Project #ASCENT COE-2014-01

Techno-Economic Evaluation of Sustainable Jet Fuel Conversion Processes: The Alcohol-to-Jet Process

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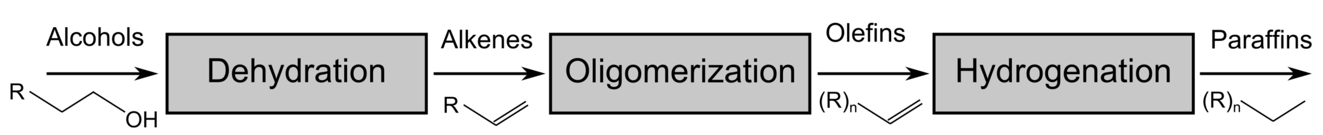
Motivation and Objectives

Alcohol-to-jet (ATJ) is a process for the upgrading of alcohols to an alternative jet fuel. With the potential to generate these alcohols from biorenewable resources, this pathway provides a means for producing a sustainable alternative jet fuel (SAJF). This process has been under development by several organizations and is the subject of recent updates to the current ASTM standards for commercial jet fuel. With the large installed capacity of domestic alcohol production, ATJ may offer a near-future opportunity for renewable alcohols to enter the market for drop-in aviation biofuels. ATJ is a flexible process capable of generating a range of fuel products and commodity chemicals in addition to jet fuel, and is based on several catalytic steps historically utilized by the petrochemical industry. Process simulation and economic modeling is employed to assess some varying implementations of ATJ conversion schemes.



Chemistry of the “Core ATJ” Process: Catalytic Upgrading of Alcohols to Paraffins

Objectives:

- Apply new standardized ASCENT methodology to generate process and economic data of ATJ for comparison with other technologies
- Compare alternative implementation strategies of ATJ conversion
- Identify areas requiring further research, and potential co-products to improve process economics

Methods

Process models for ATJ conversion were constructed based on data from literature and generated using Aspen Plus simulation software. Capital and operating expenses were estimated for both standalone “Core ATJ” units to upgrade alcohols as well as “Full ATJ” facilities to process generic sugar streams into SAJF. These models were constructed for both the use of ethanol as an intermediate as well as a higher alcohol (isobutanol), to compare the contrasting advantages of the direct production of higher alcohols over more conventional fermentation processes.

Acknowledgements

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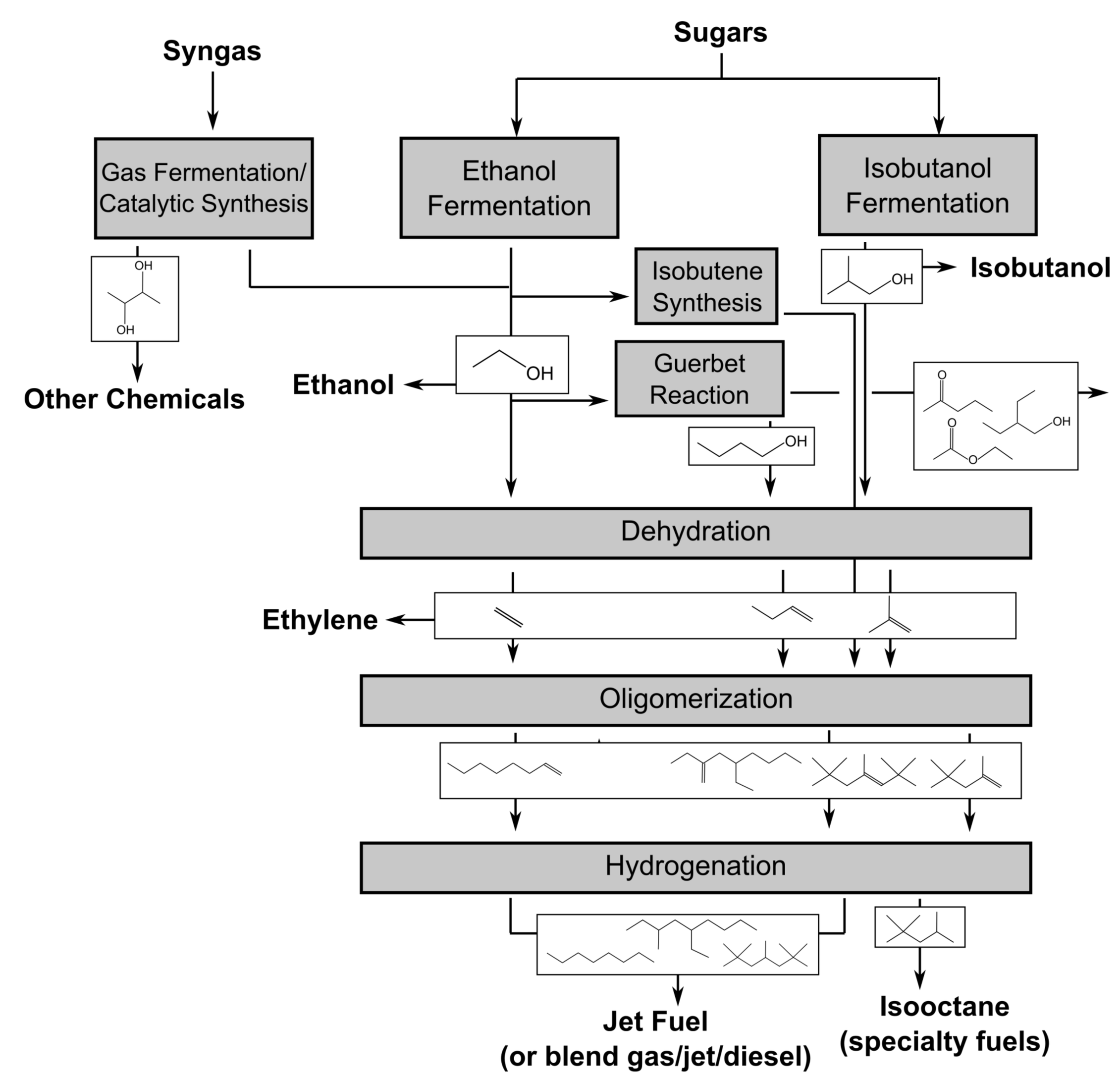
Summary

There are several strategies currently under investigation by commercial entities for the production of alcohols for use in ATJ conversion. Although higher alcohols provide greater yield and efficiency in the catalytic upgrading steps, they face trade-offs in the form of lower fermentation yield and higher production costs. In addition, the type of intermediate alcohols used will impact the final hydrocarbon distribution and fuel properties.

Comparison of Alcohol Producing Strategies for ATJ Conversion:

Alcohol-Producing Process	Companies and Institutions Interested/Invested in Technology	Alcohol Intermediate	Expected Hydrocarbon Product Distribution
Gevo Integrated Fermentation Technoloy (GIFT®) Process	Gevo	iso-butanol	C8, C12, C16 branched
N-butanol Fermentation (via ABE fermentation or other)	Cobalt, Butamax	n-butanol	C8, C12, C16 unbranched
Ethanol Fermentation	Byogy	Ethanol	C4-C12 unbranched
Gas (CO, syngas) Fermentation	Lanzatech, PNNL	Ethanol	C4-C16 range unbranched
Catalytic (thermochemical) Conversion of Syngas to Ethanol	PNNL	Ethanol	C4-C16 range unbranched

A “Road-Map” of ATJ Conversion and Co-Product Opportunities:



Careful selection of alcohol intermediates is a key to the successful implementation of an ATJ conversion process. Efficient utilization of available low-cost feedstock (gas or sugar) and existing process infrastructure provides cost-reduction opportunities. The production of higher alcohols through direct production or additional upgrading stages provides opportunities to improve process costs downstream as well as the potential for co-product generation that may greatly improve commercial viability. This “road-map” (left) illustrates potential process schemes and co-products.

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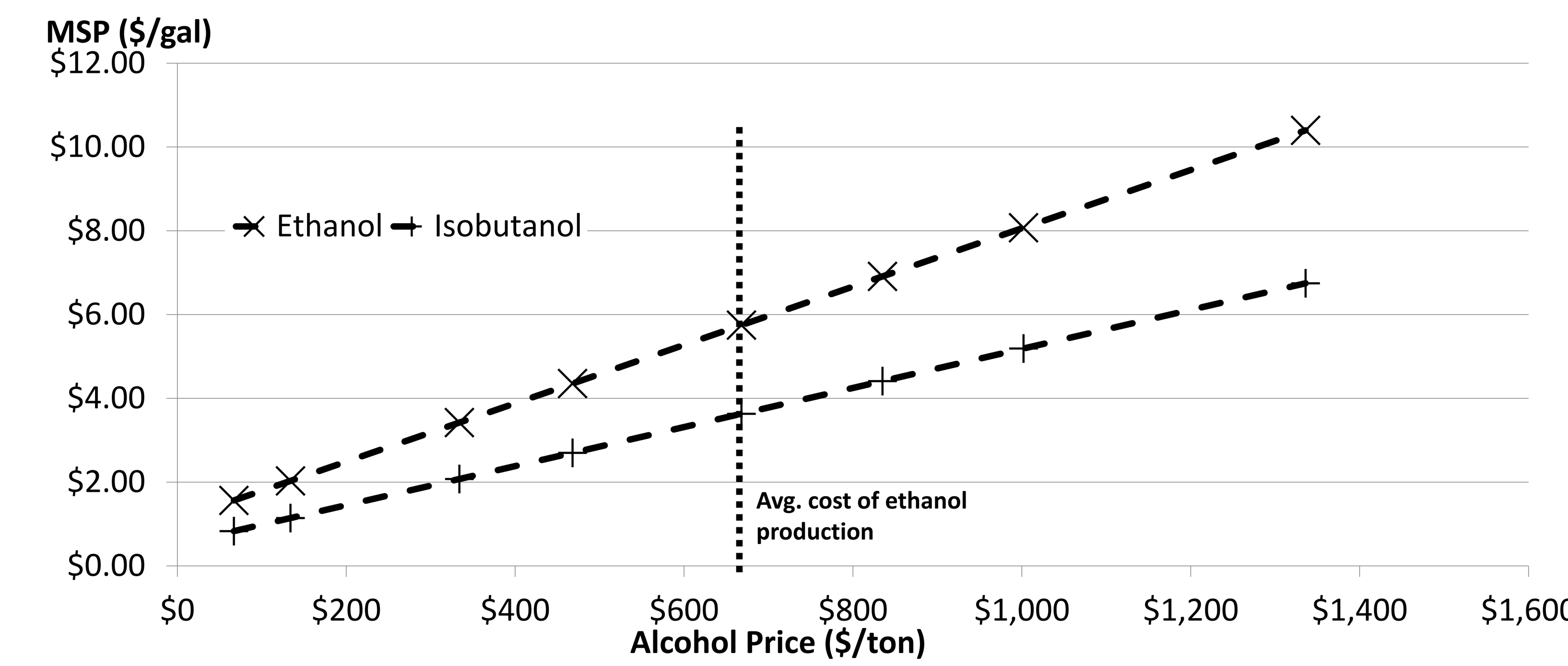
Results and Discussion

Comparisons between ethanol and isobutanol-based ATJ conversion processes using fermentation are shown below. Ethanol fermentation is an established technology, while isobutanol fermentation requires proprietary engineered biocatalyst. Two isobutanol fermentation scenarios are compared: one with expenses equal to ethanol fermentation, and one with double capital and variable operating costs. Even in the high-cost scenario, isobutanol fermentation offers a lower conversion cost (minimum fuel selling price) over ethanol fermentation.

	Ethanol Conversion	Isobutanol Conversion (low cost)	Isobutanol Conversion (high cost)
Overall Mass Yield	0.230	0.276	0.276
Alcohols Processed (ton/day)	200	161	161
Total Capital Investment, MM$	$82.60	$54.91	$94.17
OpEx, MM$/yr	$16.8	$13.9	$18.4
Production Rate, MMgal/yr	9.85	11.83	11.83
Cost per ton sugar	$188.43	$145.48	$209.33
Conversion Cost, $/gallon fuel	$2.734	$1.757	$2.528

Comparison of Upgrading Costs of Ethanol and Isobutanol:



The minimum selling price (MSP) of jet fuel produced from ethanol and isobutanol, as a function of alcohol production price, illustrates the cost benefits of higher alcohol production. An isobutanol production cost of 1.68 times the cost of ethanol results in equal selling prices.

Conclusions and Next Steps

1. Alcohol-to-Jet conversion technology provides a flexible platform for SAJF conversion that can utilize existing alcohol production capacity and generate a variety of fuels.
2. A need for further research and development of higher-alcohol production technologies to improve process economics in ATJ conversion is identified.
3. Techno-economic process models with standardized assumptions and methods are shown to be useful for comparison of SAJF pathways. Further application of this modularized approach is recommended to continue comparing conversion strategies.
4. Co-product generation technologies may be necessary to identify and compare viable SAJF pathways.