ENERGY CLUB AT ROSS: MARITIME BIODIESEL USE CASE

January 16, 2022

Prepared by request for the Great Lakes St. Lawrence Governors & Premiers

Special thanks to Adrian Mitterhuber of Sterling Fuels, Paul Topping from the Chamber of Marine Commerce, Yousef El Bagoury from CSL and John Schmidt (GSGP) for their support, expertise and insight

UNIVERSITY OF MICHIGAN TEAM

Victoria Bronstein (Project Coordinator, Computer Science and Economics Major)

Winston Langridge (MBA Student, Ross School of Business)

Grant Alpert (Dual-Degree MBA/MS Student, Ross School of Business and the School for Environment and Sustainability)

KEY FINDINGS

Current U.S. and Canadian subsidies and credits are critical in making biofuels an attractive alternative fuel source. Industry sentiment analysis indicates that the greatest internal barrier to biofuel adoption is the price differential with traditional fuel and reluctance to over-commit while long-term bio-diesel markets and carbon offsets are still developing. The greatest functional barrier to biofuel adoption is the 12-14% difference in energy density between biofuels and traditional marine diesel, but within the operational context of the Great Lakes region this does not present a significant barrier.

PROJECT DESCRIPTION AND BACKGROUND

The Great Lakes St. Lawrence Governors & Premiers (GSGP) are investigating the viability of the transition of ships operating on the Great Lakes-St. Lawrence system from traditional fossil fuels to non-fossil fuel alternatives. Biofuels may enable shipping companies to achieve their environmental goal of reduced carbon emissions while also allowing them the maximum operational flexibility of their existing fleet. Second-generation biofuels are particularly attractive because this alternative fuel can generally be used by shipping companies within their existing vessels without the need for replacing or re-engineering the engines or fuel systems already present on their ships. Canada Steamship Lines (CSL), a Canadian shipping company, tested biofuels on its Great Lakes and St. Lawrence Seaway ships during the 2021 season. GSGP is seeking to understand the differences in pricing and operations between biofuels and traditional fuels as well as the near-term issues related to carbon taxes and carbon credits. Understanding how regulations, operational ramifications and supply/demand economics affect the interested parties is critical if stakeholders and participants in this system are to scale and time biodiesel adoption over the following years. The Energy Club at Ross (ECR) team's ultimate goal with this analysis is to understand the most effective means to close current price gaps between biofuels and fossil fuels and to determine the price and regulatory signals which could encourage ship owners to increase biofuel adoption.

BIODIESEL FUNGIBILITY AND MAINTENANCE

In 2021, CSL conducted extensive trials of B100 (100% biodiesel) in eight of its ships and collected data on how biofuel affects upkeep, performance and maintenance costs. According to Louis Martel, CEO of CSL, "reducing our environmental footprint has been an objective for many years. Our tests showed that we can operate our fleet with biodiesel as a drop-in fuel, we don't have to modify any piece of our engine or equipment."[1]

The benefits of biodiesel are that it is largely equivalent to traditional fuels, can be sourced from multiple providers, and can be used in multiple engines. This "drop-in" fuel increases the likelihood that economies of scale will contribute to overall market competitiveness as production increases in the coming years. In trials using B100 as fuel in auxiliary power generators and main engines, maintenance costs either remained constant or decreased. CSL did not need to swap filters or other components to account for the biodiesel.[2] In fact, some maintenance technicians commented that the filters looked brand new when they would normally be covered in residue.[3] CSL has so far accumulated over 27,000 hours of engine run time with B100, seeing no negative effects.[4] Additionally, B100 can be swapped in and out based on needs. If there is a supply shortage of B100, it is assumed that the use of traditional fuel can resume with no adverse effects on the engines or fueling infrastructure.

ENERGY DENSITY AND PRICE EFFECTS ON ADOPTION

Sterling Fuels, a fuel supplier in Windsor, Canada, is able to provide year-long contracts for biodiesel at a "rack plus" price.[5] Prices are only able to remain competitive due to carbon credits available to U.S. suppliers that help offset the

price of production, and credits used by Canadian industry. Canada Clean Fuels (CCF) imports the fuel and functions as a credit trader, working to keep biofuel priced competitively. Long-term contracts are critical to commodity consumers like CSL, but this does not change the fact that the two fuels have different calorific values, a measure of the energy density of fuels. Although reports claim that biodiesel is only ~5% less energy-dense than fossil fuels,[6] CSL research indicates the actual energy density is closer to 12-14% less.[7] There are a number of additive products which claim to increase biodiesel efficiency by as much as 9%,[8] but discussions with CSL suggested that any additives they tried did not have an impact on fuel energy density. A final note to consider is that this reduced efficiency impacts traversable distance, requiring ships navigating between ports to fuel more frequently, further impacting the cargo churn rates and the bottom line. More research is needed to determine if other shipping operators in the area agree with CSL's opinion that B100's energy discrepancy is not of considerable concern.

CARBON ADVANTAGE, TRANSPORTATION BREAKEVEN DISTANCE

CCF imports and handles the logistics of biofuels, and its trucks transport the fuel from Toronto to Windsor, Ontario. CCF has to date imported 100% of the biodiesel used by CSL, or roughly 30% of the total fuel provided to CSL, and Sterling Fuels operates as a regional provider of biodiesel, servicing three ports in the area. Recently, CCF procured its fuel from larger suppliers in Illinois (although this could change subject to production quantity and price), which ship the fuel by rail to Toronto. From there, CCF trucks the fuel into the serviced ports (Sterling Fuels' main operation is in the Port of Windsor), a distance of approximately 230 miles. The ECR team was unable to determine the extent that energy expended in transporting biodiesel reduces the carbon advantage when factoring in the entire supply chain. However, Argonne National Laboratory conducted a full life-cycle analysis and concluded that B100 results in a 74% reduction in carbon dioxide emissions compared to petroleum diesel, offsetting at least in part the inefficiencies related to collection, distribution and energy density of biofuels.[9] According to a statement released by CSL after running B100 in its engines for nearly 30,000 hours, CO2 life-cycle emissions were reduced by 23% compared to marine gas oil.[10] Life-cycle analysis is incredibly complex, and researchers approach their analysis from a variety of starting points and assumptions, but these studies indicate that at least on a raw equivalence basis B100 has a distinct carbon advantage.

BIODIESEL SEASONALITY

CSL currently uses 100% biofuel in its test vessels, up from a 50/50 mix that it initially trialed. Biodiesel is considerably more hygroscopic (attracts water) than diesel fuel, which can complicate storage.[11] Cold weather precipitates additional water separation in the fuel. CSL has chosen to forgo using the fuel on "shoulder" months in December/January and March, and shipping on the upper Great Lakes effectively shuts down between these months. The lack of cold weather resilience and increased overhead in fuel storage and heating means that year-round usage of biodiesel is unlikely under current conditions. Additionally, CSL has not yet performed testing using B100 for winter lay-up to understand what may occur to any components with leftover fuel inside fuel tanks during the winter, as any testing has a large associated risk compared to simply using traditional fuel.

CRITICAL FACTORS AFFECTING BIODIESEL ADOPTION (2-10 YEARS)

- **Taxes**

- Currently there is no carbon tax applied to marine fuel for ships on the Great Lakes. The exact timing and scale of a potential marine fuel tax is outside the scope of this paper, as is how the tax would break down among individual constituents. For reference, Canada is slated to charge $50 CAD per ton of CO2 for traditional fuels by 2022 for certain provinces that have not met federal criteria for pricing carbon emissions.[12] This charge applies to marine fuels used by ships and from 2023 to 2030 will rise by $15 per year to $170 per ton of CO2.[13] Globally, marine shipping emits ~1 billion metric tons of carbon per year[14] and the 174 member states of the International Marine Organization, the UN's agency that sets global rules for ships' safety and environmental protection, is currently deliberating on how to put a worldwide price on ships' carbon emissions. However, a marine fuel tax could still be implemented by countries for domestic shipping or by a cohort of wealthy nations that would have some discretion on how the tax rolls out. Regardless, it is reasonable to assume that such a tax would greatly incentivize shippers to convert to lower carbon fuels. That said, this tax would also penalize one of the most energy-efficient modes of transportation (shipping) when what governments are primarily focused on abating are the least efficient modes of transportation with the highest emissions (aviation, trucking, etc.).

- **Carbon Credits**

- The obverse of taxes, credits provide an incentive to switch fuels and could greatly impact both the supply and the demand side of the biodiesel industry. CCF has already witnessed this firsthand, and the reason it sources from a U.S.-based supplier is because of the tax credits provided in the U.S. to biodiesel producers. If Canada adopts similar tax credits, this provides an obvious incentive for a Canadian company to enter the market at scale. A concern is that broad-based incentives, not tied to marine fuel use specifically, increase the likelihood that other industries in the "hard to abate" sectors of the economy will flood the demand for biodiesel. Other large consumers such as the mining/heavy equipment sectors may prove to be less price-sensitive, consuming available supply for the carbon credits rather than underlying economic fundamentals. For CSL, carbon credits it earns using B100 can be used to subsidize some additional costs, although as discussed there are few associated switching costs. Another consideration is a fuel dependent on tax credits could face price shocks if credits are withdrawn by governments prematurely.

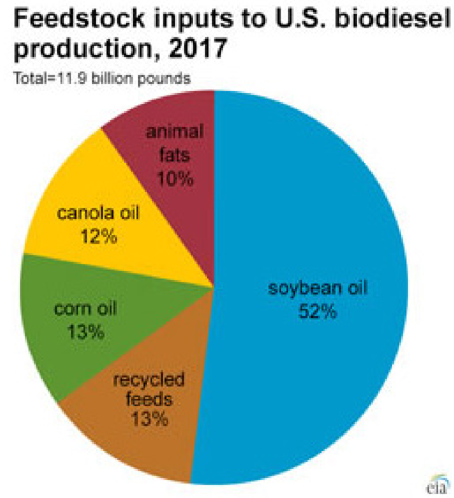
- **Supply-Side Economics**

- CCF does not appear to currently have any issue procuring B100 biodiesel in the amount required to satisfy CSL's demand. That said, biodiesel supply is largely inelastic in the short run. "Second-generation" B100 can be made from fats, grease, vegetable oils and used cooking oils, some of which are not produced expressly as ingredients for biodiesel. Governmental regulatory guidance does not require Fatty Acid Methyl Esters (FAME) fuels to be added to traditional diesel in the same way that most gasoline in the United States is cut with a 10% ethanol blend. In the event that the U.S. or Canadian governments legislate a 1-10% FAME blend into standard diesel, demand will increase dramatically and it is possible that Sterling Fuels and other providers will no longer be able to source biofuel from their U.S.-based supplier.

- **Biodiesel Scalability**

- Despite the secular growth in demand expected broadly for biofuels, manufacturing biodiesel relies heavily (~77%) on repurposing plant-based oils from soy (55%), corn (12%) and canola (10%) according to a 2017 Energy Information Administration report.[15] It is important to note that the ECR team could not determine the exact amount of plant-based oil that was purpose-grown for use as biodiesel (vs recycled as cooking oil). Production from this method is subject to scrutiny, and critics dislike the intentional growth of food crops that are destined for use in fuel as opposed to food. A CSL representative stated that CCF sources fuel made as a byproduct of making soy meal for use as livestock feed, providing less direct competition to the food supply chain. A sizable, and less controversial, source of biodiesel comes from recycled cooking oil sourced through foodservice and hospitality businesses, according to an IBIS World Specialized Industry Report.[16] Overall, biodiesel is difficult to scale due to limited (or controversial) feedstocks and the difficulty with bulk shipping.

- **Safety Requirements**
- Marine fuels are subject to global safety rules and quality standards. This is to protect crews from fire and explosion risks in engine rooms (ships often have people working beside operating engines) and to protect ships' engines from stalling due to contaminants. Biofuels were not envisioned when these standards which focus on petroleum products were written. While exemptions can now be obtained, regulatory changes are needed for wider biofuel adoption.

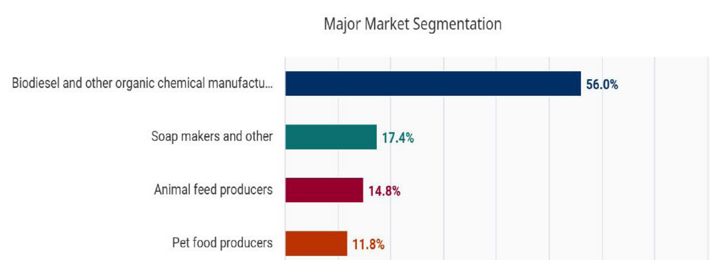


Source: U.S. Energy Information Administration (EIA), *Monthly Diodiesel Production Report*, March 2018

It remains to be seen whether food-for-fuel will become more mainstream in the coming years, but the industry is unlikely to scale without it. Despite higher recycling targets on used oils by many state and local governments, the total revenue for the (U.S. based) industry was ~$2.5 billion USD, negligible when compared to the broader fuels market.[17] While early technological advancements in recycling oil and a favorable regulatory environment may contribute to early industry growth, it is unlikely that the industry will scale to the point of impacting industrial diesel use.

Unlike fossil fuels which are centrally located in large reserves, recycling cooking oil depends on stitching together many relatively small regional providers, which in and of itself increases labor and transportation costs significantly. Transporting this fuel to the use site further reduces the underlying carbon advantage (although the ECR team as stated does not have a "net" carbon impact to offer here).

Another issue complicating the available supply is that as of 2020, only 56% of recycled cooking oil went into biodiesel production, with the remaining demand split between animal feed production and chemical manufacturing.[18] There are also bio-fermentation methods to extract fuels from municipal waste (usually methane and methanol), which holds potential for greater scalability, but such methods currently exist only on the research or laboratory scale.



Source: Diment, Dmitry. "Cooking Oil Recycling."

CONCLUSION AND RECOMMENDATION

The ECR team believes the biodiesel industry will benefit in the near term from strong governmental support, and potential carbon credits/taxes will deliver strong growth over a 5–10-year timeline. This advantage benefits producers, but the inherent inability to scale production constrains the industrial applicability for maritime biofuels. Until and unless specific tax and carbon credit guidance on maritime fuel consumption is dictated by a quorum of international governments, the risk level for large-scale adoption will remain elevated. There is a conceivable future where incentives drive biodiesel production to occur at a regional level and local producers service local consumption, but the interplay between commodity consumers and the unknown impact of government regulations advise a cautious approach to broad adoption. This complex system will reward participants for phasing in renewable fuels at the right time. However, if governments intend to incentivize biodiesel use in the near term, the ECR team believes that the greatest external barrier right now is the 12-14% difference in energy density between traditional fuels and biofuels. The Chamber of Marine Commerce, a bi-national, private sector, not-for-profit association that represents more than 100 marine industry stakeholders, also reports that the greatest barrier for its members is the price difference from conventional fossil fuels.[19] The greatest internal barrier is hesitation to over-commit while long-term biodiesel markets are still developing, and the threat that if current subsidies and credits were to disappear, prices will become much less competitive. Bridging this economic gap by reducing fees and taxes or offering outright subsidies to shipping companies reduces the largest barrier to entry. At the very least, it positions these companies to be early in the adoption cycle should maritime biofuels come to market at scale.

REFERENCES

i. Atkins, Eric. "In the Search for Less Carbon-Intensive Fuels, Great Lakes Freighters Powered by Soybean May Be the Answer." The Globe and Mail, February 8, 2022. https://www.theglobeandmail.com/business/article-in-the-search-for-less-carbon-intensive-fuels-great-lakes-freighters/.

ii. El Bagoury, Yousef. Interview. Personal, December 9, 2021.

iii. Ibid.

iv. Ibid.

v. Ibid.

vi. Mitterhuber, Adrian. Interview. Personal, November 23, 2021.

vii. El Bagoury, Yousef. Interview. Personal, December 9, 2021.

viii. Prabu, A. "Nanoparticles as Additive in Biodiesel on the Working Characteristics of a DI Diesel Engine." Ain Shams Engineering Journal 9, no. 4 (2018): 2343–49. https://doi.org/10.1016/j.asej.2017.04.004.

ix. Wang, Michael, Jeongwoo Han, Jennifer B Dunn, Hao Cai, and Amgad Elgowainy. "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Ethanol from Corn, Sugarcane and Cellulosic Biomass for Us Use." Environmental Research Letters 7, no. 4 (2012). https://doi.org/10.1201/b18466-17.

x. CSL. "CSL Successfully Completes World's Largest B100 Biofuel Tests." CSL Successfully Completes World's Largest B100 Biofuel Tests | CSL Group, December 9, 2021. https://www.cslships.com/en/media-center/news-events/csl-successfully-completes-worlds-largest-b100-biofuel-tests.

xi. He, B, J Thompson, D Routt, and J Van Gerpen. "Moisture Absorption in Biodiesel and Its Petro-Diesel Blends." Applied Engineering in Agriculture 23, no. 1 (2007): 71–76. https://doi.org/10.13031/2013.22320.

xii. Government of Canada. "The Federal Carbon Pollution Pricing Benchmark." Canada.ca, August 5, 2021. https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/carbon-pollution-pricing-federal-benchmark-information.html.

xiii. Government of Canada. "Fuel Change Rates for Listed Provinces and Territories for 2023 to 2030." Canada.ca, December 3, 2021. https://www.canada.ca/en/department-finance/news/2021/12/fuel-charge-rates-for-listed-provinces-and-territories-for-2023-to-2030.html

xiv. Olmer, Naya, Bryan Comer, Biswajoy Roy, Xiaoli Mao, and Dan Rutherford. "Greenhouse Gas Emissions From Global Shipping, 2013–2015." International Council on Clean Transportation, October 2017.

xv. U.S. Energy Information Administration. "Biodiesels Produced from Certain Feedstocks Have Distinct Properties from Petroleum Diesel," May 3, 2018. https://www.eia.gov/todayinenergy/detail.php?id=36052.

xvi. Diment, Dmitry. "Cooking Oil Recycling." Industry Report OD5810, April 2021.

xvii. Ibid.

xviii. Ibid.

xix. Topping, Paul. Email Exchange. Personal, February 11, 2022.

Endnotes

1 Atkins, Eric. "In the Search for Less Carbon-Intensive Fuels, Great Lakes Freighters Powered by Soybean May Be the Answer." The Globe and Mail, February 8, 2022. https://www.theglobeandmail.com/business/article-in-the-search-for-less-carbon-intensive-fuels-great-lakes-freighters/.

2 El Bagoury, Yousef. Interview. Personal, December 9, 2021.

3 Ibid.

4 Ibid.

5 Ibid.

6 Mitterhuber, Adrian. Interview. Personal, November 23, 2021.

7 El Bagoury, Yousef. Interview. Personal, December 9, 2021.

8 Prabu, A. "Nanoparticles as Additive in Biodiesel on the Working Characteristics of a DI Diesel Engine." *Ain Shams Engineering Journal* 9, no. 4 (2018): 2343–49. https://doi.org/10.1016/j.asej.2017.04.004.

9 Wang, Michael, Jeongwoo Han, Jennifer B Dunn, Hao Cai, and Amgad Elgowainy. "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Ethanol from Corn, Sugarcane and Cellulosic Biomass for Us Use." *Environmental Research Letters* 7, no. 4 (2012). https://doi.org/10.1201/b18466-17.

10 CSL. "CSL Successfully Completes World's Largest B100 Biofuel Tests." CSL Successfully Completes World's Largest B100 Biofuel Tests | CSL Group, December 9, 2021. https://www.cslships.com/en/media-center/news-events/csl-successfully-completes-worlds-largest-b100-biofuel-tests.

11 He, B, J Thompson, D Routt, and J Van Gerpen. "Moisture Absorption in Biodiesel and Its Petro-Diesel Blends." *Applied Engineering in Agriculture* 23, no. 1 (2007): 71–76. https://doi.org/10.13031/2013.22320.

12 Government of Canada. "The Federal Carbon Pollution Pricing Benchmark." Canada.ca, August 5, 2021. https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/carbon-pollution-pricing-federal-benchmark-information.html.

13 Government of Canada. "Fuel Change Rates for Listed Provinces and Territories for 2023 to 2030." Canada.ca, December 3, 2021. https://www.canada.ca/en/department-finance/news/2021/12/fuel-charge-rates-for-listed-provinces-and-territories-for-2023-to-2030.html

14 Olmer, Naya, Bryan Comer, Biswajoy Roy, Xiaoli Mao, and Dan Rutherford. "Greenhouse Gas Emissions From Global Shipping, 2013–2015." *International Council on Clean Transportation*, October 2017.

15 U.S. Energy Information Administration. "Biodiesels Produced from Certain Feedstocks Have Distinct Properties from Petroleum Diesel," May 3, 2018. https://www.eia.gov/todayinenergy/detail.php?id=36052.

16 Diment, Dmitry. "Cooking Oil Recycling." *Industry Report OD5810*, April 2021.

17 Ibid.

18 Ibid.

19 Topping, Paul. Email Exchange. Personal, February 11, 2022.