PROVIDING DULLES INTERNATIONAL AIRPORT WITH SUSTAINABLE AVIATION FUELS PROCESSED FROM THE WOODY WASTE FEEDSTOCK IN VIRGINIA

MARATHON MARTINEZ BIOFUEL REFINERY FIRE: WHY AN IMPATIENT TRANSITION FROM FOSSIL FUELS TO BIOFUELS WON'T WORK

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

In the U.S. commercial aviation community, there is a recent and powerful push toward achieving net zero carbon emissions by 2050 by focusing on how the fuel industry can cut ties with traditional fossil fuels and establish sustainable aviation fuels (SAF) (U.S. Department of Energy, 2022). To accomplish these goals set by the Federal Aviation Administration and the U.S. Department of Energy, a systems approach to the problem is necessary to ensure proper steps are taken to support new sustainable fuel supply chains. Dulles International Airport (IAD) needs a holistic evaluation of potential low-carbon, supply chain options that consider the social, economic, and environmental impacts to determine if SAF is viable. I will conduct this evaluation, building off of past small-scale case studies, to ensure IAD and other stakeholders can maximize their metrics of priority. Because the development of a supply chain will rely on many different stakeholders and "actors," it is important to understand the factors that led to the Marathon Martinez refinery (a biofuel refinery) fire in November of 2023 and how they created an environment where a large scale incident was inevitable. I will use the actor-network theory (ANT) science, technology, and society (STS) framework to examine how unattainable goals set by government organizations combined with a lack of industry-wide experience can cause shortcuts to be taken resulting in a life-threatening incident, like the Martinez refinery fire.

If only the technical analysis of supply chain logistics is focused on, the commercial aviation industry will never learn to first prepare an industrial culture before demanding goals from it and lives will be unnecessarily threatened time and time again. Because the challenge of achieving net zero carbon emissions in the commercial aviation industry is sociotechnical in nature, it requires attending to both its technical and social aspects to accomplish successfully. In what follows, I set out two related research proposals: a technical project proposal for developing

potential supply chains to supply IAD with SAF and an STS project proposal for examining irresponsible political pressure and a lack of industry-wide experience in the Marathon Martinez refinery fire.

Technical Project Proposal

The green commercial aviation movement was initiated with the publishing of the Sustainable Aviation Fuel (SAF) Grand Challenge Roadmap in 2022 by the U.S. Departments of Energy, Transportation, and Agriculture, which lays out what needs to be done for the biofuel industry to reach the goal of producing 3 billion gallons of domestic SAF per year by 2030 and enough SAF to meet 100% of the aviation fuel demand by 2050 (projected to be around at least 35 billion gallons per year) for the Federal Aviation Administration, or FAA (U.S. Department of Energy, 2022). Sustainable aviation fuel is a type of drop-in fuel that can be mixed in with fossil jet fuel without a special processing procedure (U.S. Department of Energy, 2022). There are a few states and airports that have titled themselves as key players in SAF production and supply chain logistical success, specifically Pennsylvania and Pittsburgh International Airport (PIT), but not Virginia (CNX Resources Corporation, 2024). For the first step to keeping up with this political and industrial change, Washington Dulles International Airport (IAD) needs to know if the development of a low-carbon, biofuel supply chain that potentially utilizes Virginia's biomass feedstocks is possible, and the environmental, economic, and social impacts of the facilities to be utilized or created.

Minimal studies have been conducted that analyze this need. The majority of this analysis was conducted by a University of Virginia graduate school team with work mainly conducted by Curtis Davis. Their work, a *Geospatially explicit technoeconomic assessment of sustainable aviation fuel production: A regional case study in Virginia*, is a research and analytical evaluation

of the potential sourcing, processing, and transporting of SAF in Virginia to determine if it is technically and economically feasible (Davis, C. D., et al, 2024). They, also, determine the scale of necessary government subsidization to allow the price per gallon of SAF to be remotely competitive with traditional fossil jet fuel. Their work considers two independent feedstock types, woody waste (leftover wood material from lumber work, dead forest wood, etc.) and municipal solid waste (biodegradable waste usually soured from landfills before being processed), and two independent biofuel processing methods, gasification Fischer Tropsch (GFT) and pyrolysis (pilot-scale tested), allowing for the comparison of separate solutions. They generated the price per gallon for SAF for each method combination using the U.S. Department of Transportation's (USDOT) *Freight and Fuel Transportation Optimizaiton Tool* (FTOT) and the Aviation Sustainability Center's (ASCENT) series of technoeconomic assessment (TEA) models for SAF production to initially analyze and optimize supply chain logistics (Davis, C. D., et al, 2024).

While the Virginia SAF case study highlights potential opportunities within the state, it fails to provide the comprehensive evaluation necessary for IAD to confidently move forward with meeting SAF goals. The data that was used for the research and analytics is outdated and generalized were made to the available data so it could be applied to Virginia as a case study (Davis, C. D., et al, 2024). Methods selected for processing biofuels, specifically pyrolysis, are only tested at the pilot-scale level and are not currently used on the commercial production scale, so there is little confidence in their ability to be reliable and sustainable. There is minimal sensitivity analysis done on how external impacts can affect the cost of locally sourced SAF. The analysis only considers Virginia rather than other potential supply chain options that could provide IAD with SAF at lower costs. Finally, the case study doesn't provide information about

the social and environmental impacts sustained on the communities where the feedstocks are sourced from, which is pertinent to gaining the support of powerful environmental and political groups (Davis, C. D., et al, 2024).

More must be done to satisfy the aviation community's need for trusted SAF supply chain logistics and its effect on all stakeholders involved. Curtis Davis's work will be a link in the holistic approach that includes many more links and nodes. Multiple other supply chains will be analyzed, including SAF sourced from Pittsburgh International Airport, processing facilities in the South, and utilizing current transportation of jet fuels, such as the Colonial pipeline. This will offer multiple solutions for the stakeholders and allow them to choose a maximized solution based on the factors that they prioritize and also allows the stakeholders to know what must happen in the Virginia supply chain for costs to be competitive with the rest of the United States. The analysis will consider the social and environmental impacts on communities, especially in low-income Appalachia where the most woody waste potential is (Davis, C. D., et al, 2024). Lastly, up-to-date and applicable feedstock, processing, transportation, and storage costs and data will be used to produce more accurate cost-per-gallon results.

Multiple methods and tools will be used to accomplish this. Initially, a risk management analysis with valuable strengths, weaknesses, opportunities, and threats (SWOT) will be explicitly determined and analyzed to find potential supply chains for testing. Using the SWOT analysis, a defined objectives tree will be used as a method of top-down metric selection and justification to determine what is important to the stakeholders. After these processes, the FTOT tool will be used to find the ideal logistical details like feedstock-to-processor transportation, hypothetical processor locations, and processor-to-end use transportation for each supply chain option. ASCENT's TEA series will then be used to determine the end cost per gallon of SAF for

each solution. Sensitivity analysis will be applied to the solutions to understand how our metrics will change when external variables fluctuate (such as annual feedstock collection amounts). The stakeholders will have the ability to select solutions using multiattribute decision-making (using the marginal rates method to determine how they want different metrics weighted based on their priority). This method produces a solution for the stakeholder-based on what factors they value in a pool of many factors. These factors are developed from the analysis to come and are dependent on the supply chain that they relate to. The factors valuable to stakeholders include the cost per gallon of SAF produced, supply chain carbon emissions, sustainability of the feedstock, number of jobs created, support from supply chain node communities and political organizations (incentives), and potentially more.

STS Project Proposal

In early 2021, the Marathon Petroleum Corporation was given the green light to convert a crude oil refinery located in Martinez, California (part of the San Francisco Bay area) to a biofuel refinery with plans for using animal fat, soybean oil, and corn oil as the renewable feedstocks (Marathon Petroleum Corporation, 2020). On November 19th, 2023, the Martinez biofuel refinery experienced a severe fire caused by the overheating and rupturing of piping carrying hot biodiesel and hydrogen in one of their reactor charge furnaces, prompting the evacuation and shutdown of the facility. The materials in the ruptured pipe left the field operator, who was sent to respond to the alarms, with life-threatening burns (U.S. Chemical Safety and Hazard Investigation Board, 2024).

The information released by the U.S. Chemical Safety and Hazard Investigation Board (CSB) from their ongoing investigation of the incident goes in-depth about the technical timeline of the fire and the operational steps of the reactor charge furnace taken by the employees (U.S.

Chemical Safety and Hazard Investigation Board, 2024). Although CBS hasn't formally released their relevant facility, corporate, and industry standards findings, other sources that have conducted their own investigations are blaming the incident on the interaction between the company and their employees. The president of the United Steel Works (USW) Local 5 Union, Tracy Scott, blames the company's deficient training and staffing of new employees during the transition to biofuel feedstocks as expressed by many workers in the Union (Goldberg, 2023). One of the nine violations that the California Division of Occupational Safety and Health (Cal/OSHA) cited Marathon was the failure to remove employees from imminent danger which resulted in life-threatening injuries to an employee (Goldberg, 2024).

Although these company-employee interactions are the partial cause for the incident that happened in November of 2023, focusing only on the scope of technical and training factors does not allow for a holistic investigation into the case to be taken. The previous investigations overlook the role that large corporations and government culture, and uncontrollable factors had in causing a large-scale refinery failure to be inevitable. I argue that the investigation results of Cal/OSHA and the reports from USW along with the COVID-19 pandemic impact on the refinery industry and the political pressure put on biofuel supply chain links to support unattainable carbon emission-reducing goals set by vehicle and aviation administrations are to blame for the Martinez Refinery fire. If these factors aren't understood, lower-level, company-specific policy may still be implemented by Marathon Petroleum Corporation to prevent this specific scenario from happening, but a whole-of-government approach to solving these industry-wide issues will never be possible.

To understand the factors that are a part of the Marathon Martinez Refinery fire, I will be using the actor-network theory (ANT) science, technology, and society (STS) framework as an

organization and analysis tool. ANT was developed in the late 1980s in an engineering research center by Michel Callon, Bruno Latour, Madeleine Akrich, Antoine Hennion, and John Law (Muniesa, 2015). Actor-network is the framing of a technological network by the actors (human and non-human) that make it up and how they interact to explain its behavior or success (Callon, 1987, p. 92-97). To answer my research question of why Marathon's Martinez Refinery experienced a large-scale fire in 2023, I will use information primarily from various news articles and vehicle and aviation administration fuel guideline publications. Specifically, I will use reports from KQED on the Martinez refinery employee layoffs and closure in 2020 to understand a lack of post-pandemic worker experience and the industry-wide delayed transition from crude oil to biomass as well as the Federal Aviation Administration's (FAA) publication of the Sustainable Aviation Fuel (SAF) Grand Challenge Roadmap (Goldberg, 2020; Sparling, 2020; U.S. Department of Energy, 2022).

Conclusion

To provide Dulles International Airport with an answer to the question *is a supply chain that provides the airport with cost competitive sustainable aviation fuel viable while addressing the social, economic, and environmental impacts viable?* I will conduct a proper analysis of multiple supply chain options and provide alternative solutions based on the stakeholders' wants and needs, further helping the commercial aviation industry reach its biofuel goals. I will use the actor-network theory science, technology, and society framework to investigate the impact that political pressure caused by unattainable biofuel goals and a lack of company-wide experience caused by a global pandemic had on the Marathon Martinez refinery fire in 2023 and present the lessons learned so they apply to the sustainable aviation fuel industry to ensure similar mistakes are not made with other actors in the broader system. Other insights from the investigation of the

refinery fire case, including the effect of a lack of expertise in a dangerous work environment on a company's culture and the effect of corporate-level personnel burdened with excessive political and economic pressure on their decision making, are intended to be applied to the technical project. I plan on using these lessons and the relationships of actors in an actor network to strengthen the final product for IAD and other stakeholders.

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