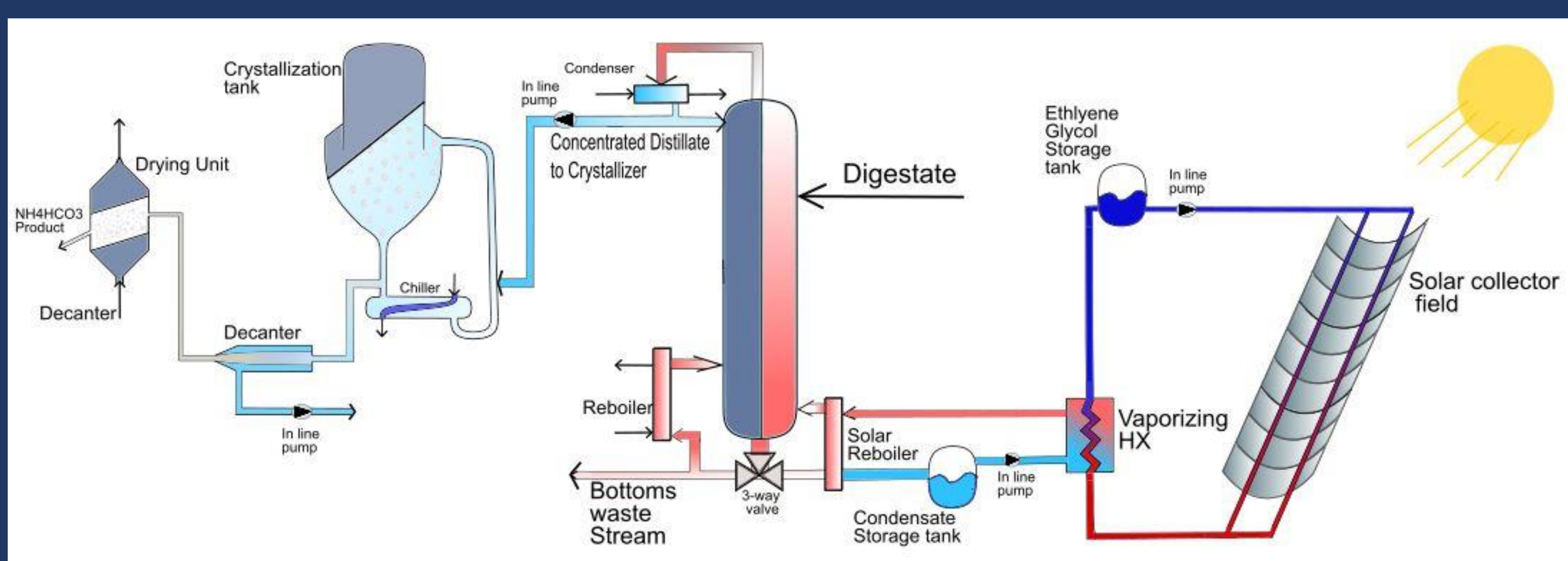
Introduction

- In recent years there has been an increase in the use of biogas to generate clean and renewable energy which has led to an increase in nitrogen rich digestate byproduct
- Due to the presence of nitrogen in the liquid digestate byproduct it is necessary to engineer a use for this digestate to prevent nitrogen contamination
- Currently this digestate is being sold directly to farms for use in the field to recover the nutrients
- The direct to field application has issues with green house gas emissions and the nitrogen in the digestate is not being effectively recovered
- Because of these issues a process for converting the digestate into NH4HCO3(Ammonia Bicarbonate) which is a nitrogen-based fertilizer



Process for conversion

- The process for conversion consists of a distillation column for concentrating ammonium and bicarbonate, a crystallizer where solid ammonium bicarbonate is precipitated, and a decanter and dryer for filtering out the solids(A solar collector can be used to offset energy costs for the column and is incorporated in the new optimized design)



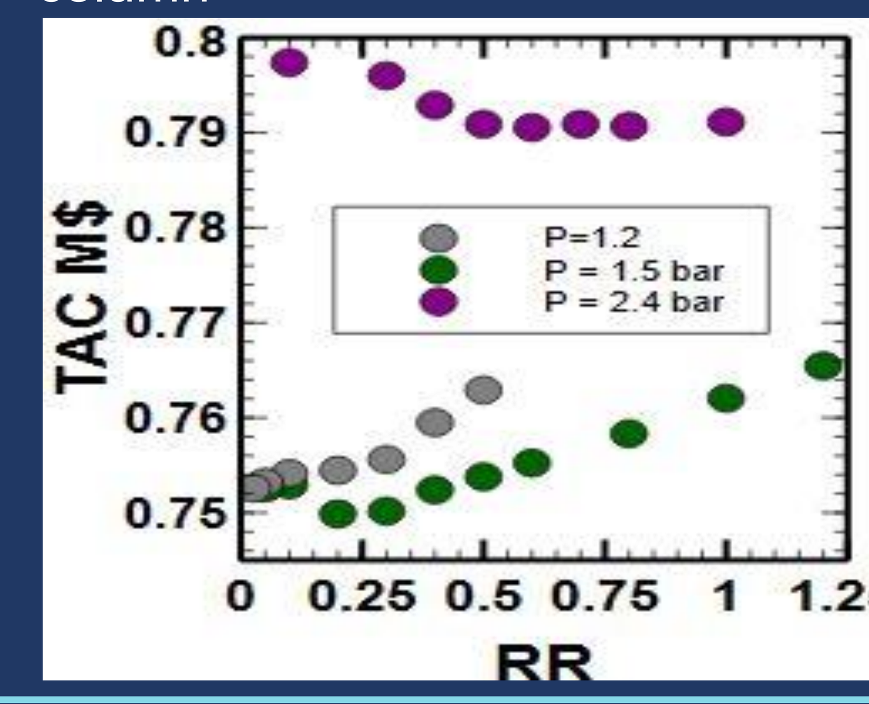
Optimization

- The goal of analyzing this process is to minimize the cost of operating the while still maximizing output
- Most of the cost in the process is associated with the operation of the distillation column
- This is quantified by calculating total annualized cost(TAC) measured in $/year

$$\text{TAC}=\frac{\text{Capital Cost}}{3}+\text{Utilities + Ammonia Loss- } NH_4HCO_3 \text{ Production}$$

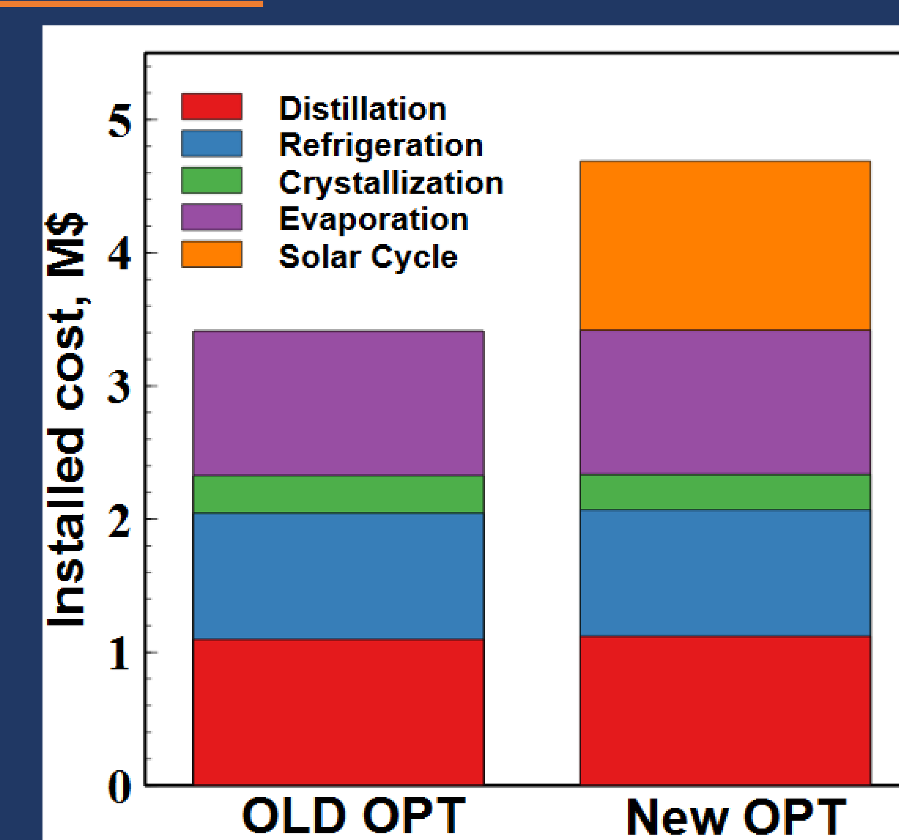
Results

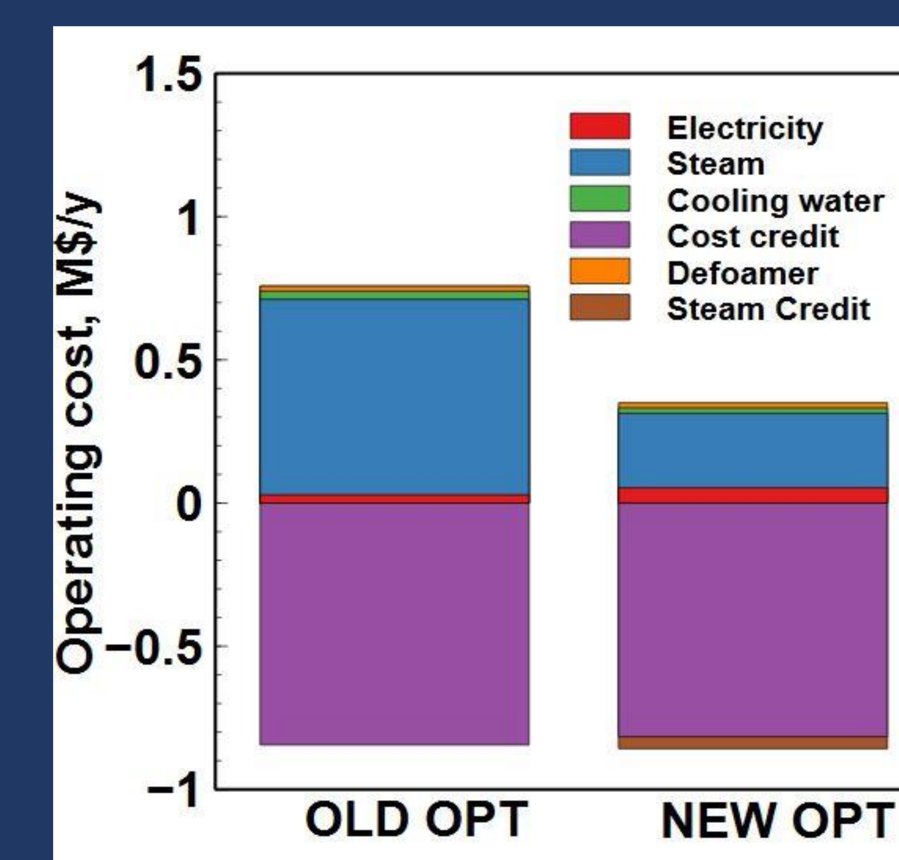
- The key operating parameters analyzed were the reflux ratio and the pressure of the column



- For both variables there was a trade off between the utility costs and rate of ammonia production and ammonia loss
- It was found that the minimum TAC was found at a pressure of 1.5 bar and a reflux ratio of .2
- The operating temperature was also examined but the minimum operating temperature was decided based on the use of cooling water

Economics





- As can be seen in the above plot on the left the main difference in capital cost between the newly designed process and the old process is the presence of the solar collector
- The plot on the right highlights the difference in variable costs between the new and old process. The use of the solar collector and optimized reflux ratio and pressure lead to significantly lower steam costs associated with the new process.

Conclusions & Next steps

- It can be seen that the new optimized operating parameters cause a reduction in amount of energy needed to operate the process due decreased usage of steam, and the process appears to be economically viable
- Next steps include a more in-depth economic analysis of the process and dynamic modelling of performance of the solar cycle

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Acknowledgement(s): ***David and Lorraine Freed Undergraduate Research Symposium, Lehigh University, Jonas Baltrusaitis, Nicholas Fox, Robert Handler, Donata Drapanauskaite***

References

[1] Baltrusaitis, Jonas, et al. “Transformation of Liquid Digestate from the Solid-Separated Biogas Digestion Reactor Effluent into a Solid NH4HCO3 Fertilizer: Sustainable Process Engineering and Life Cycle Assessment.