Project ASCENT COE-2014-01

Alternative Jet Fuel Production in Integrated Biorefineries Using Existing Dry Corn Mill: Cost Reduction Opportunities

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Motivation and Objectives

Alternative jet fuel (AJF) production technologies are receiving a lot of attention for their low environmental impact [1]. But plant and biomass based AJF technologies face consistent challenges arising from the economic point of view. High capital expenditure (CAPEX) and operational cost (OPEX) often add up to other technological concerns such as feedstock quality variation, product yield, feedstock price etc. High costs of AJFs hurdle for the commercialization of several of the exmerging AJF pathways. In the current scope of work, we propose a number of integration strategies between AJF and existing dry grind corn ethanol mill to reduce CAPEX, OPEX and consequently decrease the minimum selling price of biojet fuels. Following are the technologies studied in this scope: Dry grind corn ethanol mill (DGCEM), Virent's BioForming (VB), Direct sugar hydrocarbon (DSHC), Alcohol to jet (ATJ), Fast Pyrolysis (FP) and Gasification & Fischer Tropsch (FT).

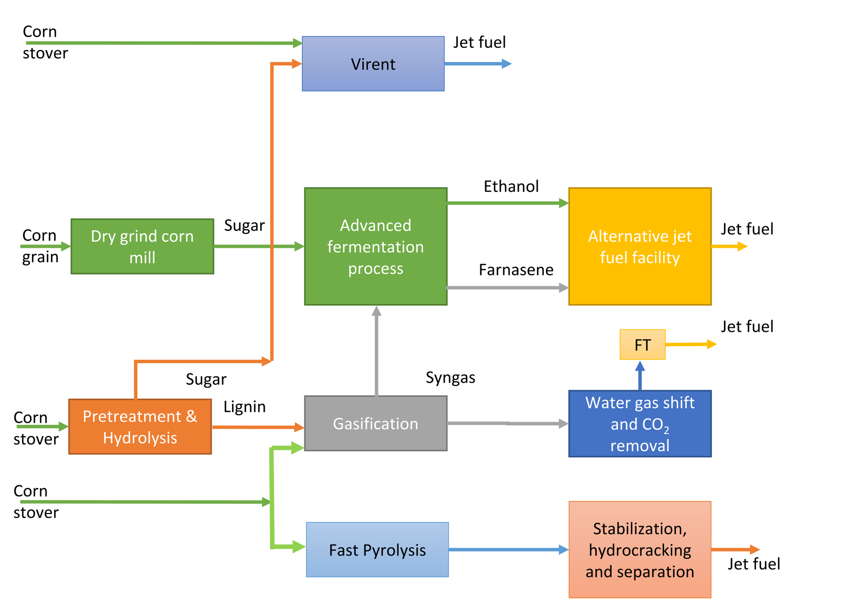

Figure 1: Potential integration opportunities between DGCEM and AJF production technologies

In co-location strategy [2], a separate entity is installed inside or just outside the battery limit to utilize part of the feedstock, feedstock infrastructure or utilities of the existing plant without altering the existing production line. On the other hand, repurposing strategies alter the existing production to produce a new product.

Objectives

- Integration between DGCEM and VB, DSHC and ATJ, FP and FT, one at a time
- Process and cost inputs are to be standardized before integration

Methodology of Analysis

Table 1: List of standalone technologies that were studied

Standalone (Base case)	Technology	Feedstock	Product
Case 1_Corn	Dry grind corn (DGC)	Corn grain	Ethanol
Case 1_A	Virent's BioForming (VB)	Corn stover	Alternative jet
Case 1_B	Alcohol to Jet (ATJ)	Corn stover	Alternative jet
Case 1_C	Direct sugar to hydrocarbon (DSHC)	Corn stover	Alternative jet
Case 1_D	Fast Pyrolysis	Corn stover	Alternative jet
Case 1_E	Gasification & Fischer - Tropsch	Corn stover	Alternative jet

Table 2: List of co-located and repurposed strategies based on base cases

Co-location	Reduction opportunity	Designation
Case 2_X	Waste stream utilization	Case 2_A1; Case 2_A3; Case 2_B1; Case 2_D1; Case 2_E1
Case 2_X	Operating labor Utilities Service facilities Land Buildings & Yard improvements	Case 2_A2; Case 2_B2; Case 2_E2

Repurpose	Reduction opportunity	Designation
Case 3_X	Operating labor Utilities Service facilities Land Buildings & Yard improvements Contingency	Case 3_B1; Case 3_B2; Case 3_C1

Figure 2 show the methodology of carrying out a co-location strategy between DGCEM and VB, DSHC and ATJ. All the process data (cost, material and energy) are taken from the literature which are standardized to specific set of values.

Minimum Selling Prince (MFSP) is the final output of this standardized model which utilizes a specific set of financial assumptions (Table 3). After the initial standardization, each concept - whether a standalone or an integrated, will provide a purchased equipment cost. Lang factor (ratio of FCI to purchased cost) will be used to derive the capital cost of our study. This factor varies from one concept to another due to the co-location and repurposing strategies. Other type of costs are also scaled to the current year. Product capacity is set to 40 million gallon per year and all the literature capacities were scaled accordingly.

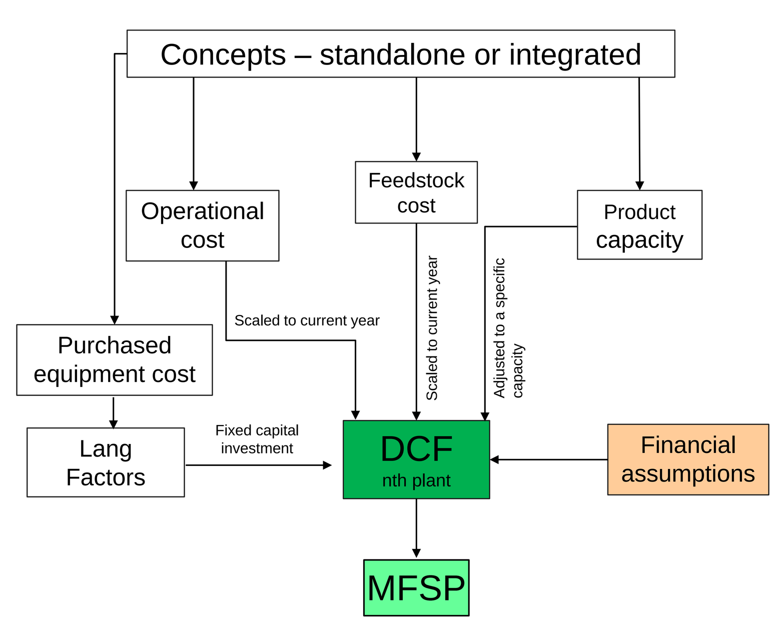

Figure 2: Minimum fuel selling price (MFSP) calculation by discounted cash flow analysis in a standardized method

For our approach, we assumed a nth plant design which means our integrated plants are already assumed to be matured. We acknowledge the lack of a pioneer plant analysis which would bring different results.

The main financial assumptions are shown in Table 3

Table 3: Main Financial assumptions[6]

Parameters	Assumptions
Year Of Cost Analysis	2015
Project life (years)	22
Construction time (years)	3
% spent in year 1	8
% spent in year 2	60
% spent in year 3	32
Startup period (year)	0.5
Startup variable expenses	75%
Startup fixed expenses	100%
Working capital (% of FCI)	15%
Federal tax rate	16.5%
Loan term	10 year 8% APR
Depreciation	200% declining balance; MACRS; 7 year recovery period
Finance (Debt/equity)	50%/50%

Process input – standalone or integrated

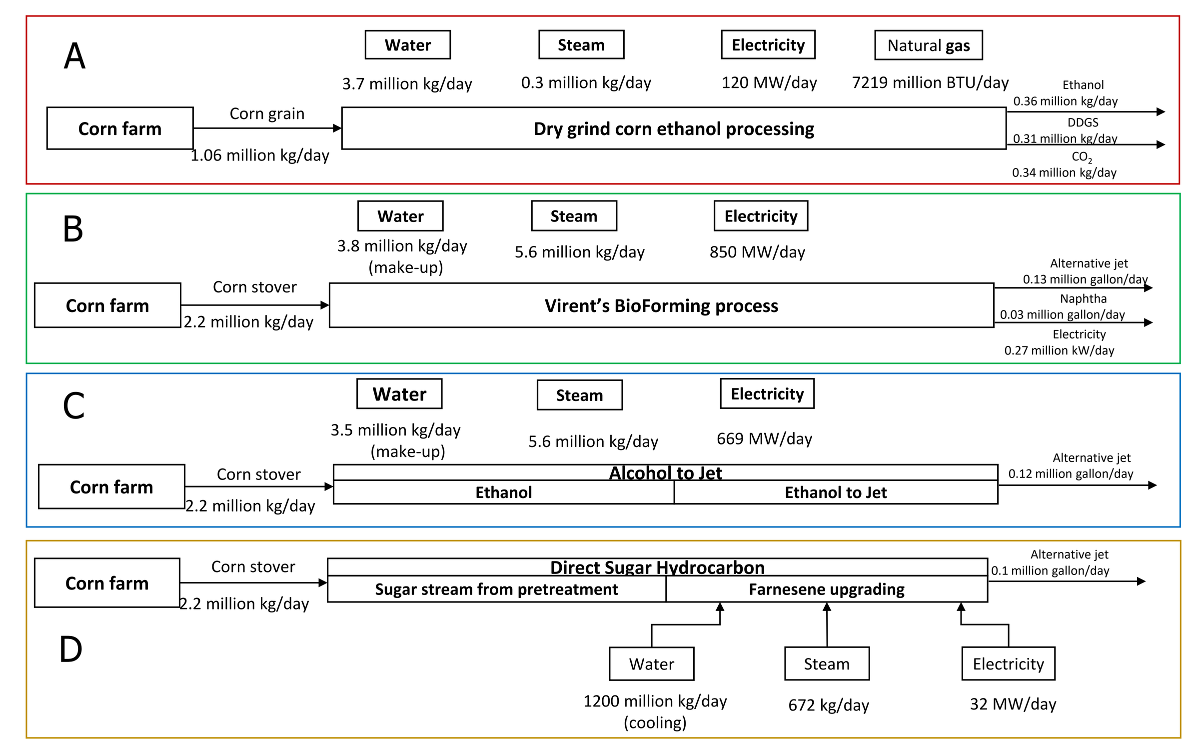

Figure 3: Material balances of some of the standalone pathways studied

Figure 3(A) represents the material flow in an existing corn ethanol plant with an annual production capacity of 40 MM gal, established in 2006. Figure 3(B-D) represents three different alternative jet fuel (AJF) production pathways with different production capacities. The methodology described in figure 2 are applied to each of the technologies before any integration. Two types of integration strategies were applied in this work looking for potential low cost scenarios. Applying percent delivered method to estimate the capital cost (Table 4), we sought for capital cost reduction opportunities in some of the following categories:

Table 4: Percent delivered equipment method

Direct cost	Fraction
Total delivered equipment cost	100%
Purchased equipment installation	39%
Instrumentation and controls (installed)	26%
Piping installation	31%
Electrical systems (installed)	10%
Buildings (including services)	29%
Yard improvements	12%
Service facilities (installed)	55%
Total installed cost (TIC)	302%
Indirect costs	
Engineering and supervision	32%
Construction expenses	34%
Legal expenses	4%
Contractor's fee	19%
Contingency	37%
Total indirect cost	126%
Fixed capital investment (FCI)	428%
Working capital (15% of total investment)	75%
Total project investment (TPI)	503%
Land (4-8% of TDEC)	6%

- Buildings and yard improvements
- Land
- Site development
- Service facilities (steam, electricity, water etc.)
- Contingency

Table 5 shows an example of such a scenario. These cost reduction scopes are reflected in the reduced Lang factor for various scenarios (Table 6). We also assumed a cost reduction scenario in the intellectual properties, in terms of the salaries.

We assumed 20% reduction in salaries because of the existing management group of manager, supervisor and administrative officer in the corn ethanol plant.

Table 5: Examples of cost reduction opportunities in capital cost components including land (Virent_Case 2_A2)

Component	Fraction	Reduction	New fraction
Total delivered equipment cost	100%	0%	100%
Buildings (including services)	29%	75%	7%
Yard improvements	12%	30%	8%
Service facilities (installed)	55%	40%	33%
Land (4-8% of TDEC)	6%	15%	5%

Single point sensitivity analyses were carried out on selected parameters to see how the estimated MFSPs change with the change in those parameters. All the parameter values are described in the table below.

Table 6: All the sensitivity parameters are taken from the literature

Parameters	Equity	Discount rate	Federal tax	Startup revenue	FCI	Operating days	Plant life	Product capacity (gal/year)	Feedstock cost ($/ton)
Favorable	0%	5%	10%	80%	70%	300	30	60,000,000	50
Base case	**50%**	**10%**	**17%**	**50%**	**100%**	**310**	**22**	**50,000,000**	**60**
Unfavorable	100%	20%	35%	20%	130%	330	20	40,000,000	70

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Process input

Table7: Minimum fuel selling price for various co-location and repurposing strategies; Each of the strategies assumed a ramped product capacity of 40 MM gal per year

Type	Concepts	TPI (MM$)	Lang Factor	MFSP ($/gal)
Base	Virent Base_Case 1	745	4.28	7.03
Co-location	Corn & Virent_Case 2_A1	745	4.28	7.03
Co-location	Corn & Virent_Case 2_A2	675	3.81	6.5
Co-location	Corn & Virent_Case 2_A3	667	3.75	7.12
Base	ATJ Base_Case 1	459	4.28	6.04
Co-location	Corn & ATJ_Case 2_B1	459	4.28	6.04
Co-location	Corn & ATJ_Case 2_B2	416	3.81	5.70
Repurpose	Corn & ATJ_Case 3_B1	221	3.63	4.37
Repurpose	Corn & ATJ_Case 3_B2	63	3.38	4.34
Base	Fast Pyrolysis_Case 1	264	4.28	3.00
Co-location	Corn & FP_Case 2_D1	264	4.28	3.00
Co-location	Corn & FP_Case 2_D2	242	3.9	2.8
Base	Gasification & FT_Case 1	720	4.28	6.27
Co-location	Corn & Gasification_Case 2_E1	720	4.28	6.27
Co-location	Corn & Gasification_Case 2_E2	660	3.86	5.78
Base	DSHC Base_Case 1	300	4.28	6.81
Repurpose	Corn & DSHC_Case 3_C1	252	3.38	5.55

All the waste stream utilization strategies (A1, B1, C1, D1 & E1) used the corn stover from the corn field, purchased at the gate price. The base cases assumed the same gate price for their analyses. Therefore, the waste stream strategies did not result in any cost reduction. All other integration strategies reduced the MFSP from the base case except Corn & Virent_Case 2_A3 which had higher OPEX and lower co-product credit. The reduction in MFSPs are not drastic for any of the co-located strategies but all of the repurposing approaches have significantly lowered MFSPs due to their higher degree of CAPEX reductions.

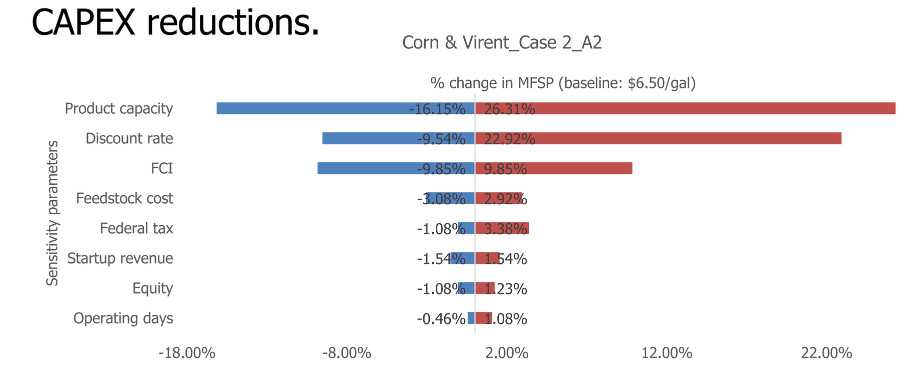

Figure 4: Example of sensitivity analyses (Corn & Virent_Case 2_A2).

Sensitivity analyses revealed the MFSP sensitivity towards some of the most significant financial and market parameters. MFSP was turned out to be most sensitive to product capacity across all of the integration scenarios.

The next three most significant sensitive parameters were discount rate (Internal rate of return), Fixed capital investment (FCI) and feedstock cost for all of the scenarios.

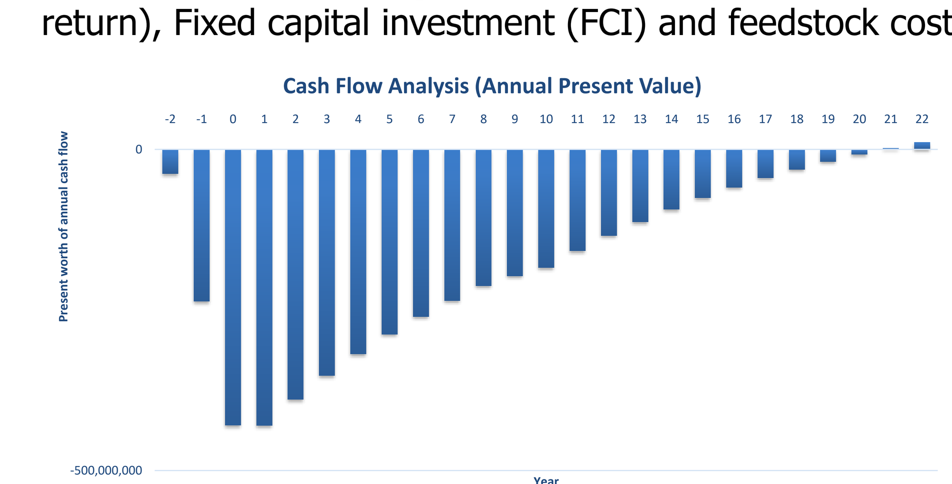

Figure 5: Example of cash flow analysis (Virent_Case 2_A2)

Figure 5 shows an example of cash flow analysis of co-located strategy (Corn & Virent_Case 2 A2). In our analyses, we evaluated the project feasibility in terms of MFSP at which point the present worth of total expenses become equal to that of total sales.

Conclusions and Future Steps

- All of repurposing strategies are appeared to have the highest degree of reduction in capital cost and minimum selling price.
- Product capacity, capital cost, discount rate and feedstock cost are the most sensitive parameters in co-location strategies. For repurposing strategies, capital investments are not quite sensitive.

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