A Life Cycle Assessment of a Corn Ethanol Refinery in Comparison to a Novel Biorefinery

Daniel Gerrior[1], Farid Sayedin[1], Matthew Eckelman[2] , Azadeh Kermanshahi-pour[1], Satinder Kaur Brar[3]
[1]Biorefining and Remediation Laboratory, Department of Process Engineering and Applied Science, Dalhousie University, Halifax, NS, CA
[2]Civil and Environmental Engineering, Northeastern University, Boston, MA, US
[3]Department of Civil Engineering, Lassonde School of Engineering, York University, Toronto, ON, CA

BIOREFINING & REMEDIATION LABORATORY

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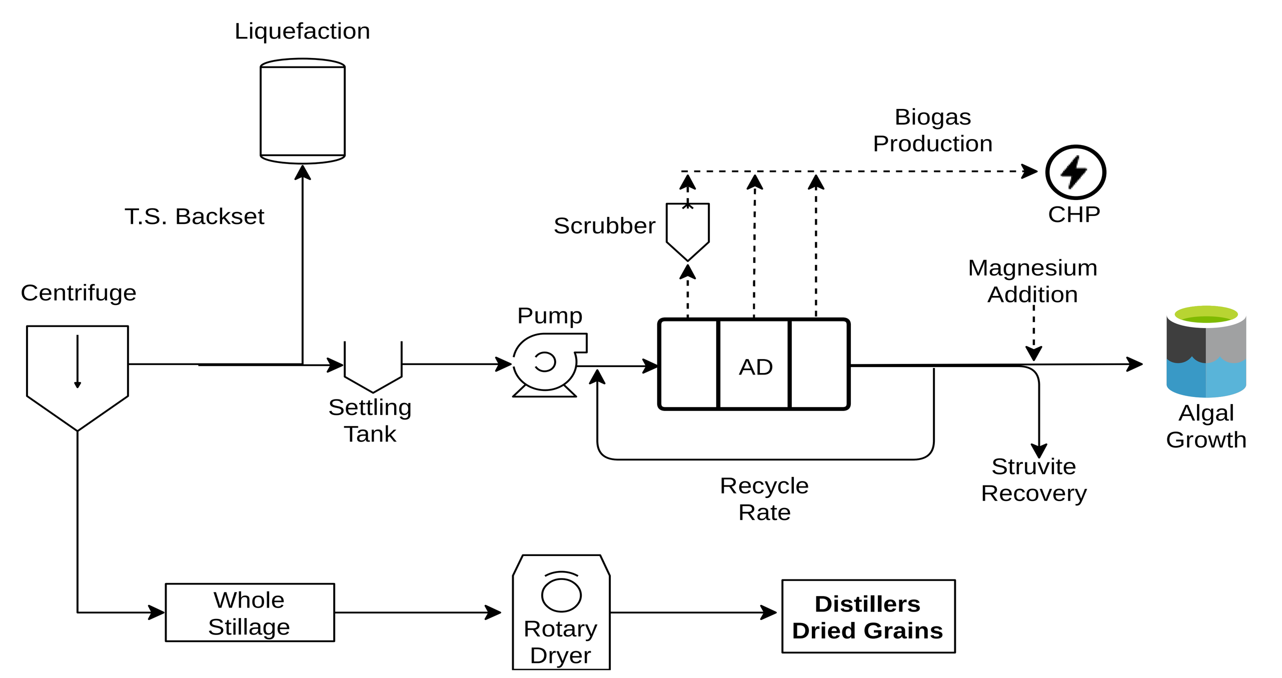
Introduction

- Corn ethanol production continues to grow as the U.S. ethanol plant capacity increased for the fourth consecutive year in 2017, reaching 15.5 billion gallons per year (1)
- IGPC Ethanol in London Ont. is the plant modelled in this analysis. In 2018 a renovation was completed to double their ethanol production and improve their technology to increase the range of co-products
- The traditional corn ethanol facility has a number of drawbacks including high energy requirements, significant water demand and large volumes of required corn feedstock
- Each liter of ethanol produced can generate up to 20 L of thin stillage, which is a liquid nutrient-rich by-product of the corn-ethanol plant. Processing of thin stillage with conventional methods (evaporation and drying) is energy intensive

The objective of this project is to enhance the sustainability of the conventional corn-ethanol plant by implementing a novel biorefinery

- The biorefinery includes the substitution of evaporators with anaerobic digesters (AD), algae cultivation, fertilizer recovery and a combined heat and power plant, utilizing the produced biogas.
- This project proposes recycling starch-rich microalgae to the front-end of the corn-ethanol plant to partially replace corn. It also provides a way to recycle the thin stillage for ethanol production and create a closed loop for process water use



Methodology

- An assessment following international standards for life cycle assessments (2) must be performed to introduce all environmental impacts from the process, this involves determining the following characteristics:
- Scope: Cradle to gate (excluding ethanol combustion)
- Function Unit: 1mm Btu of Ethanol
- Allocation method: Displacement
- Outputs: Corn ethanol, CO_2, distillers' dried grains with solubles (DDGS), Hi-Pro (high protein animal feed), Fiber plus syrup, water and fertilizer (struvite)
- Environmental impact Categories: Eutrophication, land use change, and primary energy use
- GREET (US Argonne National Lab) will be used to determine the energy use and greenhouse gas (GHG) emissions
- Ecoinvent will be used to determine the environmental impacts
- Additionally, a techno-economic analysis will be performed using Aspen Plus

Results

- The lifecycle inventory is broken into two distinct boundaries; corn cultivation and ethanol production.
- The total energy and GHG emissions were calculated using GREET (2017) and will be used to make a comparison to the novel biorefinery
- Co-product production decreases the environmental burden on producing ethanol by transferring some of the burden to co-products

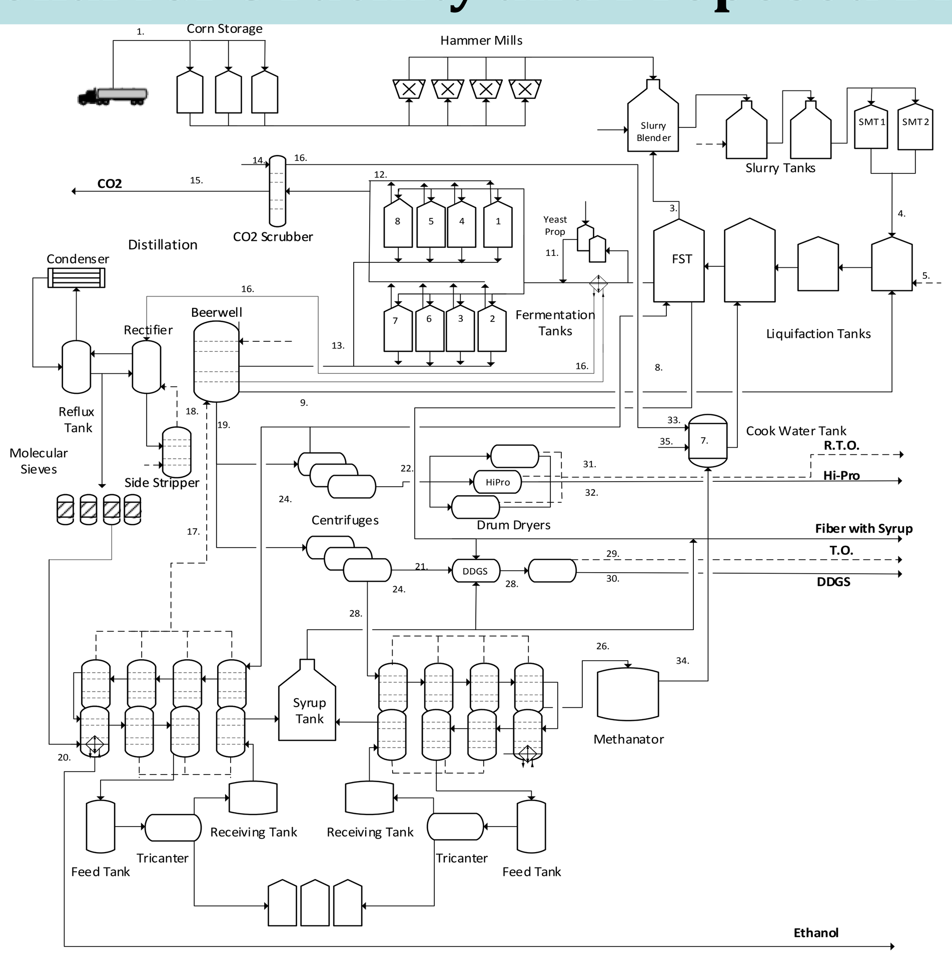
Corn Ethanol and Oil Yields, Energy Use and Fuel Type for Processing

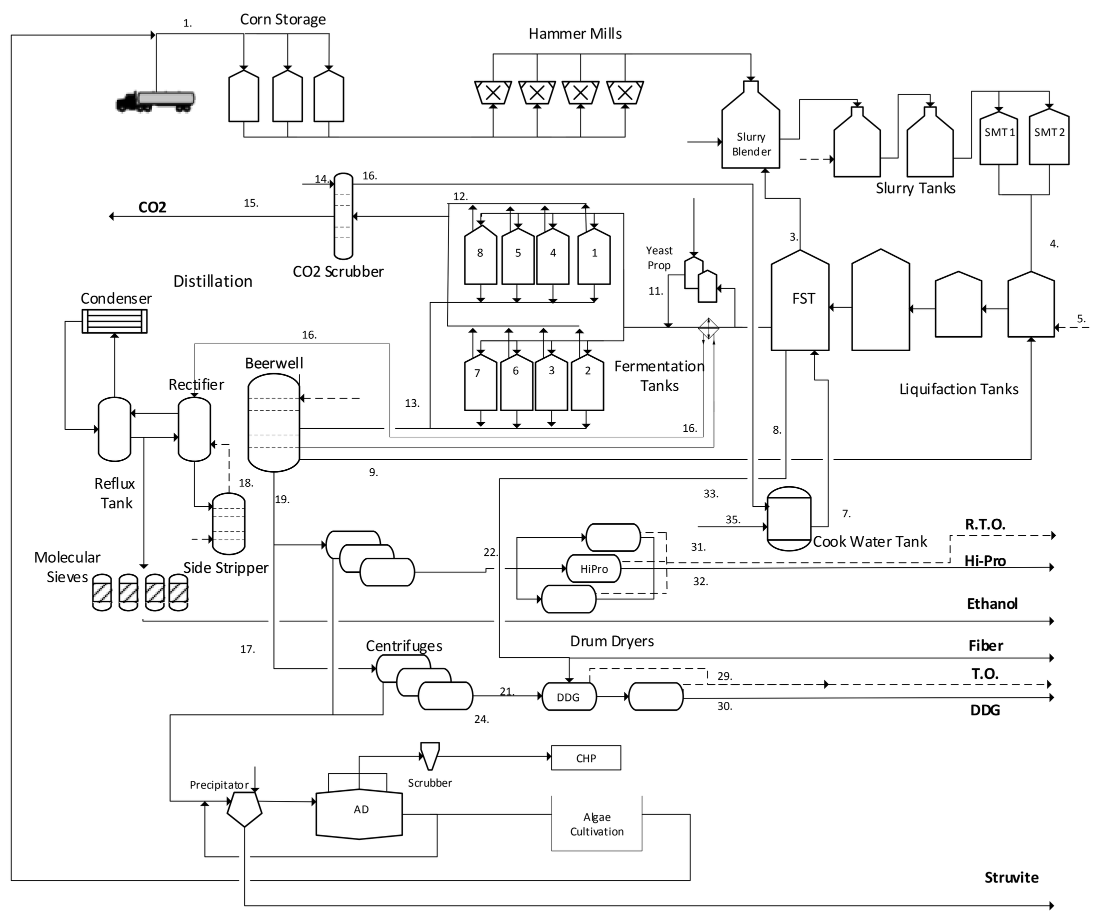
	Dry Milling	Corn Oil Extraction
Ethanol or corn oil yield: gal/Bu	2.83	0.60
Total energy use Btu/gallon	26,371	235
Share of fuels: NG, coal, biomass	90.5%	0.0%
Electricity	9.5%	100.0%

Summary of Energy Consumption and Emissions (in Btu, gallons or grams per mmBtu at each step)

	Dry Milling Corn Ethanol with Corn Oil Extraction	
	Corn	Ethanol
Total energy	-417,100	1,209,100
Fossil fuels	83,700	374,700
Water consumption	420	60
CO_2	13,000	23,700
GHGs	23,500	26,200

Traditional IGPC Facility and Proposed Biorefinery





Facility Improvements

- The total energy input to produce the co-product DDGS in the traditional facility was reported as 16.86% and the profit of DDGS to the total revenue was 16.87%; hence condensing thin stillage is non-profitable, and it should only be regarded as a final disposal method (3)
- The evaporator and some of the drum dryer capacity will be replaced by a novel anaerobic digester which will present significant energy savings
- Further savings can be expected from the methane produced in the AD

Energy that can be avoided by eliminating the drying of thin stillage (4)

Unit	Electricity Savings	Percent of Plant Energy Use (50MGPY Plant)
Evaporator	1140 kWh	25.8%
Drum Dryer	390 kWh	8.8%
Total	**1520 kWh**	**34.5%**

- The anaerobic digester is able to significantly reduce the chemical oxygen demand to where analysis indicated the digestate would be of suitable quality for recycling as process water (5)
- The use of algae to supplement the corn used in the process will decrease the upstream environmental burdens from producing corn; including decreasing pesticide, fertilizer, diesel and water use
- The new DDG product is of a higher value without syrup because of the increased protein concentrations due to a relatively lower concentration of salts (6)

Expected Outcomes and Future Work

- The improved operation of the novel biorefinery is expected to reduce the energy requirements and GHG emissions in comparison to IGPC's current facility
- It is also expected to positively affect the impact categories for land use change, primary energy use and eutrophication due in part because of the reduced GHG emissions but also due to the upstream reduction in corn required for the process

Future Work

- Incorporating the algae as a starch source for the production of ethanol
- Determining the environmental impacts of the emissions for both ethanol plants
- Performing a technoeconomic analysis on the production of ethanol

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Acknowledgements

- The authors would like to thank IGPC Ethanol Inc. and Sheena Holt for their continued support

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