Assessing the Feasibility of Siting a Biofuel Refinery in Lewis County, Washington

Caitlin Cruz

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science

University of Washington

2022

Committee:

Clare Ryan

Renata Bura

Program Authorized to Offer Degree:

School of Environmental and Forest Sciences

University of Washington

Abstract

Assessing the Feasibility of Siting a Biofuel Refinery in Lewis County, Washington

Caitlin Cruz

Chair of the Supervisory Committee:

Clare Ryan

School of Environmental and Forest Sciences

Currently, 95% of global greenhouse gas emissions in the transportation sector originate from fossil fuels. Biofuels are renewable transportation fuels that can be used in place of traditional transportation fuels like gasoline or diesel, and they typically emit lower amounts of greenhouse gases than fossil fuels. As policies in the United States begin to incentivize renewable fuels, states are starting to consider the production of biofuels. This study used case studies of successfully initiated biorefineries in the United States to explore technical and policy feasibility elements surrounding siting a new biofuel refinery in Lewis County, Washington. The proposed Lewis County facility shares a many of the key facility characteristics and policy tools identified in the case studies, suggesting that the siting of a biofuel refinery in Lewis County WA appears to be feasible. Non-food feedstocks, ethanol output, technology, co-location, co-products, and at least $100 million in federal funding (mostly from the U.S. Department of Energy) were facility characteristics most common to successfully initiated biorefineries. Common policy tools included biofuel funding programs, state fleet Alternative Fuel Vehicle requirements, tax incentives, and blend requirements. Future work should evaluate the social acceptability and environmental benefits of biofuel refineries to assess project feasibility more completely.

EXECUTIVE SUMMARY

In the transportation sector, 95% of global greenhouse gas emissions come from fossil fuels, which are made from the fossilized remains of plants and animals. Because of the high level of emissions from fossil fuels, research into alternatives for the transportation sector has begun. Biofuels are transportation fuels created from renewable materials like biomass, and they serve as substitutes for traditional transportation fuels like gasoline or diesel. Because biofuels are made from renewable materials, they typically release lower levels of greenhouse gas emissions than fossil fuels. The transportation sector is projected to rely strongly on liquid fuels until 2050, so it is crucial to understand what conditions help to facilitate these projects. Biofuels policy is implemented at the local, state, and federal levels across the United States, and the presence and strength of these policies vary.

Lewis County, Washington was interested in creating a new biofuel refinery, so they partnered with a team at the University of Washington to conduct a feasibility study. This study addresses the primary research question:

What is the feasibility of a biorefinery being created in Lewis County, Washington?

To address this question, two sub-questions are asked:

- *What are the characteristics of successfully initiated biorefineries in the United States?*
- *What underlying policy conditions pave the way for biorefinery creation?*

To study these questions, case studies were conducted on four biorefinery facilities across the United States. These case studies involved document analysis, policy analysis, and interviews. The results from the case studies were then compared to projections for the proposed Lewis County project to answer the primary research question.

Key Findings

Overall, the proposed Lewis County facility shared many of the identified key commonalities found in the four case studies. This may indicate that the conditions in Lewis County could be supportive for the siting of a new biorefinery in the county. The key findings are identified below.

What are the characteristics of successfully initiated biorefineries in the United States?
• Second-generation, non-food feedstocks were used to create fuels. • Cellulosic ethanol was produced. • Similar types of technology were used, such as dilute acid, and enzymatic hydrolysis and fermentation. • Two of the facilities were co-located beside existing infrastructure to decrease transportation and production costs from the facility. • Additional co-products were made alongside the fuel that could be sold for higher prices.

• Each facility received a minimum of $100 million in federal funding and was also funded in part by state and/or local programs. • The U.S. Department of Energy (at least partially) funded every case study facility.
What underlying policy conditions pave the way for biorefinery creation?
At a federal level: • The Renewable Fuel Standard Program is the major biofuel federal policy in the United States. • This program aims to reduce United States carbon emissions from the transportation sector by requiring certain levels of renewable fuels to replace fossil fuels each year, on an increasing scale. At a state level: • Biofuel funding programs allow government agencies to offer different types of funding (subsidies, grants, or loans) to renewable fuel projects to increase project success. • State fleet Alternative Fuel Vehicle (AFV) requirements vary across states, but in general these policies require state vehicle fleets to purchase and use the most fuel-efficient vehicles possible, or the most low-carbon fuel possible. • Tax incentives can directly or indirectly reduce the amount of tax a producer or retailer owes to the government if they produce or sell renewable fuels. • Blend requirements outline different types of state requirements for the amount of renewable fuels that must be blended into traditional fuels. Interviews identified: • Several challenges are faced by the biofuel industry. • Certain policy tools (state low carbon fuel standard, tax incentives, regulations, programs) tend to be beneficial to biofuel projects. • Economic competitiveness is crucial for long-term facility success. • Local community support is important in the creation of a new facility. • Environmental benefits are relevant to facility creation. • Government support through policies or funding is crucial.

Considerations for Further Research

This study sought to understand the feasibility of the proposed Lewis County facility based on analysis of facility characteristics and policy conditions. Social acceptability and environmental benefits are important feasibility considerations, and future research should focus on engaging in deep community-based studies and environmental analysis to understand these features. Once these are understood, they may help to determine project feasibility more comprehensively.

Acknowledgements

First and foremost, I am extremely grateful to my advisor and committee chair Dr. Clare Ryan for her constant advice, feedback, and patience in helping me complete this thesis. Dr. Ryan's support has guided me throughout this entire study. I would also like to express my deep appreciation for Dr. Renata Bura, my other committee member, for her consistent support and assistance in understanding complicated engineering processes.

Furthermore, this work would not have been possible without funding from the Washington State Legislature, the Lewis County .09 Rural Development Fund, and the Centralia Coal Transition Grant.

Finally, special thanks to my wonderful family who has supported me from across the country. Thank you to my mother and Grandma for constantly offering words of encouragement and motivation. Thank you to my father and brother for the many phone calls to keep my spirits up. Thank you to my Amma and Tata for their never-ending support and constant reminders of how proud they are. The tremendous support from my family kept my spirit and motivation high throughout this process.

TABLE OF CONTENTS

List of Figures

List of Tables

1. Introduction

For the last few decades, fossil fuels have been the most used source of energy in the world, accounting for up to 80% of the total global energy consumption (Milano et al., 2016). Fossil fuels like coal, natural gas, and crude oil are all made from the fossilized remains of plants and animals, leading to high levels of carbon dioxide emissions being released when these fuels are burned (Denchak, 2018). These emissions lead to global warming as heat is trapped within the earth's atmosphere. Furthermore, fossil fuels are non-renewable, and are projected to run out within the next century (Shafiee & Topal, 2009) As a result, research into renewable, sustainable, and non-toxic alternatives to fossil fuels has begun. Globally, nearly 80% of energy consumption comes from fossil fuels, while the remaining 20% comes from renewable sources like nuclear, hydropower, wind, solar, biofuels, and other renewables (Ritchie & Roser, n.d.).

When focusing only on the transportation sector, 95% of global greenhouse gas emissions come from fossil fuels (US EPA, 2022). For this reason, it is important to begin to move away from fossil fuels in the transportation sector as a means of reducing global greenhouse gas emissions. There are three fossil fuel alternatives typically considered in the transportation sector: battery electric vehicles, hydrogen fuel cells, and biofuels (Contestabile et al., 2011), though battery electric vehicles and biofuels are the two most used and studied. Although battery electric vehicles have smaller negative climate impacts than biofuels (Sathre & Gustavsson, 2021), there are currently major hurdles to the wide-scale implementation of electric vehicles. For example, using only electric vehicles could lead to the scarcity of valuable minerals like lithium and magnesium, and that energy-economy feedbacks resulting from immediate implementation of electric vehicles could create a rebound effect that would drastically defeat the benefits of implementation (de Blas et al., 2020). Additionally, the transportation sector is projected to rely strongly on liquid fuels until 2050, even if effective climate policy was implemented (Pietzcker et al., 2014). Thus, understanding biofuel production and the policies that encourage them is an immediate necessity, as it has been shown that using the market alone will not create alternatives at a fast enough rate to effectively reduce emissions, so policy intervention is necessary (Contestabile et al., 2011).

This research used case studies to assess the feasibility of siting a biofuel refinery in Lewis County, Washington. To address this overarching question, this study focused on identifying the facility characteristics of successfully initiated biofuel refineries across the United States as well as identifying common biofuels-related policy conditions across the case studies. The results of these case studies were then used to compare against the proposed Lewis County facility to better understand project feasibility.

1.1. Biofuels

Biomass, or organic matter, was the largest source of total annual energy consumption in the United States until the mid-1800s, when the country began to shift towards coal and natural gas (EIA, 2013). Recently, however, the use of biomass to produce biofuels has increased as a way to offset carbon emissions from fossil fuels. Biofuels are transportation fuels created from renewable materials like biomass (Refer to Appendix A for a glossary of terms). They are carbon neutral, which means that the carbon emitted from burning biofuels simply returns to the atmospheric carbon dioxide that is processed through photosynthesis, without adding any further carbon into the environment (Hanaki & Portugal-Pereira, 2018). Therefore, when biofuels are consumed in place of fossil fuels, carbon emissions are reduced. Biofuels serve as substitutes for traditional transportation fuels, and the two most common types are ethanol and biodiesel.

In 2019, the United States consumed a total of 1.09 million barrels of biofuels per day, ultimately accounting for 7.3% of total motor gasoline, distillate, and jet fuel consumption (EIA, 2020). In the future, the U.S. Energy Information Administration projects an increase in biofuels production through 2050, with a predicted increase of 30,000 barrels per day of biodiesel and 80,000 barrels per day in other biofuels (EIA, 2020). With this increase in prevalence of biofuels usage, many states are investing in both the use and production of biofuels.

1.2. Technology

1.2.1. Biomass to ethanol

Currently, most of the biofuels produced and used in the United States are ethanol (EIA, 2020). In the US, all the commercial-scale ethanol is made from corn. These fuels are known as first-generation biofuels, and are made from food crops (US EPA, 2021). Almost 90% of ethanol plants in the United States use dry-milling processes, which grind corn into flour then ferment it into ethanol. Wet-milling plants separate out materials in the corn such as proteins, starch, and fiber before processing the components into ethanol. In 2020, the United States had 201 ethanol plants across the country, with a combined capacity of 17.4 billion gallons per year, and a combined production rate of 14 billion gallons per year (AFDC, n.d.). The United States is the world's largest producer of ethanol, followed by Brazil (AFDC, n.d.).

Although all the commercial ethanol in the United States is made from corn, ethanol and other types of biofuels can also be produced from lignocellulosic biomass. Lignocellulosic biomass is non-food organic matter, including agricultural residues (stover, straw, bagasse), forest biomass (softwood residuals, hardwood residuals), and municipal solid waste (Mussatto & Dragone, 2016). Fuels made from these non-food, lignocellulosic forms of biomass are called second-generation biofuels. Second-generation biofuels can be beneficial in that they do not compete with the food industry and because their biomass is relatively cheap and abundant (Mussatto & Dragone, 2016), but oftentimes the high cost of production of these fuels makes them economically non-competitive with fossil fuels and first-generation biofuels like corn ethanol. Second-generation biofuels can be produced using three main types of processing technologies: biochemical conversion, thermochemical conversion, and physicochemical conversion.

1.2.1.1. Biochemical conversion

Biochemical conversion involves two primary options— anaerobic digestion to biogas, or fermentation of sugars to ethanol. During lignocellulosic biomass to ethanol conversion, the feedstock (lignocellulosic biomass) must first be preprocessed, and then pretreated to release cellulose and hemicellulose carbohydrates (Aden et al., 2002). Then, there is a detoxification process of the liquid stream to remove fermentation inhibitors, followed by an enzymatic hydrolysis of the solid stream to break cellulose down into glucose monomers. Next, the monomeric sugars are fermented into ethanol by microorganisms, and finally the final product (ethanol) can be recovered (Aden et al., 2002).

1.2.1.2. Thermochemical conversion

Thermochemical conversion includes three main process routes— pyrolysis, gasification, and combustion. Pyrolysis converts feedstocks into gas, oil, and biochar under controlled temperatures (starting at 350-550 °C, up to 700 °C) and absent of oxygen. Pyrolysis is generally best used for conversion of feedstocks into liquid fuel (Goyal et al., 2008), but any resulting outputs (gasses or oils) can be used to power generators, or to create diesel or chemicals from the gasses. Gasification begins with breaking down the lignocellulosic feedstocks into synthetic gas— mostly carbon monoxide and hydrogen— using heat. Then, the feedstock is partially oxidized using high temperatures (800-900 °C) (Goyal et al., 2008), or reformed with a gasifying agent like air, oxygen, or steam, ultimately producing a synthetic gas (syngas). Finally, combustion relies on directly burning biomass in the presence of oxygen to convert it into heat, electricity, or mechanical energy. Biomass can also be co-fired with existing fossil fuel plants. Often, biomass requires some type of pretreatment before combustion (Goyal et al., 2008).

1.2.1.3. Physicochemical conversion

Physicochemical conversion generally relies on transforming fresh or used oil into liquid fuels through extraction by esterification, which is when an alcohol reacts with the oil to create ester and glycerol. The oil used for physicochemical conversion is obtained by crushing oilseeds to extract the oil. This process produces biodiesel instead of bioethanol.

1.3. Energy Policy

There are many levels on which energy policy can be implemented in the United States. Policies related to biofuels production can vary significantly at the local, state, and federal level, making it difficult to site new biorefineries when these policies do not align. The major federal biofuel policy in the United States is the Renewable Fuel Standard. Created in 2005, the program aimed to decrease the United States' reliance on carbon-intensive, non-renewable fuels. The program set lofty goals for renewable fuel requirements in the United States, but these goals were overambitious (Breetz, 2020). This led to the creation of various loopholes like weakened mandates or exemptions in order for producers to still 'comply'. Policy implementation at a state level can buffer negative feedback loops at a federal level by offering an opportunity to identify strong policy tools, understand best practices for implementation, and garner public support, all of which are necessary for biofuel success (Breetz, 2020). However, while implementing renewable energy policies at a state level can be a beneficial first step in testing policy effectiveness, states will need to begin integrating their policies to make a cohesive national market for biofuels to become widespread (Fischlein & Smith, 2013). Currently, state policies supporting renewable projects vary drastically. Thirty-two states have policies mandating the adoption of renewable energy— these generally set goals for increasing the sales and capacity of renewable energy over time. However, the compliance timelines between states vary drastically, in addition to differences in their specific fuel and energy requirements and in the methods of their implementation and enforcement (Fischlein & Smith, 2013). For further industry success, there must be a functional market for renewable energy. To achieve this cohesive national market, the differences between state policies will need to be addressed (Fischlein & Smith, 2013).

Traditionally, locations for new biorefineries were chosen based solely on economic metrics such as the costs of total delivered feedstock, electricity, infrastructure, and human labor/wages (Martinkus et al., 2019). In the last decade, movement towards an integrated decision-making model for siting new biorefineries has been made in academia. These new integrated decision-making models move away from considering only economic metrics, and instead begin to integrate additional factors— mainly focusing on adding social assets to the site-selection process, but also integrating a metric for biomass availability. Social asset factors commonly used in the new integrated decision-making models include social capital, creative capital, and human capital (Martinkus et al., 2017). Social capital describes social networks that are present in a community. The number of these networks, as well as their strength and types, can affect the success of environmental policy implementation in the community (Jones et al., 2009). Cultural capital focuses on conditions in a community that impact the creativity and innovation of community members (Jones et al., 2009), which is important for adaptability during projects such as biorefinery siting as well as for the success of sustainability programs (Budd et al., 2008). Human capital refers to various indicators of community health, which impact the abilities and skills of a local community workforce. However, although these integrated models now consider social assets, they do not consider local- or state-level policy conditions in the decision-making process (Martinkus et al., 2014; Martinkus et al., 2017). This is problematic, as policies that incentivize biofuel production can drastically change biomass supply curves (Lauer et al., 2015), impacting the economic metrics that are often the core of site selection for biorefinery projects. For this reason, it is important to understand policy conditions so that they can be integrated into future decision-making models for biorefinery site selection.

When policy around renewable energy and fuel is studied, there are typically two categories of research: the adoption of state-level renewable energy standards, and the description and evaluation of energy policies (Yi & Feiock, 2014). Most of the policy studies in the biofuels field tend to isolate the focus on the policies themselves, rather than on their implementation and effectiveness in the state. A few studies have considered policy effectiveness, finding that the implementation of renewable energy standards tends to lead to higher levels of renewable energy success (Carley, 2009), and that explicit regulatory requirements can lead to higher levels of renewable energy success (Kneifel, 2008). However, the studies that consider policy effectiveness in the state only consider biofuels that already exist in the market. This alienates any consideration for which policies may be most useful in the beginning stages of creation for new biorefineries. Eventual success of renewable energy and fuel projects were shown to be impacted by regulatory agencies, political support, and legislature professionalism (Yi & Feiock, 2014), but this still does not identify policies useful in incentivizing facility creation. The lack of analysis around policy in biorefinery creation highlights an area of research that needs to be addressed to bolster the future market success of biofuels.

1.4 Lewis County Project

In 2018, the state of Washington consumed 25 trillion Btu (or 11,812 barrels/day) of ethanol and 3.1 trillion Btu (or 1,465 barrels/day) of biodiesel. The same year, Washington produced 10 trillion Btu (or 4,725 barrels/day) of biofuels (EIA, 2020). The state houses two major biofuel producers— REG Grays Harbor Biorefinery and SeQuential— as well as General Biodiesel, a smaller and more localized producer based in Seattle. Although these biorefineries are currently operational, many similar plants are shutting down across the country, citing the difficulties of competing with the low price of oil (Henderson, 2020). To remedy this issue, a small handful of biorefineries have instead chosen to create other biomaterials, or *co-products*, in conjunction with their production of biofuels to make enough money to survive economically.

Following the lead of other emerging biorefinery projects across the United States, Lewis County, Washington sought to conduct a feasibility study focused on the possible construction of a biorefinery. Lewis County is located in Western Washington and hosts an estimated population of 75,457 (U.S. Census Bureau, 2019). The largest city in the county— Centralia— currently hosts the Centralia Coal Plant, which is slated to be shut down in 2025. Searching for alternatives, Lewis County aimed to investigate the possibility of turning the existing plant into a biorefinery. Representatives from Lewis County partnered with a research team at the University of Washington to create projections for a proposed biorefinery in the county. Engineers on the team created supply curves and conducted economic analyses for biomass projections in Lewis County. This study works in tandem with the engineering portion of the project to better understand the feasibility of the team's work. This study analyzes four case studies to understand characteristics of biorefinery facilities, along with which policies are most beneficial in biorefinery creation, addressing an existing research gap. Using these conclusions, the technical and policy feasibility of the proposed Lewis County project can be evaluated.

1.5 Research Objectives:

1.5.1. Research Question: What is the feasibility of a biorefinery being created in Lewis County, Washington?

The potential Lewis County project proposes siting a new biorefinery beside the existing Centralia Coal Plant in Lewis County, Washington. While the project has already projected many of the proposed technical characteristics, there has not yet been any research into the facility characteristics or policy conditions that facilitate biorefinery creation. By comparing the proposed Lewis County project with case studies of other biorefineries, the project's potential technical and policy feasibility will become clearer. This study does not address the environmental or social elements of the project's feasibility. To address this research question, two sub-questions are also investigated:

What are the characteristics of successfully initiated biorefineries in the United States?

It is important to understand the characteristics of biofuel refineries that have been created in the United States in order to understand the characteristics that were important in leading the refineries to be initiated. This objective aims to understand which characteristics are common to pilot-scale biorefineries in the United States. By analyzing these biorefineries, patterns of facility characteristics may be identified that tend to aid in the start-up of biorefineries.

What underlying policy conditions pave the way for biorefinery creation?

Local, regional, and national policies play an important role in shaping market demand for different types of fuels (Demirbas, 2008). A broad range of policy tools drive different aspects of biorefinery creation, such as environmental protection laws, economic incentives, and mandatory fuel requirements. By understanding the patterns of policy dynamics that lead to biorefinery development, it may be possible to identify and target areas with policy contexts that may be more conducive to siting new biorefinery projects.

2. Methods

This study relies on the case study method, which includes document analysis, policy analysis, and interviews. Cross-case comparison is then used to gauge the feasibility of the proposed Lewis County project through comparison to the case studies.

2.1. Case Study Design

To better understand the characteristics that may facilitate securing federal funding and ensure successful biorefinery development, case studies were conducted on four separate biorefineries. Case studies take an intensive study of one or a few units and generalize the findings across a broader set of units (Gerring, 2004). They allow in-depth and thorough research into real-life examples (Yin, 2009), and because there are no large data sets or well-developed theories surrounding biorefinery creation, case studies offer an advantageous, exploratory option for researching biorefinery development. Furthermore, case studies allow the consideration of a wide range of data types, including interviews, direct observations, and numerical data. Exploratory case studies, more specifically, tend to approach these data types as a means of gathering information about the topic in a general way, aiming for coherent patterns to emerge (Kanazawa, 2017). Because of the lack of understanding surrounding facility characteristics and policy dynamics of biorefinery creation, exploratory case studies were used to identify patterns among the four selected biorefineries. This study used several sources of data to inform the development of the case studies (document analysis, policy analysis, and interviews).

2.1.1. Case Selection

Across the United States, there are seven pioneer-scale (or commercial-scale) integrated biorefinery projects that have been funded by the Department of Energy (Bioenergy Technologies Office, n.d.). For this study, four were selected— POET-DSM's Project LIBERTY plant in Emmetsburg, Iowa, Abengoa's plant in Hugoton, Kansas, INEOS and New Planet Energy's joint Indian River Bioenergy Center in Vero Beach, Florida, and Red Rock Biofuels' plant in Lakeview, Oregon. These four biorefineries were selected based on two major criteria. First, they all received significant amounts of federal funding, largely from the U.S. Department of Energy. Second, each of these plants offered other goods or services in addition to their biofuels, just as the proposed Lewis County biorefinery is hoping to do.

2.1.2. Document Analysis

As a method, document analysis relies on systematically evaluating various types of documents, including reports, papers, press releases, application forms, and more (Bowen, 2009). Data is gathered from each document, analyzed, and grouped into major themes to give meaning and deeper understanding about a topic (Corbin & Strauss, 2008). Analysis includes finding the data, grouping and understanding it, and then synthesizing the groups and excerpts into meaning (Labuschagne, 2003). Document analysis is often used in tandem with additional research methods and is particularly useful in qualitative case studies because it can offer grounding context and structure for the rest of the case study (Stake, 1995).

For this study, document analysis was used to understand the characteristics of each of the case study biorefineries. For each case study, fifteen key facility characteristics were recorded. The characteristics were chosen because of their relevance in securing federal funding, and include: parent company, plant location, facility construction cost, dates of operation, feedstock type, feedstock capacity, output type, output capacity, technology and processes used, job projections, projected economic benefits, whether the facility was co-located with other infrastructure, additional co-products, amount and sources of federal funding received, and amount and sources of additional funding received. Documents were chosen based on their inclusion of the listed characteristics, and included documents listing expected or projected characteristics, and documents listing achieved and realized characteristics. Documents analyzed included federal government facility reports, government funding receipts, government websites, company and facility websites, newspaper articles, and company press releases. Each document was read and any information pertaining to the characteristics of interest was recorded. Once data for each facility was compiled, characteristics were grouped together and compared across cases.

2.1.3. Policy Analysis

Policy analysis involves the coding and analysis of various policies to understand their applications (Yanow, 2007). Within policy analysis methodology, there are two basic directions in which analysis can be taken. Descriptive policy analysis is the process of analyzing and interpreting the ways in which historical policies were understood and applied, whereas prescriptive policy analysis considers current policy options and recommends specific actions to bring about certain results (Patton et al., 1993).

This study uses both descriptive and prescriptive policy analysis methods. Descriptive methods are used to characterize the case studies, while prescriptive methods are used in application to the proposed Lewis County project. For the case studies, federal and state level policies were examined in relation to each biorefinery to understand which types of policy tools are most common in areas where biorefineries have been successfully initiated. Policy tools are specific techniques and types of policies that are used to achieve various goals (Bali et al., 2021). Policies were identified mainly through the Alternative Fuels Data Center (AFDC), an online database operating under the Office of Energy Efficiency & Renewable Energy under the U.S. Department of Energy. The AFDC database catalogs both federal and state laws and incentives relating to alternative fuels, air quality, and other transportation topics (AFDC, n.d.). Additionally, web searches were conducted for each state to identify additional relevant policies and programs. Since the AFDC database focuses specifically on policies related to alternative fuels, all federal policies and all state policies for Iowa, Kansas, Florida, and Oregon were initially considered.

Because federal policies are limited, they were described separately. For state policies, a list of all policies related to alternative fuels was created. These policies were then analyzed and grouped according to the tool they relied on. These tools included: state fuel standard, tax credits, tax exemptions, direct payments, funding programs, government amendment processes, state fleet Alternative Fuel Vehicle (AFV) requirements, blend requirements, and biofuel impact studies requirements. Refer to Appendix B for a policy codebook. Policies that did not fall into any of these categories, or policies that were not applicable to any of the case studies, were discarded. The remaining policies were checked to understand whether they were in place at the time of facility creation. Once state policy lists had been created and grouped, they were described in greater detail and compared across cases.

2.1.4. Interview Approach and Data Analysis

Interviews are useful because it is possible to gather more detailed and complete information about peoples' attitudes, beliefs, and values, and they can offer insight into human-environment interactions that may not be obtained through any other data collection methods (Kanazawa, 2017). The goal of the case study interviews was to understand which policies, programs, or incentives biorefinery stakeholders found most beneficial to developers. Semi-structured interviews rely on a combination of close-ended and open-ended questions, which allows the interviewer some flexibility in pursuing unexpected themes that may surface (Kanazawa, 2017). Because the interviews were conducted with stakeholders with different perspectives of the industry, semi-structured interviews allowed for more stakeholder opinions to be heard, while still gathering key information that can be compared across the interviews.

To identify a sample of relevant stakeholders for interviews, a key informant was identified, and snowball sampling was used. Snowball sampling relies on referrals to other potential respondents provided by current respondents (Kanazawa, 2017), which ensures a relevant sample group. Based on direction from a key informant with knowledge of relevant stakeholders, as well as from other interview respondents, participants from the biofuels industry across both the private sector and government sector were contacted. Participants were recruited beginning in June 2021 through a combination of emails and phone calls. If participants had not responded after approximately three weeks, a secondary email or phone call was sent. If they again had not responded after another month, a third email or phone call was sent. After this, contact was stopped. Twenty-one participants were contacted, and of these contacts, ten did not respond, three declined an interview, one suggested a different contact, and seven completed interviews. Interviews were completed from August 2021 through November 2021. Interviews were conducted either over Zoom or a phone call, and all were recorded on a secondary device for transcription purposes. The UW Human Subjects Division granted exempt approval (IRB ID: STUDY00013811) for this project. The seven completed interviews included one stakeholder from the federal government, three stakeholders from the Washington state government, and three stakeholders from private companies involved in the biofuels industry. Background questions involving the participant's roles in their agencies were asked of all participants to understand their positionality within the field of biofuels. Next, questions surrounding policy conditions were asked, followed by questions surrounding additional elements such as social and community conditions. Finally, concluding questions were asked to ensure that the participant had nothing else to share. Refer to Appendix C for the complete interview guide.

Analysis of the interview data involved playing back recordings and transcribing the audio into a document. Once all interviews were transcribed, the interviews were coded according to the interview codebook in Appendix D. Coding is the process of ascribing explicit units of meaning to themes brought up throughout the interviews (Kanazawa, 2017). It is done by grouping certain words, ideas, phrases, behaviors, and beliefs into a clear system of themes. Often it is done through multiple rounds, first identifying the broader themes, and narrowing codes in successive rounds (Kanazawa, 2017). The first round of coding was completed by reading through the transcripts and highlighting and making notes of common themes. A second round of coding was completed, refining themes by making them more specific or broader as needed. A final, third round of coding was completed by going through the transcripts a third time, again refining themes.

2.2. Assessing Feasibility of the Proposed Lewis County Project

While the results of the case studies are broadly applicable to biorefinery facilities as a whole, they can also serve to better determine the feasibility of siting the proposed biorefinery in Lewis County, Washington. To better understand project feasibility, the patterns that emerged from the document analysis, policy analysis, and interviews were compared to the proposed Lewis County project. For this, an additional case study was developed by gathering characteristics of the proposed Lewis County project as well as conducting Washington state policy research, using the same methods that were used in the four case studies. Additionally, some interview respondents were directly involved in the Lewis County Project, so themes specific and relevant to the Lewis County project were discussed in these interviews. Facility characteristics were gathered from key members of the University of Washington Lewis County project team. It is important to note that these characteristics are *projections*, determined through studies and models in the lab. Key facility characteristics were recorded, and policy analysis was used to identify relevant state policies in Washington. Once data regarding the projected facility characteristics and Washington state policies was collected, it was descriptively compared against the four case studies to better determine the feasibility of siting a biorefinery in Lewis County, Washington. This feasibility was assessed based on the factors of facility characteristics and policy conditions but does not address social or environmental feasibility.

2.3. Study Limitations

The major limitation of this study is that it does not address the environmental benefits or social acceptability of biorefinery creation; it only considers facility characteristics and policy tools. When conducting document analysis, some facilities considered in the case studies were no longer active, so documentation surrounding them may have been archived or removed and therefore made inaccessible. Additionally, not every characteristic category could be identified for each of the facilities. When conducting policy analysis, the largest limitation was difficulty in identification of biofuel policies. There were several noted cases of policies changing names or jurisdictional agencies. For the interview portion of the case studies, the major limitation was that there were no respondents from local communities or from the facilities themselves. There were many non-responses from contacted stakeholders, resulting in a very small sample size which is not representative of all perspectives.

3. Results and Discussion

3.1. Characteristics of successfully initiated biorefineries in the United States

To understand the key characteristics of successfully initiated biofuel refineries across the United States, case studies were conducted on the four selected biofuel refineries. These cases included Project LIBERTY (POET-DSM; Iowa), the Hugoton Plant (Abengoa; Kansas), the Indian River Bioenergy Center (INEOS; Florida), and the Lakeview Facility (Red Rock Biofuels; Oregon). The first portion of the case studies collected descriptive data about each of the facilities, including their parent company, operational timeline, processing capacity, conversion methods, output types, and capital cost. The facility characteristics for each of the four cases are presented below and in Table 1.

3.1.1. Project LIBERTY

Project LIBERTY (Table 1) was located in Emmetsburg, Iowa and was a collaborative project between POET and Royal DSM (POET-DSM, 2019). The Project LIBERTY facility opened in 2014, focusing on creating cellulosic bioethanol from corn stover, in competition with the more conventional grain ethanol on the market. The projected production capacity was 25 million gallons/year of cellulosic ethanol, from 231,000 dry tons/year of corn cobs, leaves, husk, and stalk. Based on these figures, studies projected the facility would increase Iowa's economic output by $24.4 billion and create 300 construction jobs, 65 indirect jobs for feedstock supply, logistics, equipment, and support, and 56 full-time facility jobs (Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy, n.d.). The Project LIBERTY facility was co-located beside POET's existing corn ethanol plant to share infrastructure and personnel. Additionally, the lignin leftover after processing the corn stover was used to generate thermal power to run both facilities. With these characteristics as a framework, the U.S. Department of Energy provided $100 million worth of grants for plant construction, and the State of Iowa provided $20 million for job training and construction. Ultimately, Project LIBERTY shut down in 2020, citing that they could not compete with the low price of oil (Henderson, 2020).

3.1.2. Hugoton Plant

The Hugoton Plant, located in Hugoton, Kansas, was a project by the company Abengoa (Table 1). The Hugoton Plant was their first commercial-scale cellulosic ethanol facility, and used non-food agricultural residues like wheat straw, corn stover, milo stubble, and switchgrass as feedstocks. At total projected capacity, the plant could process 300,000 dry tons/year of dry biomass into approximately 23 million gallons/year of cellulosic ethanol. The facility introduced a new enzymatic hydrolysis process at this commercial scale, after 30,000+ hours of testing at a pilot scale and 6,000+ hours of testing at a demonstration scale. In addition to the ethanol, the facility also housed a bioenergy plant, which could generate up to 21 MW of electricity per year, enough to power the entire facility. Given these conditions, Abengoa's Hugoton Plant received a $97 million grant from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), and a $132.4 million conditional loan guarantee from the U.S. Department of Energy's Loan Programs Office (Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy, n.d.). The Hugoton Plant finished construction in August 2014 and began processing fuel in September 2014, but in 2015, Abengoa Bioenergy filed for bankruptcy and the plant shut down. In 2016, the plant was sold to Synata Bio Inc. for

$48.5 million. It was then sold to High Plains Bioenergy, now renamed Seaboard Energy (Neeley, 2021).

3.1.3. Indian River Bioenergy Center

The Indian River Bioenergy Center, located in Vero Beach, Florida, was a joint venture between INEOS and New Planet Energy (Table 1). The facility was the first commercial-scale refinery in the United States to produce cellulosic ethanol from waste, and it used hybrid thermochemical-fermentation technology to create both cellulosic ethanol and electricity. The technology, supplied by INEOS, was feedstock-flexible and thus able to use construction waste, municipal solid waste, and forestry and agricultural waste. The facility was co-located beside a landfill and was able to process 100,000 dry tons/year of waste to produce 8 million gallons/year of cellulosic ethanol, as well as 6 MW of electricity/year. The plant was mostly funded by a $50 million grant from the U.S. Department of Energy's 932 Integrated Biorefinery Program for design, construction, and commissioning, as well as a $75 million loan from the U.S. Department of Agriculture's 9003 Biorefinery Assistance Program. It also received $4.3 million from a local development agency called One North East, with around $2.4 million secured through the Tees Valley Industrial Program (Renewable Technology, n.d.). The facility began generating electricity in September 2012, and commercial production of cellulosic ethanol began in June 2013. However, by December 2013, the facility faced technological challenges and safety violations. In September 2014 they announced that they had completed major renovations and revamps to upgrade the facility. Ultimately, the facility was never able to recover and was sold in 2016. INEOS stated that the United States market for ethanol had changed from when they started, and that the technology and mission no longer aligned with their strategic objectives (Voegele, 2016).

3.1.4. Lakeview Facility

The Lakeview Facility is an in-progress project by Red Rock Biofuels located in Lakeview, Oregon (Table 1). The facility uses existing technology and processes such as integrated gasification, Fischer-Tropsch, and hydroprocessing. The Lakeview Facility aims to produce ~15.1 million gallons/year of renewable cellulosic jet and diesel fuel from ~166,000 dry tons/year of wood waste. They also plan to make 3.6 million gallons/year of naphtha (Lane, 2018), a solvent used in gasoline conversion (Rennie, 2018). While the facility is not explicitly co-located with other infrastructure, the site lies in an area surrounded by forest and thus by feedstocks. Because of their interest in using renewable jet fuel for the military, the U.S. Department of Defense gave a $4.1 million grant to the facility (USAspending.gov, n.d.), paired with a $70 million joint award from the U.S. Department of Energy, U.S. Department of Agriculture, and the U.S. Navy through the Defense Production Act (USDA Release No. 0156.15, 2015; Office of Energy Efficiency & Renewable Energy, 2014). The project also received $245 million in state bonds, signed by 2018 Oregon Governor Kate Brown (Hughes, 2021). Though the Lakeview Facility originally planned to be in production by 2021, COVID, increased materials costs, and problems with suppliers led to slower progress. On April 21, 2021, the company declared bankruptcy and construction halted (Jester, 2021). In 2022, the town manager of Lakeview reported that she was told that major work on the Lakeview Facility is on hold until at least 2023 (Jester & Winter, 2022), though a small crew is still working on testing processes at the plant (Winter, 2021).

3.1.5. Cross-Case Comparison

Table 1 displays characteristics of the four case study facilities. Project LIBERTY (POET-DSM), Hugoton Plant (Abengoa), and the Indian River Bioenergy Center (INEOS) are former facilities that have since ceased operation, while the Lakeview Facility (Red Rock Biofuels) is currently in construction.

Table 1. Characteristics of four biorefinery facilities.

Facility Name	Project LIBERTY	Hugoton Plant	Indian River Bioenergy Center	Lakeview Facility
Company	POET, Royal DSM	Abengoa	INEOS, New Planet Energy	Red Rock Biofuels
Location	Emmetsburg, Iowa	Hugoton, Kansas	Vero Beach, Florida	Lakeview, Oregon
Capital cost	$275 million	$400-$500 million	$130 million	$300 million
Dates of operation	2014 - 2020	September 2014 - 2015	September 2012 - 2016	In construction
Feedstock type	Corn cobs, leaves, husk, stalk	Wheat straw, corn stover, milo stubble, switchgrass	Municipal solid waste (MSW), construction waste, forestry and agricultural waste	Wood waste
Feedstock capacity	231,000 dry tons/year	300,000 dry tons/year	100,000 dry tons/year	166,000 dry tons/year
Output type	Cellulosic ethanol	Cellulosic ethanol	Cellulosic ethanol	Cellulosic jet fuel, diesel fuel
Output capacity	25 million gallons/year	23 million gallons/year	8 million gallons/year	15.1 million gallons/year
Technology & processes	Dilute acid, enzymatic hydrolysis, and fermentation	Dilute acid, enzymatic hydrolysis, and fermentation	Hybrid thermochemical fermentation	Integrated gasification, Fischer-Tropsch, and hydroprocessing
Job projections	300 construction, 65 indirect, 56 full-time facility	300 construction, 65 full-time facility	400 design and construction, 65 full-time facility	500 construction, 31 direct manufacturing, 120 feedstock processing and transportation

Economic benefits	$24.4 billion increase in Iowa's economic output	$17 million/year increase for local farmers	$4 million increase in local economy	None explicitly stated
Co-location	Yes: Beside an existing corn ethanol facility	No	Yes: beside a landfill	No
Co-products	Thermal power for both facilities	Bioplastics, biochemicals, jet fuel, 21 MW electricity for both facilities	6 MW electricity: 4 MW for facility, 2 MW sold to grid	Naphtha
Federal funding	U.S. Dept. of Energy: $100 million in grants for construction	U.S. Dept. of Energy EERE: $97 million grant U.S. Dept. of Energy Loan Programs Office: $132.4 million conditional loan guarantee	U.S. Dept. of Energy 932 Integrated Biorefinery Program: $50 million grant U.S. Dept. of Agriculture 9003 Biorefinery Assistance Program: $75 million loan	U.S. Dept. of Defense: $4.1 million grant U.S. Dept. of Energy, U.S. Dept. of Agriculture, U.S. Navy: $70 million grant
Other funding	State of Iowa: $20 million for job training and construction	N/A	One North East: $4.3 million	State of Oregon: $245 million bonds

Comparing key characteristics of the case study facilities reveals several common features, including types of funding, the use of similar technology, the production of co-products, and co-location. Each plant received at least $100 million in federal funding. The U.S. Department of Energy was the only federal agency to fund every facility studied, though the type and amount of funding varied. Project LIBERTY was only federally funded through the U.S. Department of Energy, and they received a grant which they were not responsible for repaying. The U.S. Department of Energy was also the sole federal funding agency for the Hugoton Plant, though the funding originated in two separate offices. The Office of Energy Efficiency and Renewable Energy offered a grant with no necessary repayment, and the Loan Programs Office offered a conditional loan guarantee which did have to be repaid. The Indian River Bioenergy Center was funded in part by a grant from the U.S. Department of Energy, and by a loan from the U.S. Department of Agriculture, which had to be repaid. The Lakeview Facility received only grants from various federal agencies, meaning they do not have to repay this portion of the funding. These grants came largely through the Defense Production Act, with the facility receiving a grant from the U.S. Department of Energy, U.S. Department of Agriculture, and the U.S. Navy. The Lakeview Facility also received a smaller grant from the U.S. Department of Defense. The Hugoton Plant was the only facility to have no documented funding from other sources. Most projects also received funding from additional state or local sources. Project LIBERTY and the Lakeview Facility were also funded by their respective states (Iowa and Oregon, respectively), and the Indian River Bioenergy Center was funded through a grant from a local economic development program.

To produce their fuels, each facility utilized similar technologies. Project LIBERTY and the Hugoton Plant both used dilute acid and enzymatic hydrolysis and fermentation. The Indian River Bioenergy Center used hybrid thermochemical fermentation, while the Lakeview Facility used integrated gasification, Fischer-Tropsch, and hydroprocessing. Each plant created additional co-products alongside their fuel, though the nature of these co-products varied. Project LIBERTY generated thermal power while the Hugoton Plant and the Indian River Bioenergy Center generated electricity. The Hugoton Plant also created bioplastics and biochemicals, while the Lakeview Facility created naphtha. Finally, two of the facilities were co-located beside existing infrastructure to decrease transportation and production costs. Project LIBERTY was located beside an existing corn ethanol plant, while the Indian River Bioenergy Center was located beside a landfill from which they could divert waste as feedstocks. It should also be noted that all facilities produced cellulosic ethanol from second-generation, or non-food, forms of biomass. Types of feedstocks included agricultural waste (corn cobs, corn husks, corn stover, milo stubble, wheat straw), forestry/wood waste, and municipal solid waste.

Comparing key characteristics of the case study facilities also reveals variations. Feedstock capacity varied drastically, as did economic estimates. The lowest level of feedstock capacity was 100,000 dry tons per year at the Indian River Bioenergy Center, while the highest level was 300,000 dry tons per year at the Hugoton Plant. The range of economic projections also varied between cases, as each facility projected the creation of between 300-500 construction jobs and 31-65 full time jobs, with Project LIBERTY and the Lakeview Facility projecting an additional 56-120 indirect processing and transport jobs. The Lakeview Facility was the only facility without published economic benefit projections. The other three facilities each projected an increase in the local or state economy, ranging from $24.4 billion for the state of Iowa (Project LIBERTY), $17 million per year for local Kansas farmers (Hugoton Plant), and $4 million for the local Vero Beach economy (Indian River Bioenergy Center).

Ultimately, the key features shared between all case studies were the use of second-generation feedstocks, ethanol production, the use of new technology, co-location, the production of co-products, and federal funding. The commonality of these features may indicate that they are influential in the creation of new biorefineries. However, the wide variation in some of the other characteristics indicates that facility features and characteristics alone are not enough to predict biorefinery success.

3.2. Policy conditions that pave the way for biorefinery creation

In addition to understanding facility characteristics, the case studies sought to better understand the federal and state policy contexts for siting biorefineries. This section presents findings related to the analysis of federal and state policies for each of the selected cases. It also presents data from interviews regarding additional elements that may be important for establishing biorefineries.

3.2.1. Federal Policy: Renewable Fuel Standard Program

In the United States, the major federal policy that dictates action in the field of biofuels in the federal Renewable Fuel Standard Program (Public Law 110-140). As it is a federal program, it applies to all facilities considered in this study. All states must remain in compliance with the program, though some states may have more stringent requirements and regulations. The Renewable Fuel Standard Program is implemented by the United States Environmental Protection Agency, in tandem with the U.S. Department of Agriculture and the Department of Energy. The Renewable Fuel Standard Program was created in 2005 under the Energy Policy Act, which itself was created as an amendment to the Clean Air Act. In 2007, the Energy Independence and Security Act expanded the program. Now, the program functions by requiring certain levels of renewable fuels to replace petroleum-based fuels on the market, including transportation fuels, heating oil, and jet fuel. Each year through 2022, the amount of renewable fuels required increases. The Renewable Fuel Standard also sets four categories of renewable fuels: biomass-based diesel, cellulosic biofuel, advanced biofuel, and total renewable fuel. The requirements for each of these categories increases each year, as outlined in Table 2 below.

Table 2. Fuel requirements outlined by the federal Renewable Fuel Standard each year.

Year	Cellulosic Biofuel (billion gal./year)	Biomass- Based Diesel (billion gal/year)	Advanced Biofuel (billion gal./year)	Total Renewable Fuel (billion gal./year)	Conventional Biofuel (billion gal./ year)
2009	NA	0.5	0.6	11.1	10.5
2010	0.1	0.65	0.95	12.95	12.0
2011	0.25	0.8	1.35	13.95	12.6
2012	0.5	1.0	2.0	15.2	13.2
2013	1.0	1.0	2.75	16.55	13.8
2014	1.75	1.0	3.75	18.15	14.4
2015	3.0	1.0	5.5	20.5	15.0
2016	4.25	1.0	7.25	22.25	15.0
2017	5.5	1.0	9.0	24.0	15.0
2018	7.0	1.0	11.0	26.0	15.0
2019	8.5	1.0	13.0	28.0	15.0
2020	10.5	1.0	15.0	30.0	15.0
2021	13.5	1.0	18.0	33.0	15.0
2022	16.0	1.0	21.0	36.0	15.0

Overall, the Renewable Fuel Standard aims for 36 million gallons of renewable fuel by 2022. The Renewable Fuel Standard also sets specific definition requirements for each type of renewable fuel. For a fuel to be considered a renewable fuel, it must meet these qualifications *and* must have a reduction in greenhouse gas emissions compared to the 2005 baseline level for equivalent petroleum products. Requirements for the four fuel pathways are as follows in Table 3.

Table 3. Fuel pathway requirements outlined in the federal Renewable Fuel Standard.

Fuel	Requirements
Biomass-based diesel	● 50% lifecycle GHG reduction
Cellulosic biofuel	● 60% lifecycle GHG reduction ● Produced from cellulose, hemicellulose, or lignin
Advanced biofuel	● 50% lifecycle GHG reduction ● Produced from qualifying renewable biomass (except corn starch)
Renewable (conventional) fuel	● 20% lifecycle GHG reduction ● Ethanol derived from corn starch

Under the Renewable Fuel Standard, gasoline or diesel refiners and importers in the United States are obligated to comply (called *Obligated Parties*). To comply, these companies must blend renewable fuels into their transportation fuels, or must purchase Renewable Identification Numbers (RINs), which are credits that count towards the EPA-defined Renewable Volume Obligation (RVO). Yearly RVOs are established by the EPA based on the Clean Air Act volume requirements as well as gasoline and diesel production projections for the following year. RINs are used to prove compliance with the Renewable Fuel Standard regulations and can be earned by producing a gallon of renewable fuel, traded between holders, purchasing renewable fuels with associated RINs, and purchasing RINs directly on the market. Furthermore, unused RINs can be carried over to the following year, along with compliance deficits, which must be made up in the next year. Cellulosic fuels are granted additional flexibility, and the EPA offers cellulosic waiver credits that may be purchased instead of blending cellulosic biofuels (Renewable Fuel Standard Program | US EPA, 2021). Because the program was implemented in 2005, it was in place during the creation of all four case study facilities. Since the program aimed to incentivize the production of renewable fuel in the United States, it likely aided in the funding and creation of the four case study facilities.

3.2.2. State Policies

Often, states set more stringent standards and policies around alternative fuels compared to federal regulations. Although state-level policies varied from state to state, many states use similar policy tools. These policy tools are as follows:

- *State fuel standards* refer to any state-level renewable fuel standard that aims to lower the state's carbon emissions through the reduction of non-renewable transportation fuels

(Lane, 2020). Though specific requirements may vary state to state, the overarching definition of this policy tool relies on comprehensive state legislation aimed at reducing emissions and moving away from non-renewable fuels.

- *Tax incentives* are policy tools that either directly or indirectly reduce the amount of tax that a company or consumer owes to the government. Tax credits are often offered as incentives for producing or purchasing renewable fuels, and they directly decrease the amount of tax owed by subtracting 'credits' from the original tax amount. Tax exemptions indirectly reduce the amount of tax that a company or consumer owes to the government by reducing the level of taxable income. Both tools are often offered as incentives to companies for producing renewable fuels.
- *Direct payments* authorize government entities to offer direct compensation to producers of renewable fuels.
- *Biofuel funding programs* refer to a broad category of policy tools that authorize government agencies to offer various types of funding to renewable fuel projects, including subsidies, grants, and loans.
- *Government amendment* processes are a policy tool that specifically mandate the option for citizens to appeal directly to the government to make local progress towards producing more renewable fuels.
- *State fleet Alternative Fuel Vehicle (AFV) requirements* vary state to state, but generally are a policy feature that require any state-owned or operated vehicle to meet minimum requirements in fuel efficiency and alternative fuel usage.
- *Blend requirements* are specific policies that outline various types of requirements regarding alternative fuel blends in the state. The first major type of blend requirement outlines the amount of alternative fuel that must be blended into traditional transportation fuels. The other major type of blend requirement sets schedules for adoption of increasingly higher levels of alternative fuel usage across the state.
- *Biofuel impact studies* requirements are policies that require certain government agencies to conduct period studies regarding the efficiency of alternative fuels in the state.

Outlined above were the results of the state policy analysis. Below, state policy highlights are discussed for each case. Refer to Table 4 to compare policy tools among states.

3.2.2.1. Project LIBERTY

At the time of facility creation, the state of Iowa had no state-wide clean fuel standard. Of the four major incentives, three were tax credits. Two tax credits were offered to ethanol blend retailers, one for selling 15-69% ethanol blends, and the other for selling 70-85% ethanol blends. The third tax credit was focused on producers of biomass and biofuels and was broader, offering tax credits on investors, services, construction costs, and property taxes. Another incentive was a biofuels infrastructure grant program, offering financial assistance to retailers of ethanol or biodiesel. The program also offered financial assistance for installing biofuels infrastructure, up to 50% coverage for a three-year contract (limit of $30,000), or up to 70% coverage for a five-year contract (limit of $50,000). The state of Iowa also offered grant funding for people to purchase alternative fuel vehicles for research purposes and required that 10% of state-owned vehicle fleets should be able to operate on alternative fuels. The Biofuels Quality Program run by the state Department of Agriculture and Land Stewardship audited fuel facilities that product renewable fuels. The state also had regulations defining fuel exclusivity contracts, fuel-dispensing infrastructure, fuel labeling requirements, biofuel blend definitions, and biofuel tax rates. The Iowa Renewable Fuels Infrastructure Program offered grants to fuel retailers to assist in conversion to biofuel-cooperative infrastructure and fueling stations. Finally, Iowa had a High Quality Jobs program that provided loans, forgivable loans, tax credits, tax exemptions, or tax refunds to facilities for locating, updating, or expanding operations, which could apply to biofuel facilities. The High Quality Jobs program also offered state tax incentives to biofuel producers specifically. For more detail on Iowa state policies, see Appendix E.

3.2.2.2. Hugoton Plant

The state of Kansas did not have a state-level clean fuel standard when the Hugoton Plant was created. The major incentives in Kansas focused on taxes and financing. Kansas offered two major biofuel tax credits. One offered an income tax credit for 40% of the conversion cost of qualified Alternative Fuel Vehicles, or a tax credit for 5% of the purchase price for an Alternative Fuel Vehicle up to $750. These credits could be rolled over for three years. The second tax credit covered 40% of the cost of installing alternative fueling infrastructure, up to $100,000 per fueling station. The state offered one tax incentive that would provide quarterly payments to fuel retailers based on how much renewable fuels were sold above a minimum threshold. Kansas also offered two tax exemptions. They both exempted the participants from state property taxes if they used equipment for blending biofuels with petroleum-based fuels, but one targeted fuel retailers and the other targeted fuel producers. Another state incentive allowed the Kansas Development Finance Authority the ability to offer bonds to financially assist the construction or expansion of biomass-to-energy facilities. For state-owned vehicle fleets, Kansas regulations required that Flexible Fuel Vehicles must be purchased and that diesel-powered vehicles must use biodiesel blends when available. State regulations also defined biofuel and biodiesel blend requirements, tax rates, and fuel labeling requirements. For more detail on Kansas state policies, see Appendix F.

3.2.2.3. Indian River Bioenergy Center

When the Indian River Bioenergy Center was created, Florida did not have a state-level clean fuel standard. The main incentive in the state was a waste-reduction credit that county governments could use towards their own recycling goals, given that they used renewable wastes as feedstocks for the production of renewable fuels. This credit would apply to the Indian River Bioenergy Center. Florida regulations outlined that state-owned vehicle fleets must purchase the most fuel-efficient vehicles possible, given the vehicle use class (outside of emergency response vehicles), and that state vehicle fleets must purchase biofuels for use in their fleets as much as possible. Another regulation allowed local governments to use income generated from infrastructure taxes to offer loans, grants, or rebates to both residential and commercial property owners for installing alternative fuel infrastructure. The state of Florida also had a regulation allowing landowners to apply to amend local government plans to expand the usage of agricultural industrial facilities to include facilities that can be used to prepare biomass or produce biofuels, ultimately aiming to increase local economic development. Another regulation allowed the Florida State Board of Administration to invest 1.5% of net assets into biofuel-related businesses. Finally, Florida regulated that the Florida Department of Management Services (DMS) in conjunction with the Florida Department of Transportation must analyze fuel additives and biofuels as well as transportation fuel usage, to be reported to the DMS. For more detail on Florida state policies, see Appendix G.

3.2.2.4. Lakeview Facility

In 2016, Oregon implemented a state-level clean fuel standard called the Oregon Clean Fuels Program. Since the Lakeview Facility is currently in construction, the Oregon Clean Fuels Program will apply to the facility. The program aims to decrease the amount of greenhouse gas emissions created during the production, processing, transportation, and consumption of transportation fuels, with a goal of reducing average carbon intensity by 10% from 2015 levels by 2025. The state of Oregon offered two tax incentives. The first established Rural Renewable Energy Development Zones, in which properties can receive a 3–5-year tax exemption if they are used for renewable energy activities, up to $250 million. The second exempts specifically biofuel production facilities from property taxes with no explicit cap if they are located within a Rural Renewable Energy Development Zone. The Oregon Department of Energy also hosts the Small-Scale Local Energy Loan Program that offers low-interest loans to alternative fuel projects. Oregon regulations also mandate the creation of Alternative Fuel Vehicle Only parking spots, and no other car may park in these spaces. The state of Oregon also aims to get all state-owned vehicle fleets to Zero-Emission Vehicles. Furthermore, blend regulations outline required levels of biofuel blends to be sold in petroleum-based gasoline and diesel fuels. The Oregon Public Utility Commission also maintains requirements for Renewable Natural Gas that increase by 5% every 5 years. The Oregon Department of Environmental Quality is required to submit carbon emissions reports for fuel producers. The Oregon Department of Energy is required to impact studies about biofuel producers in the state, including metrics such as job creation, feedstock availability, production and consumption amounts, and environmental impacts. For more detail on Oregon state policies, see Appendix H.

3.2.2.5. Cross Case Comparison

To understand key policies present when biofuel refineries are successfully initiated, policies were analyzed for the four case study states. The states included Iowa (Project LIBERTY), Kansas (Hugoton Plant), Florida (Indian River Bioenergy Center), and Oregon (Lakeview Facility). This portion of the case study compares the types of policies present within each of the states. The comparison is presented in Table 4 below.

Table 4. Cross-case state policy comparison.

Policy Tool	Project LIBERTY (IA)	Hugoton Plant (KS)	Indian River Bioenergy Center (FL)	Lakeview Facility (OR)
State fuel standard				X
Tax incentives	X	X		X
Direct payments		X		
Biofuel funding programs	X	X	X	X
Government amendment processes			X	
State fleet AFV requirements	X	X	X	X
Blend requirements	X	X		X
Biofuel impact studies requirement	X		X	

When comparing the four case studies in terms of state policies, biofuel funding programs and state fleet Alternative Fuel Vehicle requirements were common to all states. Most states also offered tax incentives and had blend requirements.

All states had ***state-government-program funding*** opportunities for biofuel projects. The type and amount of funding varies depending on the state and project. Iowa, Florida, and Oregon all had funding programs that offered grants or loans to retailers selling fuel to install or update biofuel infrastructure. Iowa, Kansas, and Oregon also had funding programs that offered loans or bonds to fuel producers for the construction or expansion of biofuel production facilities. Iowa uniquely offered grants to individuals purchasing Alternative Fuel Vehicles to do research. Overall, Oregon had the most generalized state government funding programs, as they offered loans for a broad range of biofuel projects, including refinery construction, feedstock production, and acquisition of Alternative Fuel Vehicle fleets. The other state funding programs were more specific, but Oregon's programs allowed for more funding for a broader range of biofuel-related projects.

All states also had ***clean state Alternative Fuel Vehicle fleet requirements***. These policies included specific types of vehicle acquisition and usage of a certain level of renewable fuels, though these levels varied by state. Every state had some form of state fleet alternative fuel vehicle requirements, broadly requiring any state-owned vehicle fleets to either use renewable fuels, or to purchase the most fuel-efficient vehicles possible.

Most states offered ***tax incentives*** that either directly or indirectly reduced the amount of taxes owed by companies producing renewable fuels. Tax credits tend to directly reduce tax owed, while tax exemptions indirectly reduce tax owed. Iowa and Kansas had tax credits that worked by decreasing the amount of taxes owed by renewable fuel retailers, refunding some state taxes, and returning some income tax if a facility installs alternative fueling infrastructure As for tax exemptions, Iowa's tax exemptions allowed for up to 100% exemption from property tax if a facility produces renewable fuels, as well as flexible exemptions to incentivize the location, expansion, or modernization of fuel facilities in the state. Kansas' tax exemptions allowed for ten years of exemption from property taxes for facilities that either produce or blend biofuels. Oregon's tax exemptions also exempted property taxes for facilities involved in renewable energy activities if they were located within Rural Renewable Energy Development Zones.

All states except for Florida had ***blend requirements***, though these varied drastically from state to state. Some states, like Oregon, required renewable fuels to be blended into all transportation fuels sold on the market. Other blend requirements simply focused on the labeling and fuel composition of renewable fuels that were sold on the market.

While the states shared some common policy tools, there were also tools that were unique to only one or two states including state fuel standards, direct payments, government amendment processes, and biofuel impact studies requirements.

The only state to have a state-level clean fuel standard was Oregon. Thus, the Lakeview Facility is the only facility formed under a state fuel standard. Iowa, Kansas, and Florida did not have clean fuel standards, so those facilities did form without one. While state fuel standards are typically perceived to be crucial in biorefinery development, this may indicate that they may not be as important in creation as they are once the facility is fully operational. Kansas was the only state with a direct payment tool in place. The Kansas Retail Dealer Incentive Fund was eligible to provide quarterly payments directly to fuel retailers if they sold and dispensed renewable fuels. Florida was the only state with explicit government amendment processes written into their state statutes. This law allowed landowners to apply to amend local government plans to expand local agricultural centers to include facilities that could prepare and process biomass materials to be used for renewable energy or fuels. By doing so, property owners could stimulate local economic development. Iowa and Florida were the only states to require biofuel impact studies, ensuring that certain government agencies consistently conducted studies to document the usage, efficiency, and economics of biofuels within the state.

Overall, the key policy tools shared between all or most of the case studies were biofuel funding programs, state fleet Alternative Fuel Vehicle requirements, tax incentives, and blend requirements. The commonality of these features may indicate that they are highly beneficial to the creation of new biorefineries. However, the variation in other types of policy tools may indicate that the usefulness of certain types of policy tools may differ state to state, and that there is no 'one size fits all' approach to state-level policy creation that will incentivize new biorefineries. Broadly, this could mean that states should aim to have the more common policy tools in place at facility creation but could be further incentivized with additional policy tools as well.

3.3. Stakeholder Perspectives on Biorefinery Siting

The interviews provided perspectives about which types of policies were most important, as well as additional conditions that were important for the establishment of new biorefineries in the United States.

All Interviews

Across all seven interviews, six themes were mentioned by all participants (refer to Appendix D Codebook for Interviews): challenges, policy tools, the importance of economic competitiveness, the importance of local community support, environmental benefits, and the importance of government support (Table 5).

Table 5. Interview themes mentioned by all seven interview participants.

Theme	Explanation	Frequency of mentions
Challenges ● Lack of policy ● Misinformation ● Lack of political harmonization ● Permitting processes ● Scaling up to commercial production	Overall, the varying difficulties that can occur when trying to site a new biorefinery.	38
Policy tools ● State-level low carbon fuel standard ● Carbon tax ● Regulations (emission reduction, renewable fuels) ● Tax reductions ● Funding programs ● Cap and trade ● Credit programs	An overarching theme focusing on different types of policy options for the purpose of supporting and incentivizing renewable fuels. These policy tools include both those already in place across the country, and those idealized by stakeholders but not yet in place.	36
Economic competitiveness ● Incentives, government support, funding ● Cost of fuel ● Profitable and sustainable long-term	The importance of a facility's ability to stand up to be economically competitive on its own, after the use of government incentives and funds.	31
Local community support	The importance of sustained support from communities around the proposed biorefinery site.	22
Environmental benefits	A broad theme encompassing the environmental benefits of many aspects of the biofuel production process, from biofuels themselves, to the conversion of waste materials, to the reduction of carbon emissions during processing.	14

Government support ● Policy support ● Effective passing of legislation ● Financial support	The importance of various levels of government (local, state, and federal) support as necessary to project success. Much focus during the interviews was on the importance of federal government support specifically.	11

The most often-mentioned theme across all seven interviews was related to the ***challenges*** in establishing a successful biorefinery. This theme is broad, but it covers any type of challenge acknowledged by these stakeholders in the biofuel industry. The most common challenge mentioned was the current *lack of existing biofuel-related policies* in the United States. This lack of strong policy nationwide is a limiting factor in the implementation of renewable fuels across this country because strong policies can incentivize the production of biofuels as well as decrease the cost of these fuels for consumers. On top of the lack of policy, a private company representative reflected on the difficulties of navigating policies for renewable fuel projects:

> "One of the biggest challenges in building a renewable fuels project is having the underlying policy in place, and understanding the value of the underlying policy and how to take advantage of it."

Another challenge mentioned often was an overarching idea of *misinformation*. This theme included perspectives that various narratives of misinformation can harm the biofuels industry as different stakeholders may believe untrue ideas which could lead them to distrust the industry as a whole. Interviewees described common sources of misinformation, such as ideas about the impact of biofuels on gasoline prices (non-supporters tended to believe that the introduction of biofuels into the market would increase the cost of gasoline), the carbon intensity of burning biofuels, and the carbon intensity of harvesting biomass. For example, a government representative described challenges when facing groups of non-supporters of the biofuels industry. The respondent felt that often, these groups of non-supporters took their position based on misinformation. They explained,

> "…there's a lot of false reporting out there, reporting that is not science-based or fact-based. It gets in the media, solid advertising time, and it influences people to have that position and have it reinforced. A lot of bad messaging out there."

Lack of political harmonization was also cited as a challenge, where varying levels of government had discordant policies regarding biofuels, making it difficult to establish facilities in those locations, as well as to expand the biofuels market across the country. Because of the variations in policies between different levels of government, the biofuel market struggles to safely establish itself on a widespread scale since incentives can vary from place to place. Interview respondents also cited the *permitting process* as a challenge in starting biofuel projects. Many interviewees mentioned that typically, permitting processes can be a barrier to renewable fuel projects if they are too complicated or too long, and government respondents were especially cognizant of this challenge. A final challenge mentioned in a few interviews was the *difficulty of scaling up biofuel production processes to a commercial level*. A private company representative explained,

> "The problem with biofuel scale up… was that most of these tasks that are done at pilot scale are done at non-representative biomass feedstock streams that are finely graded and selected and things like that. It's not something that you would use for a large-scale plant, which has a lot more contaminants, a lot less uniformity, and that has impacts on the mechanical equipment, the chemical processing equipment, and kind of the economics of

> the project. That's just a problem of using feedstocks that have wide variability in characteristics from day to day and hour to hour and week to week and season to season. It just becomes very difficult to anticipate all this because you don't run these bioplants typically for multiple years using lots of different biomass feedstocks and sites, then you run into unanticipated problems that can sometimes prove very fatal to these types of projects…"

The second-most mentioned theme across all seven of the interviews was different types of ***policy tools***. Again, this theme is broad— it includes any mention of a specific type of policy tool that could be useful in supporting and incentivizing biorefineries. Sometimes this theme would emerge when describing current or former policies, but most often it surfaced while respondents described what policies would be most useful in general, even if those policies were not currently in place. The policy tool thought to be most useful in siting new biorefineries was a *state-level low carbon fuel standard*, which is a comprehensive state-level program that includes varying kinds of policies, regulations, and tax incentives with a goal of moving the state's transportation sector towards lower levels of carbon emissions. Often these fuel standards go through a rigorous rulemaking process in which the directing government regulatory agency determines the levels of the standards for the programs, as well as considering public input. For the four case studies, the only state to have a low carbon fuel standard in place at the time of facility implementation was Oregon. The Oregon low carbon fuel standard was intended to work in tandem with the low carbon fuel standards in California, Washington, and British Columbia to establish a single, comprehensive biofuels marketplace on the West Coast. Another common policy tool was a *carbon tax*, which is a tax placed on companies who are emitting carbon. Thus, by reducing carbon emissions, a company can pay less taxes— a financial strategy that also benefits the environment by incentivizing a reduction in greenhouse gas emissions. A private company representative who strongly supported the use of carbon taxes explained,

> "I think the number one thing that would help all companies who are working on any kind of alternative non-fossil fuel would be a carbon tax that would be evenly applied, technology agnostic, and have a substantial tax associated with the emission of carbon that could be then calculated to use for alternative fuels."

This representative was especially supportive of carbon taxes because they can apply equally across all process types, so no one technology is incentivized more than others. A more straightforward policy tool that was mentioned was *regulations*. These are laws that directly require companies to reduce emissions, or to produce a certain amount of renewable fuels or otherwise make up for their non-renewable fuels. The idea of regulations can be broad, and they can include certain carbon reduction standards for a state or county, certain blend requirements, or even tax and funding requirements. Another broad policy tool theme that emerged from the interview data analysis was *tax reductions*. These allows for companies to pay lower levels of taxes if they are producing or assisting in the production of renewable fuels. *Programs* were also mentioned as a useful policy tool, both at the state and local level. These programs typically exist within the framework of government agencies and tend to work in tandem with tax incentives to assist in funding for renewable fuel projects to help reach the county or state's regulations. A c*ap and trade* system was also mentioned, which works in tandem with regulations to set limits on the amount of allowable carbon emissions. It allows companies to earn and trade carbon credits to continually meet program requirements. A similar idea was a *credit system*, which relies on the same sort of credit system as cap and trade by giving credits to companies for producing renewable fuels, but instead relying on consumers to fund these credits.

Economic competitiveness was brought up in a few different ways, but it referred to a facility's ability to be economically competitive on its own. When discussing economic competitiveness, most respondents acknowledged that facilities would need strong incentives, government support, and funding assistance in order to get started because the initial cost of biorefineries can be large. However, they explained that eventually, a facility should be economically competitive enough to continue profiting without the support of those agencies. In order to get facilities to a commercial scale, incentives and policies may be necessary, but a facility needs to be able to sell its renewable fuel at a cost equal or lower than fossil fuels in order for the fuels to be successful on the market and to have an environmental benefit. In the four cases studied, three shut down because they could not compete with the low cost of fossil fuels.

A fourth theme brought up in all the interviews was the importance of ***local community support***. For a facility to be successful, respondents stressed the need for local community support from early in the siting process. They mentioned that, typically, communities tend to be supportive of these projects because of the wealth of economic benefits that these facilities can provide. For example, biorefineries tend to focus on using local biomass because of the low transportation costs. However, this can mean that for local farmers or forest managers, they can earn additional profit by selling wastes that were previously going unsold. The construction of biorefineries can also create tens to hundreds of new jobs, and once the biorefineries are functional, they tend to support up to approximately 65 permanent, full-time jobs. These jobs, however, do not include permanent jobs created in biomass harvesting or transportation. Overall, respondents seemed to agree that so long as a new biorefinery worked with the local community from early in the siting process, the community tended to be supportive of the project.

Environmental benefits were mentioned in all seven interviews. The types of environmental benefits were broad, but all respondents agreed that these were extremely important to consider when siting a new biorefinery. Some named environmental benefits included carbon reduction, decreased environmental degradation, and lower levels of pollution. Ultimately, the goal of producing biofuels is to find a renewable alternative to fossil fuels that will create lower levels of greenhouse gas emissions. This theme ties closely to many of the other themes because it relies on the success of other themes like strong policies and incentives and successful economic competitiveness for there to be any environmental benefit. Respondents discussed the environmental benefits at various stages of the biorefining process, from biomass harvesting and transport to processing and manufacturing to the ultimate carbon reduction when the fuel is in use.

The final theme mentioned across all seven interviews was the importance of ***government support***. This theme included support at every level of government— local, state, and federal. It included both political and financial support. In terms of political support, respondents highlighted the importance of having government representatives willing to support and pass legislation relatively quickly. However, respondents acknowledged that while policies were needed that could incentivize the production of biofuels, it was also important for governments to use their financial resources to assist in funding renewable fuel projects in order to de-risk them for the private sector. Since governments have access to the largest level of funds, their direct (funding programs and contracts) and indirect (tax incentives and policies) financial support may be able to truly get a new biorefinery off the ground.

3.3.1. Government Sector Perspectives

The government representative respondents identified three additional themes that were not mentioned by the three private sector respondents. The themes focused on the importance of private sector involvement, the importance of technological innovation, and the importance of academia involvement (Table 6).

Table 6. Interview themes identified by government representative participants.

Theme	Explanation	Frequency of mentions
Private sector involvement	The importance of private sector involvement in renewable fuel projects, typically to de-risk funding	9
Technological innovation	The importance of technological innovation in the field of biofuels to increase efficiency	7
Academia involvement	The importance of academia involvement in renewable fuel projects, typically to research	4

The first theme specific to the government interviews was the importance of ***private sector involvement***. Government respondents explained that involving private sector companies from the beginning of new biofuel projects can help in de-risking the projects. Often, companies will sign private contracts with to produce fuels, and obtaining multiple private companies can decrease the share of cost from government agencies. In addition to beneficial cost-sharing, a respondent explained how oftentimes private companies have the most influence in getting beneficial biofuel policy to be passed in legislation:

> "You have got to get them all on board early because, quite truthfully, that's who makes the policy in DC, is the private sector and their advocates, their lobbyists, their associations, their business groups. Congress does not always listen to individual taxpayers, they don't listen to individual county commissioners, they don't listen to government employees acting in small groups. They are heavily influenced by the lobbyists, though. If they're part of the initial project… that's going to change the form and shape, the project policy that you're working with. Trying to get them in after the fact is never as successful as if they have a stake in the game."

Government respondents also identified ***academia involvement*** as an additional factor that can be useful in de-risking biofuel projects. Academia tends to initiate research at a university level, figuring out the most cost-effective and efficient ways to produce the desired fuels. Once the processes are proven out at the lab scale, they can be gradually scaled up and re-tested along the way, ensuring processes are still financially viable at every scale. The academic expertise and close, detailed study of these processes at multiple scales can eventually de-risk commercial facility development. Finally, respondents also identified the importance of ***technological***

innovation in incentivizing production and securing funding. As biofuel production technology is developed and tested, processes become more efficient and more cost-effective, leading to overall lower levels of capital cost needed to create a biorefinery.

3.3.2. Private Sector Perspectives

Two themes were raised across the private sector interviews that were not mentioned at all in the government sector interviews: reason for involvement in the biofuels sector, and the importance of technical neutrality (Table 7).

Table 7. Interview themes identified by private sector participants.

Theme	Explanation	Frequency of mentions
Reason for involvement in the biofuels sector	A theme explaining reasons for the company's involvement in the biofuels sector	3
Technical neutrality	The importance of the biofuels field and policies remaining technically neutral, meaning that they do not favor or incentive certain types of technologies over others	2

Private sector respondents gave explicit reasoning for their company's ***involvement in the biofuels sector***, while government respondents did not. Respondents explained that their involvement in biofuel projects were incentivized and motivated by the environmental and sustainability benefits of these biofuel projects. They noted that while economic feasibility is important, they would not partner with biofuel projects if there were not actual environmental benefits to them. The second theme unique to the private sector interviews was the ***importance of technical neutrality***, which is when policies do not favor any one solution over another. Rather, achieving specific results is the most important goal, regardless of the path taken to get there. With technical neutrality, fuels or technologies that reduce carbon intensity most efficiently or drastically should be the ones receiving the highest level of incentives or rewards.

3.3.3. Discussion

Overall, the interviews highlighted several themes that may indicate their importance in facilitating biorefinery development. First, it is important for new biorefineries to understand the challenges that they may face in development. When creating a new biorefinery, respondents felt that it was crucial to have effective policy tools and local community support in place. These new refineries should also be economically competitive in order to succeed long-term. When biorefineries are in the first stages of development, environmental benefits may be a large driver of project take-off, but these rely on the success of many other factors. Finally, respondents agreed that government support is crucial at all levels, and this support can come in the form of policies or funding. Again, it must be noted that there was a small sample size and that these results may not be wholly representative of the entire field of biofuel stakeholders, although they raise important considerations for future biorefinery projects.

3.4. Feasibility of Proposed Lewis County Project

In order to assess the technical and policy feasibility of the potential Lewis County biofuel project, a case study of Lewis County was developed, using the same approach as for the four case studies. Key facility characteristics of the Lewis County Project were identified from team projections, and a policy analysis of relevant Washington state policies was conducted. The Lewis County case was compared to the characteristics, policies, and interviews from the four case studies in order to better understand potential project feasibility.

3.4.1. Lewis County Facility Characteristics

The Lewis County proposal is unique because it was not initiated by a private company, but rather by local community members including government officials and private business leaders who were interested in the economic benefits of siting a new biorefinery in Lewis County. The community members and local government partnered with a team at the University of Washington to conduct a comprehensive feasibility study, and from this study an idealized scenario was created. Refer to Appendix I for more detail. The facility was evaluated on three different scales: small-scale processing 150,000 tons of dry biomass per year, intermediate-scale processing 250,000 tons of dry biomass per year, and large-scale processing 760,000 tons of dry biomass per year. The most realistic scale was the intermediate scale, since the small scale could not produce enough profit to be economically feasible, and the large scale would saturate the market of the co-products, formic acid and xylitol. The new facility would be located in Centralia, Washington, a city within Lewis County. It would be co-located with an existing coal plant in order to share pre-existing infrastructure. The total capital investment of the project is estimated to be $559 million. The proposed facility aims to use a mixture of hybrid poplar, reed canary grass, and hardwood residuals as feedstocks, ideally processing 250,000 dry tons per year to produce 11 million gallons of jet fuel per year. The facility would use biochemical conversion for this process, and using the wastes of this processing period, would also produce 64,000 tons of formic acid per year and 27,000 tons of xylitol per year, which can be sold for an additional profit. Although the Lewis County project has not yet been implemented, its projections can still be compared against the characteristics of the other four case studies in order to understand project feasibility (Table 8).

Table 8. Comparison of the four biorefinery case study facilities to the proposed Lewis County facility characteristics.

Facility Name	Project LIBERTY	Hugoton Plant	Indian River Bioenergy Center	Lakeview Facility	*Proposed Lewis County facility, Intermediate scale*
Company	POET, Royal DSM	Abengoa	INEOS, New Planet Energy	Red Rock Biofuels	N/A
Location	Emmetsburg, Iowa	Hugoton, Kansas	Vero Beach, Florida	Lakeview, Oregon	Centralia, Washington
Capital cost	$200 million	$400-$500 million	$130 million	$300 million	$557 million
Dates of operation	2014 - 2020	September 2014 - 2015	September 2012 - 2016	In construction	N/A
Feedstock type	Corn cobs, leaves, husk, stalk	Wheat straw, corn stover, milo stubble, switchgrass	Municipal solid waste (MSW), construction waste, forestry and agricultural waste	Wood waste	Hybrid poplar, reed canary grass, hardwood residuals
Feedstock capacity	231,000 dry tons/year	300,000 dry tons/year	100,000 dry tons/year	166,000 dry tons/year	250,000 dry tons/year
Output type	Cellulosic ethanol	Cellulosic ethanol	Cellulosic ethanol	Cellulosic jet fuel, diesel fuel	Jet fuel
Output capacity	25 million gallons/year	23 million gallons/year	8 million gallons/year	15.1 million gallons/year	11 million gallons/year
Technology & processes	Dilute acid, enzymatic hydrolysis and fermentation	Dilute acid, enzymatic hydrolysis and fermentation	Hybrid thermochemical fermentation	Integrated gasification, Fischer-Tropsch, and hydroprocessing	Biochemical conversion

Job projections	300 construction, 65 indirect, 56 full-time facility	300 construction, 65 full-time facility	400 design and construction, 65 full-time facility	500 construction, 31 direct manufacturing, 120 feedstock processing and transportation	N/A
Economic benefits	$24.4 billion increase in Iowa's economic output	$17 million/year increase for local farmers	$4 million increase in local economy, 2 MW electricity	None explicitly stated	
Co-location	Yes: Beside an existing corn ethanol facility	No	Yes: beside a landfill	No	Yes: with a power plant
Co-products	Thermal power for both facilities	Bioplastics, biochemicals, jet fuel, 21 MW electricity for both facilities	6 MW electricity: 4 MW for facility, 2 MW sold to grid	Naphtha	Formic acid: 64,000 tons/year; Xylitol: 27,000 tons/year
Federal funding	U.S. Dept. of Energy: $100 million in grants for construction	U.S. Dept. of Energy EERE: $97 million grant U.S. Dept. of Energy Loan Programs Office: $132.4 million conditional loan guarantee	U.S. Dept. of Energy 932 Integrated Biorefinery Program: $50 million grant U.S. Dept. of Agriculture 9003 Biorefinery Assistance Program: $75 million loan	U.S. Dept. of Defense: $4.1 million grant U.S. Dept. of Energy, U.S. Dept. of Agriculture, U.S. Navy: $70 million award	N/A
Other funding	State of Iowa: $20 million for job training and construction	N/A	One North East: $4.3 million	State of Oregon: $245 million bonds	N/A

Compared to the four cases, the proposed Lewis County project uses similar feedstocks (hardwood residuals and grasses), however the proposed facility also plans to use dedicated hybrid poplar feedstocks. None of the other case study facilities used designated feedstocks. Of all the facilities, the proposed Lewis County facility has the largest projected feedstock capacity at 250,000 dry tons per year, but an output on the lower range of the comparison facilities. This is likely made up for through the proposed co-product projections of 64,000 tons of formic acid per year and 27,000 tons of xylitol per year. No other facilities had co-product projections anywhere near as close as the Lewis County projections. The proposed Lewis County facility would also be co-located with an existing coal plant, decreasing construction and transportation costs.

3.4.2. Lewis County Policy Analysis

Washington state has six of the eight policy tools that were present in the four case studies (Table 9). These tools include a state fuel standard, tax incentives, biofuel project funding programs, state fleet AFV requirements, blend requirements, and biofuel impact studies requirements.

Table 9. Cross-state policy comparison including Washington state.

Policy Tool	Project LIBERTY (IA)	Hugoton Plant (KS)	Indian River Bioenergy Center (FL)	Lakeview Facility (OR)	Proposed Lewis Co. (WA)
State fuel standard				X	X
Tax incentives	X	X		X	X
Direct payments		X			
Biofuel project funding programs	X	X	X	X	X
Government amendment processes			X		
State fleet AFV requirements	X	X	X	X	X
Blend requirements	X	X		X	X
Biofuel impact studies requirement	X		X		X

Although much of Washington's renewable transportation legislation focuses on electrification, there are still beneficial policies that can serve to incentivize biofuel production and consumption in the state.

First, Washington does have a ***state-level fuel standard*** in place. In 2021, the Washington Legislature passed the Clean Fuel Standard (E3SHN 1091; RCW 70A.535), permitting the Washington Department of Ecology to begin a rulemaking process for implementation in 2023. The Clean Fuel Standard aims to reduce the carbon intensity of the state's transportation sector by requiring fuel producers to decrease their carbon intensity. While the program will not be implemented until 2023, it plans to include a credit system, blend requirements, and a regulatory schedule in order to meet its goals. However, it is important to note that specific technical characteristics of legislation are often changed between adoption and final implementation. Because the Clean Fuel Standard is still in the rulemaking period and regulations are still to be developed, the final regulations may not be as strong as they were intended to be.

Washington also has ***tax incentives*** that may be beneficial to the biofuels market in the state. Washington has three tax exemption policies. The first exempts purchasers of alternative fuel vehicles (AFVs) from paying the 6.5% retail sales and state use tax (RCW 82.12.9999). The second exempts renewable alternative fuels from public utility taxes, and exempts businesses that distribute natural gas from utility taxes for any machinery or equipment used to produce renewable transportation fuel (RCW 82.08.0205). Finally, the third policy allows individuals who purchase waste vegetable oil in order to create biodiesel to be exempt from paying sales and use taxes on their purchase (RCW 82.08.0205).

There is one ***biofuel project funding program*** called the Green Transportation Grant Program. It is offered through the Washington State Department of Transportation and offers grants to projects that reduce the carbon intensity of the Washington Transportation System (RCW 47.66.120).

Washington has many ***state fleet AFV requirements***. There are two policies that require state fleets to purchase more efficient vehicles. The first requires purchasing of electric vehicles, but for vehicle types where these are unavailable, fleets must use the most efficient, low-emission vehicles (E.O. 21-04,2021). The second policy requires state agencies to purchase vehicles that can run on low carbon fuel if the price is financially comparable to typical usage (RCW 43.19.622). In addition, there are two more state fleet AFV requirements that mandate certain levels of use of alternative fuels in state fleet vehicles. The first requires that a minimum of 20% of diesel used in state vehicles must be biodiesel (RCW 43.19.642; RCW 43.19.646). The second requires all state agencies to use 100% biofuels in their vehicles if possible (E.O. 18-01,2018; WAC 194-28; RCW 43.19.647; RCW 43.19.648).

Washington also has ***blend requirements*** policies. The first follows the Renewable Fuel Standard and requires that a minimum of 2% of diesel sold in Washington state must be biodiesel 19.112.020; RCW 19.112.110 - 19.112.180). There are two biofuel definitions— one defines E85 as a blend of 75-85% ethanol and hydrocarbon (RCW 19.112.010), and the other defines biodiesel (RCW 19.112.010; RCW 43.19.643). There are also two fuel labeling requirements. One requires that any vehicle utilizing alternative fuels must display a National Fire Protection Association label indicating their use of alternative fuels (RCW 46.37.467), and the other requires that pumps dispensing ethanol or biodiesel must be labeled with the respective blend percentages (RCW 19.112.020; WAC 16-662-115).

Finally, Washington has one policy requiring a ***biofuel impact study***. It mandates that the Washington State Department of Agriculture Biofuel Quality Program must test biofuel quality and quantity before the fuels can be sold to consumers (RCW 19.112.005 - 19.112.080). For more detail, refer to Appendix I: Proposed Lewis County Facility for more details about Washington's state policies.

The four original case studies identified biofuel funding programs, state fleet Alternative Fuel Vehicle requirements, tax incentives, and blend requirements as the four most common policy tools in the creation of biorefineries. Washington has all four of these tools already in place in the state, as well as additional tools that may prove to be beneficial in facility creation as well.

3.4.3. Assessment of Lewis County Project Feasibility

Based on the comparison of projected Lewis County Project facility characteristics and Washington policies, the feasibility of these two factors can be assessed. However, it must be noted that this study does not address the environmental nor social elements that may influence biorefinery creation in the United States.

Results from the case studies indicated that common facility characteristics included the use of second-generation feedstocks, ethanol production, the use of similar technology, co-location, the production of co-products, and procurement of federal funding. Because of their commonality to each of the four case studies, these characteristics may indicate importance in the initiation of new biorefineries in the United States. The proposed Lewis County facility plans to use biochemical conversion technology to process second-generation feedstocks into cellulosic ethanol. These technology, feedstock, and processing characteristics all align with the results from the case studies. Additionally, the proposed facility plans to co-locate beside an existing coal plant as well as to produce multiple high-value co-products (formic acid and xylitol). Co-location can decrease project capital cost because new infrastructure does not need to be built. The production of co-products may also help to further decrease the overall capital cost of the facility since the co-products can be produced using waste products from biofuel production. These co-products that can be sold to increase revenue so the price of the resulting biofuels can be lowered (Figure 1). Interviews indicated the importance of a facility being economically competitive to succeed long-term. Co-location and the production of co-products could help lower the capital cost of a facility, likely improving facility economic competitiveness. Based on results from the other case studies, federal funding seems fairly reliable as each facility received a minimum of $100 million in federal funding, largely from the U.S. Department of Energy. However, the case studies indicated that state, local, and company investment is also needed for facility creation.

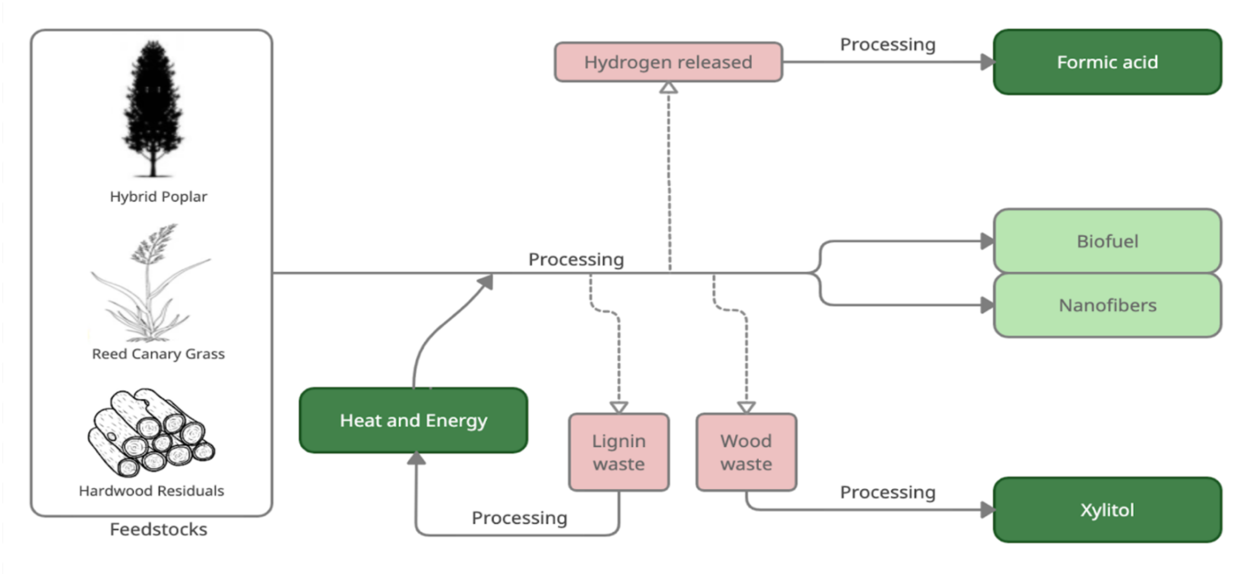

Figure 1. A simplified proposed processing plan for the Lewis County facility. Nanofibers are an additional co-product created from the original feedstocks, while formic acid, xylitol, and heat and energy are additional co-products created from process wastes.

Washington has in place the four key policy tools that were shared across the four case studies: biofuel funding programs, state fleet Alternative Fuel Vehicle requirements, tax incentives, and blend requirements. As these policy tools were common to all or most of the case studies, they could indicate that these features are particularly beneficial to the creation of new biorefinery facilities. Washington's Green Transportation Grant Program (RCW 47.66.120), implemented by the Washington State Department of Transportation, offers funding to a broad range of biofuel projects. This program could be utilized as a source of funding for the proposed Lewis County facility if it were to be created. Washington also has four state fleet Alternative Fuel Vehicle requirements. These requirements could help to create a larger market for biofuels in the state since vehicles that could use biofuels are being required at increasingly high levels in state fleets. The state has tax incentives that may be useful in encouraging increased production, sale, and consumption of biofuels for both companies and individuals. Finally, Washington has various blend requirements that may require higher levels of biofuel production to meet them. On top of the four common policy tools, Washington has additional types of policies that may serve to further incentivize biofuel production. The interviews also mentioned a suite of policy tools which respondents considered to be most important for siting new biorefineries. Of the policy tools mentioned in the interviews, Washington will have a state-level low carbon fuel standard (Clean Fuel Standard), a carbon tax, stringent regulations, tax reductions, programs to fund biofuel projects, and cap and trade. Interviews also highlighted challenges that may befall biofuel projects. By staying cognizant of challenges such as a lack of policy, misinformation, and permitting processes, Washington state may be able to navigate them more successfully.

Overall, the proposed Lewis County facility and Washington state share many of the common features identified in the case studies, encompassing facility characteristics and policy conditions.

4. Conclusion and Future Research

Based on the two factors studied (facility characteristics and policy conditions), the proposed Lewis County project does seem feasible. By studying similar cases across the United States, the feasibility of the proposed Lewis County facility was better understood. The case study method allowed for a deep comparison of a wide range of data, and ultimately found that the start-up of new biorefineries may be influenced by a set of common facility characteristics and policy conditions. The presence of these conditions may help to best incentivize the creation of new biorefineries in the United States. Facility characteristics like federal funding, technology, co-products, and co-location can all impact the feasibility of a new biorefinery. Policy conditions such as the federal Renewable Fuel Standard and state policies like biofuel funding programs, state fleet Alternative Fuel Vehicle requirements, tax incentives, and blend requirements may be useful in new biofuel projects. In comparison with the other case studies, the proposed Lewis County facility seems to have many of the elements needed in facility characteristics and policy conditions. Historically, biorefineries have been difficult to implement because of a suite of challenges, so Lewis County should be cognizant of these challenges moving forward.

Overall, this study analyzed the facility characteristics and policy conditions that may be most beneficial in the creation of new biorefineries, however, future research should be done to analyze social and environmental conditions that may also support the creation and feasibility of new biorefineries, as outlined in Figure 2 below.

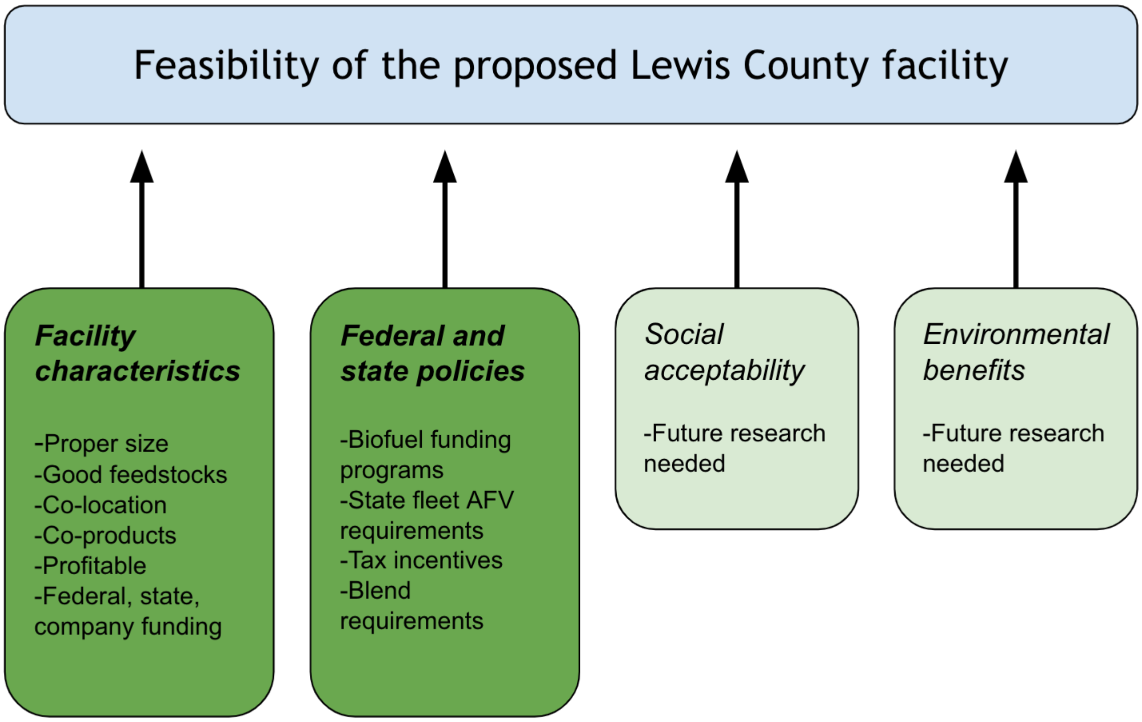

Figure 2. Factors contributing to the feasibility of the proposed Lewis County facility. Facility characteristics and federal and state policies were considered in this study, while social conditions and environmental benefits were not.

Analysis of social acceptability and environmental benefits will require future community-based work that more deeply studies those elements, which will assist in a more comprehensive understanding of facility feasibility.

REFERENCES

Aden, A., Ruth, M., Ibsen, K., Jechura, J., Neeves, K., Sheehan, J., Wallace, B., Montague, L., Slayton, A., & Lukas, J. (2002, June 01). Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover. *NREL/TP-510-32438*. National Renewable Energy Lab., Golden, CO. (US)

Alternative Fuels Data Center: Ethanol Production. (n.d.). Alternative Fuels Data Center. Retrieved April 16, 2022 from https://afdc.energy.gov/fuels/ethanol_production.html

Bali, A. S., Howlett, M., Lewis, J. M., & Ramesh, M. (2021, August 17). Procedural policy tools in theory and practice. *Policy and Society*, *40*(3), 295-311. https://doi.org/10.1080/14494035.2021.1965379

Bioenergy Technologies Office. (n.d.). *Integrated Biorefineries*. Department of Energy. https://www.energy.gov/eere/bioenergy/integrated-biorefineries

Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy. (n.d.). *Abengoa*. Department of Energy. Retrieved April 15, 2022 from https://www.energy.gov/eere/bioenergy/abengoa

Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy. (n.d.). *INEOS-New Planet: Indian River Bioenergy Center*. Department of Energy. Retrieved March 7, 2022 from https://www.energy.gov/eere/bioenergy/ineos-new-planet-indian-river-bioenergy-center

Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy. (n.d.). *POET-DSM: Project Liberty*. Department of Energy. Retrieved March 7, 2022 from https://www.energy.gov/eere/bioenergy/poet-dsm-project-liberty

Bowen, G. A. (2009, November). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27+.

Breetz, H.L. (2020, November). Do big goals lead to bad policy? How policy feedback explains the failure and success of cellulosic biofuel in the United States. *Energy Research & Social Science*, *69*, 101755.

Budd, W., Lovrich Jr, N., Pierce, J. C., & Chamberlain, B. (2008, October). Cultural sources of variations in US urban sustainability attributes. *Cities*, *25*(5), 257-267. https://doi.org/10.1016/j.cities.2008.05.001

Carley, S. (2009, August). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071-3081. https://doi.org/10.1016/j.enpol.2009.03.062

Contestabile, M., Offer, G. J., Slade, R., Jaeger, F., & Thoennes, M. (2011, August 16). Battery electric vehicles, hydrogen fuel cells and biofuels. Which will be the winner? *Energy & Environmental Science*, *4*(10), 3754-3772.

Corbin, J., & Strauss, A. (2008). Strategies for Qualitative Data Analysis. *In: Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, *3*. https://dx.doi.org/10.4135/9781452230153

de Blas, I., Mediavilla, M., Capellán-Péreza, I., & Duce, C. (2020, November). The limits of transport decarbonization under the current growth paradigm. *Energy Strategy Reviews*, *32*. https://doi.org/10.1016/j.esr.2020.100543

Demirbas, A. (2008). Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. *Energy conversion and management*, *49*(8), 2106-2116.

Denchak, M. (2018, June 29). *Fossil Fuels: The Dirty Facts*. NRDC. Retrieved April 16, 2022 from https://www.nrdc.org/stories/fossil-fuels-dirty-facts

Department of Environmental Quality. (2022). *Oregon Clean Fuels Program*. Oregon.gov. Retrieved March 7, 2022 from https://www.oregon.gov/deq/ghgp/cfp/Pages/default.aspx

Dinh, M., & Manternach, J. (2019, March 5). *Red Rock Biofuels Project Update*. Red Rock Biofuels. Retrieved March 7, 2022 from https://www.energy.gov/sites/prod/files/2019/04/f61/Woody%20Biomass%20Biorefinery%20Capability%20Development_EE000DPA2.pdf

Energy Information Administration. (2013, July 3). *Energy sources have changed throughout the history of the United States*. Retrieved February 8, 2021 from https://www.eia.gov/todayinenergy/detail.php?id=11951

Energy Information Administration. (2020). *WASHINGTON*. State Profile and Energy Estimates. Retrieved February 8, 2021 from https://www.eia.gov/state/?sid=WA

Energy Information Administration. (2020, March 9). *EIA projects U.S. biofuel production to slowly increase through 2050*. Retrieved February 8, 2021 from https://www.eia.gov/todayinenergy/detail.php?id=43096

Fischlein, M., & Smith, T. M. (2013). Revisiting renewable portfolio standard effectiveness: policy design and outcome specification matter. *Policy Sciences*, *46*, 277-310.

Gerring, J. (2004). What is a case study and what is it good for? *American political science review*, 341-354.

Governor Signs Clean Fuels Standard Into Law In Washington State. (2021, May 18). *BioCycle*. Retrieved March 7, 2022 from https://www.biocycle.net/governor-signs-clean-fuels-standard-into-law-in-washington-state/

Goyal, H. B., Seal, D., & Saxena, R. C. (2008, February). Bio-fuels from thermochemical conversion of renewable resources: A review. *Renewable and Sustainable Energy Reviews*, *12*(2), 504-417.

Hanaki, K., & Portugal-Pereira, J. (2018). The effect of biofuel production on greenhouse gas emission reductions. *Biofuels and sustainability*, 53-71.

Henderson, O. K. (2020, October 21). *'Project Liberty' cellulosic ethanol plant in Emmetsburg closed*. Radio Iowa. Retrieved March 7, 2022 from https://www.radioiowa.com/2020/10/21/project-liberty-cellulosic-ethanol-plant-in-emmetsburg-closed/

Hughes, G. (2021, July 26). *The Curious Case of Red Rock Biofuels – biofuelwatch*. Biofuelwatch. Retrieved March 7, 2022 from https://www.biofuelwatch.org.uk/2021/the-curious-case-of-red-rock-biofuels/

INEOS. (2022). *About*. INEOS Group. https://www.ineos.com/about/

Iowa Economic Development Authority. (2022). *Expand Your Business Grow High Quality Jobs*. Iowa Economic Development Authority. Retrieved March 7, 2022 from https://www.iowaeda.com/grow/high-quality-jobs/

Jester, D. (2021, May 5). *Red Rock Out of Money, Looks to Bonds – Advanced BioFuels USA*. Advanced BioFuels USA. Retrieved March 7, 2022 from https://advancedbiofuelsusa.info/red-rock-out-of-money-looks-to-bonds/

Jester, D., & Winter, K. (2022, January 12). *Red Rock biofuel company says Lake County work on hold until 2023*. Herald and News. Retrieved March 7, 2022 from https://www.heraldandnews.com/news/local_news/business/red-rock-biofuel-company-says-lake-county-work-on-hold-until-2023/article_e4bb4f94-f1e1-5c02-b9fe-fae6e8194bfb.html

Jones, N., Sophoulis, C. M., Iosifides, T., Botetzagias, I., & Evangelinos, K. (2009, July 24). The influence of social capital on environmental policy instruments. *Environmental Politics*, *18*(4), 595-611. https://doi.org/10.1080/09644010903007443

Kanazawa, M. (2017). The case study method. *Research methods for environmental studies: A social science approach*, 182-203. Routledge.

Kanazawa, M. (2017). Data collection II: Interviewing. *Research methods for environmental studies: A social science approach*, 313-332. Routledge.

Kneifel, J. (2008, June). Effects of state government policies on electricity capacity from non-hydropower renewable sources. *University of Florida*.

Labuschagne, A. (2003, June). Qualitative research: Airy fairy or fundamental? *The Qualitative Report*, *8*(1), 100-103.

Lane, B. (2020, November 16). *Insights: States with Low Carbon Fuel Standards & Those Considering One*. The Jacobsen. Retrieved April 29, 2022 from https://thejacobsen.com/news_items/states-considering-lcfs/

Lane, J. (2018, January 11). *The story of Red Rock Biofuels and the bond market breakthroughs*. Biofuels Digest. Retrieved March 7, 2022 from https://www.biofuelsdigest.com/bdigest/2018/01/11/it-takes-a-village-to-raise-a-biorefinery-the-story-of-red-rock-biofuels-and-all-those-others-shifting-to-bond-market-financing/

Lane, J. (2020, January 12). *From Woody Biomass to Renewable Fuels: The Digest's 2020 Multi-Slide Guide to Red Rock Biofuels' Lakeview Project*. Biofuels Digest. Retrieved March 7, 2022 from https://www.biofuelsdigest.com/bdigest/2020/01/12/from-woody-biomass-to-renewable-fuels-the-digests-2020-multi-slide-guide-to-red-rock-biofuels-lakeview-project/17/

Lauer, C., McCaulou, J. C., Sessions, J., & Capalbo, S. M. (2015, October). Biomass supply curves for western juniper in Central Oregon, USA, under alternative business models and policy assumptions. *Forest Policy and Economics*, *59*, 75-82. https://doi.org/10.1016/j.forpol.2015.06.002

Martinkus, N., Latta, G., Rijkhoff, S. A.M., Mueller, D., Hoard, S., Sasatani, D., Pierobon, F., & Wolcott, M. (2019, September). A multi-criteria decision support tool for biorefinery siting: Using economic, environmental, and social metrics for a refined siting analysis. *Biomass and Bioenergy*, *128*. https://doi.org/10.1016/j.biombioe.2019.105330

Martinkus, N., Rijkhoff, S. A.M., Hoard, S. A., Shi, W., Smith, P., Gaffney, M., & Wolcott, M. (2017, February). Biorefinery site selection using a stepwise biogeophysical and social analysis approach. *Biomass and Bioenergy*, *97*, 139-148. https://doi.org/10.1016/j.biombioe.2016.12.022

Martinkus, N., Shi, W., Lovrich, N., Pierce, J., Smith, P., & Wolcott, M. (2014, July). Integrating biogeophysical and social assets into biomass-to-biofuel supply chain siting decisions. *Biomass and Bioenergy*, *66*, 410-418. https://doi.org/10.1016/j.biombioe.2014.04.014

Milano, J., Ong, H. C., Masjuki, H. H., Chong, W. T., Lam, M. K., Loh, P. K., & Vellayan, V. (2016, May). Microalgae biofuels as an alternative to fossil fuel for power generation. *Renewable and Sustainable Energy Reviews*, *58*, 180-197. https://doi.org/10.1016/j.rser.2015.12.150

Mussatto, S. I., & Dragone, G. M. (2016). Chapter 1 - Biomass Pretreatment, Biorefineries, and Potential Products for a Bioeconomy Development. *Biomass Fractionation Technologies for a Lignocellulosic Feedstock Based Biorefinery*, 1-22.

Neeley, T. (2021, May 17). *Seaboard Energy to Build Renewable Diesel Plant on Former Abengoa Cellulosic Site*. DTN/Progressive Farmer. Retrieved March 7, 2022 from https://www.dtnpf.com/agriculture/web/ag/news/business-inputs/article/2021/05/17/seaboard-energy-build-renewable-site

Office of Energy Efficiency & Renewable Energy. (2014, October 2). *Energy Department Joins Agriculture and Navy in the Fight for Clean Energy Transportation*. Department of Energy. Retrieved March 7, 2022 from https://www.energy.gov/eere/articles/energy-department-joins-agriculture-and-navy-fight-clean-energy-transportation

Oregon Department of Energy. (2022). *Energy Loan Program*. Oregon.gov. Retrieved March 7, 2022 from https://www.oregon.gov/energy/incentives/pages/energy-loan-program.aspx

Pacific Coast Collaborative: Home. Retrieved March 18, 2022 from https://pacificcoastcollaborative.org/

Patton, C. V., Sawicki, D. S., & Clark, J. J. (1993). *Basic Methods of Policy Analysis and Planning* (3rd ed.). Routledge.

Pietzcker, R. C., Longden, T., Chen, W., Fu, S., Kriegler, E., Kyle, P., & Luderer, G. (2014, January 1). Long-term transport energy demand and climate policy: Alternative visions on transport decarbonization in energy-economy models Author links open overlay panel. *Energy*, *64*, 95-108. https://doi.org/10.1016/j.energy.2013.08.059

POET. (n.d.). POET: Home. Retrieved March 1, 2022 from https://poet.com/

POET-DSM. (2019). Project LIBERTY- The Future of Renewable Fuel. Retrieved March 1, 2022 from http://poetdsm.com/other/home.aspx

Red Rock Biofuels. (2022). *Home*. Red Rock Biofuels. Retrieved March 7, 2022 from https://www.redrockbio.com/

US EPA. (2021, December 21). *Renewable Fuel Standard Program.* US Environmental Protection Agency. Retrieved April 29, 2022 from https://www.epa.gov/renewable-fuel-standard-program

Renewable Technology. (n.d.). *Indian River BioEnergy Center, Vero Beach, Florida*. Renewable Technology. Retrieved March 7, 2022 from https://www.renewable-technology.com/projects/indian-river-bioenergy-center-vero-beach-florida/

Rennie, R. (2018, September 3). *Naphtha*. Energy Education. Retrieved March 7, 2022 from https://energyeducation.ca/encyclopedia/Naphtha

Ritchie, H., & Roser, M. (n.d.). *Energy mix*. Our World in Data. Retrieved March 7, 2022 from https://ourworldindata.org/energy-mix

Royal DSM. (2022). *DSM Corporate Home*. DSM. Retrieved March 1, 2022 from https://www.dsm.com/corporate/home.html

Sathre, R., & Gustavsson, L. (2021, December 15). A lifecycle comparison of natural resource use and climate impact of biofuel and electric cars. *Energy*, *237*. https://doi.org/10.1016/j.energy.2021.121546

Shafiee, S., & Topal, E. (2009, January). When will fossil fuel reserves be diminished? *Energy Policy*, *37*(1), 181-189. https://doi.org/10.1016/j.enpol.2008.08.016

Stake, R. E. (1995). *The Art of Case Study Research*. Sage Publications.

Town of Lakeview Oregon. (2020, March 13). *Lakeview's Red Rock Bio-Refinery – Lakeview, Oregon*. Town of Lakeview. Retrieved March 7, 2022 from https://townoflakeview.org/2020/03/lakeviews-red-rock-bio-refinery/

USAspending.gov. (n.d.). *GRANT to RED ROCK BIOFUELS LLC*. USAspending. Retrieved March 7, 2022 from https://www.usaspending.gov/award/ASST_NON_FA86501325505_5700

U.S. Census Bureau. (2019). *Lewis County, Washington*. U.S. Census. Retrieved February 8, 2022 from https://www.census.gov/quickfacts/fact/ table/lewiscountywashington,WA/PST045219

US EPA. (2021, March 4). *Economics of Biofuels*. US Environmental Protection Agency. Retrieved April 16 from https://www.epa.gov/environmental-economics/economics-biofuels

US EPA. (2022, February 25). *Global Greenhouse Gas Emissions Data.* US Environmental Protection Agency. Retrieved April 27, 2022 from https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

USDA Release No. 0156.15. (2015, May 29). *USDA to Invest Up to $100 Million to Boost Infrastructure for Renewable Fuel Use, Seeking to Double Number of Higher Blend Renewable Fuel Pumps*. USDA. Retrieved March 7, 2022 from https://www.usda.gov/media/press-releases/2015/05/29/usda-invest-100-million-boost-infrastructure-renewable-fuel-use

Voegele, E. (2016, September 7). *Ineos Bio to sell ethanol business, including Vero Beach plant | EthanolProducer.com*. Ethanol Producer Magazine. Retrieved March 7, 2022 from http://www.ethanolproducer.com/articles/13678/ineos-bio-to-sell-ethanol-business-including-vero-beach-plant

Winter, K. (2021, February 16). *Despite rumors, work continues on major Lakeview biofuels project*. Herald and News. Retrieved March 7, 2022 from https://www.heraldandnews.com/news/local_news/despite-rumors-work-continues-on-major-lakeview-biofuels-project/article_5b13fbb6-565e-5ba8-a758-24229a99e399.html

Yanow, D. (2007, March 1). Interpretation in Policy Analysis: On Methods and Practice. *Critical Policy Analysis*, *1*(1), 110-122.

Yi, H., & Feiock, R. C. (2014, August 13). Renewable Energy Politics: Policy Typologies, Policy Tools, and State Deployment of Renewables. *Policy Studies Journal*, *42*(3), 391-415. https://doi.org/10.1111/psj.12066

Yin, R. K. (2009). Case Study Research: Design and Methods. *Applied Social Research Methods Series*, *5*.

APPENDIX A: Glossary of Terms

Biofuels: Transportation fuels made from renewable materials.
Biorefinery: A facility producing biofuels.
Capital cost: The total, overall cost of a facility.
Co-product: Additional materials or products created alongside the primary product.
Feedstock: The raw material used for the processing of a product.
First-generation: Biofuels made from food crops.
Policy tool: The specific approach or technique that a policy uses to achieve its goal.
Second-generation: Biofuels made from non-food crops.

APPENDIX B: Policy Codebook

Code	Description
State fuel standards	A state-level renewable fuel standard that aims to lower the state's carbon emissions by reducing non-renewable transportation fuels.
Tax incentives	A tool that reduces the amount of tax that a company or consumer owes to the government.
Direct payments	When government entities offer direct compensation for the production of renewable fuels.
Biofuel funding programs	A tool that authorizes government agencies to offer funding to renewable fuel projects.
Government amendment processes	Allow for citizens to appeal directly to the government to make local progress towards producing more renewable fuels.
State fleet Alternative Fuel Vehicle (AFV) requirements	Requirements of any state-owned or operated vehicle to meet minimum requirements in fuel efficiency and alternative fuel usage.
Blend requirements	Any requirement regarding alternative fuel blends in the state.
Biofuel impacts studies	Policies that require certain government agencies to conduct period studies regarding the efficiency of alternative fuels in the state.

APPENDIX C: Interview Guide

Opening Statement

Introduction

> Hello, my name is Caitlin Cruz and I am a graduate student in the School of Environmental and Forest Sciences at the University of Washington.

Purpose & Goals

> For my Masters Thesis, I am researching the typical social and political contexts that occur when creating and constructing a new biofuel refinery. This interview will focus on the policy side of my research— and by the end of this interview I hope to have a better understanding of which policies were most useful to you and your team when beginning to plan and construct your refinery. I have found some federal, state, and local policies that I thought would be relevant to your refinery, but I am more interested in hearing from you. I am conducting additional interviews with representatives from other biorefineries, and at the end of my project I hope to develop a framework that shows what kinds of policies tend to help or hinder the creation of biorefineries in the United States.

Permission to Record

> Do I have your permission to record our interview so that I can accurately review and transcribe your answers in the future? You will not be quoted by name, although you may be identifiable through your association with __________ (the refinery, company, government organization).

Interview format

> This interview will follow a semi-structured format. I will ask some close-ended questions, and then follow these with open-ended questions so that you can elaborate on any topics you feel are important for me to know.

How to proceed

> That being said, do not feel restricted to elaborating only on the open-ended questions. If at any time you feel there are other topics or questions that I should consider, please feel free to mention them right away.

Expected length

> I expect that this interview will take between 30 to 45 minutes. If you ever wish to end the interview, just let me know and we can finish it.

Provide contact information

> Just in case you need to reach me in the future, I will go ahead and provide you with my contact information via [Contact information provided].

Ask for questions

Do you have any questions for me before we begin?

General Interview Questions (should be asked of **all** interview participants for each case)

Background:

Could you briefly describe your role with the facility and how long you have been/were involved?

Can you briefly describe how the facility/project came into being (if they are familiar)?

Can you describe *why* your facility received DOE funding?

How did your facility utilize this funding?

Policy conditions:

Are there any federal policies/programs/incentives that you remember as being helpful for the start-up of the facility?

→ Prompt for key federal programs or state/local programs

Were there any other particular projects, programs, or incentives that you remember helped the start-up of your facility?

Were there any other conditions or factors that you remember as being helpful or for the start-up of the facility?

→ Prompt for social/political dynamics

[YOUR STATE] did/did not have a LCFS at the time of facility construction. Do you think that helped/would have helped incentivize construction? (Y/N)

→ How?

Was there anything else you can think of about [LOCATION] that influenced the refinery to be built there?

Were there any particular projects, programs, or incentives that you remember as hindering the start-up of your facility?

Were there any particular projects, programs, or incentives that you remember hindered the continued operation of your facility?

Were there any other conditions or factors that you remember hindered the start-up of the facility?

→ Prompt for social/political dynamics

Additional elements:

Were there any social or political conditions that you felt helped the refinery to be constructed here?

→ Prompt if needed: economy, jobs, environmental impact, etc.…

Were there any social or political conditions that you felt hindered the refinery being constructed here?

Can you describe how the local community responded to the refinery being sited here?

→ Prompt if needed: Were there supporters OR non-supporters?

Can you describe some of the reasons supporters gave?

Can you describe some of the concerns raised by those who did not support?

Concluding questions:

Do you have any additional thoughts regarding policies or incentives that might influence biofuel facilities?

What are your thoughts/perspectives about the future of biofuels?

Is there anyone else you would recommend that I speak with about this facility?

APPENDIX D: Interview Codebook

Code	Description
Policy tools	An overarching theme focusing on different types of policy options for the purpose of supporting and incentivizing renewable fuels.
Challenges	The varying difficulties that can occur when trying to site a new biorefinery.
Economic competitiveness	The importance of a facility's ability to stand up to be economically competitive on its own, after the use of government incentives and funds.
Local community support	The importance of sustained support from communities around the proposed biorefinery site.
Environmental benefits	A broad theme encompassing the environmental benefits of many aspects of the biofuel production process.
Government support	The importance of support from any level of government.
Strong incentives	The importance of incentives being strong enough to truly encourage renewable fuel production.
Groups of supporters	Various groups that tended to be in support of the biofuels industry, according to biofuels stakeholders.
Groups of non-supporters	Various groups that tended to be in opposition to the biofuels industry, according to biofuels industry stakeholders.
Economic benefits	The various economic benefits associated with a biorefinery.
Improving facility economics	The importance of ensuring that a facility is able to be economically feasible. This theme considers all aspects of the facility— feedstocks, transportation, processing, and output products.
Private sector involvement	The importance of private sector companies being involved in the process of creating renewable fuels.
Technological innovation	The importance of innovative new technological advancements in the biofuels sector.
Research & development (R&D) efforts	The importance of research and development in starting biorefinery projects and making innovations in the field.

Academia involvement	The importance of academia involvement in advancing the field of biofuels.
Technical neutrality	The policy approach of incentivizing a wide range of solutions and technologies, rather than just one specific type.
Rulemaking process	The rulemaking process allows government agencies to hear from the public and to create comprehensive policy requirements over time.
Reason for private involvement	Various reasons for private companies to become involved with the biofuels industry or biorefineries.
Accessing federal funds	Ways in which biorefineries or companies can access federal funding for their renewable fuel projects.
Change in public attitude	The shift in public attitudes towards renewable fuels.
Industrial symbiosis	The idea of multiple companies using the waste products or by-products of one production process as the feedstocks for another process. Industrial symbiosis brings both environmental, logistical, and economic benefits.

APPENDIX E: Project LIBERTY

Project LIBERTY was located in Emmetsburg, Iowa and was a collaborative project between POET and Royal DSM (POET-DSM, 2019). POET, LLC is a company based in Sioux Falls, South Dakota and is one of the world's largest ethanol producers (POET, n.d.). POET specializes in feedstock procurement, organization, and storage, and owns 27 grain ethanol plants. The company provides a comprehensive business model that combines technological development with construction, operations, risk management, and marketing expertise. They produce only ethanol as fuel, but also create other products including distiller grains, corn oil, and asphalt rejuvenator. Royal DSM is an international company based in the Netherlands that specializes in three main fields— nutrition, health, and materials. The company has long been associated with significant technological and environmental progress, and has previously been successful in scaling up industrial biotechnology projects (Royal DSM, 2022). Royal DSM leads the field in conversion processes for cellulosic biomass to ethanol pathways, and it is currently the only company able to co-ferment all C5 and C6 sugars. The Project LIBERTY facility opened in 2014, focusing on creating cellulosic bioethanol from corn stover, in competition with the more conventional grain ethanol on the market. In addition to the cellulosic bioethanol, the project also aimed to offer a 'fully integrated technology package,' including assistance with site selection, biomass collection and supply chain development, regulatory assistance, process design and construction, services and support, marketing assistance, and funding. The projected production capacity was 25 million gallons/year of cellulosic ethanol, from 770 dry tons/day of corn cobs, leaves, husk, and stalk. Based on these figures, studies projected the facility would increase Iowa's economic output by $24.4 billion and create 300 construction jobs, 65 indirect jobs for feedstock supply, logistics, equipment, and support, and 56 full-time facility jobs (Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy, n.d.). POET-DSM also collaborated with government agencies and universities to study the impact of corn stover removal on soil health. Through this research, the team developed the EZ Bale system, which left approximately 75% of biomass in the field, focusing on the nutrient-rich lower stalks in order to replenish soil nutrients. Furthermore, the team ensured that local farmers had easier access to harvest equipment so that they could collect the EZ Bales. The Project LIBERTY facility was co-located beside POET's existing corn ethanol plant in order to share infrastructure and personnel. Additionally, the lignin leftover after processing the corn stover was used to generate thermal power to run both facilities. With these characteristics as a framework, the U.S. Department of Energy provided $100 million worth of grants for plant construction, and the State of Iowa provided $20 million for job training and construction. Ultimately, Project LIBERTY shut down in 2020, citing that they could not compete with the low price of oil (Henderson, 2020).

Iowa State Level Policies (from AFDC, 2022)	
State Fuel Standard	
None	N/A
Tax Credits	

Mid-Level Ethanol Blend Retailer Tax Credit	Retail stations dispensing mid-level blends of ethanol in gasoline between 15% (E15) up to 69% (E69) for use in motor vehicles may be eligible for a tax credit. Credit amounts vary by date: the credit is $0.03 per gallon from September 16 through May 31 and $0.10 per gallon from June 1 through September 15. The tax credit expires December 31, 2024. (Reference Iowa Code 214A.1 and 422.11Y)
E85 Retailer Tax Credit	Retail stations dispensing gasoline fuel blends of E85 (70%-85% ethanol) for use in motor vehicles may be eligible for a tax credit in the amount of $0.16 per gallon sold. The tax credit expires after December 31, 2024. Eligible taxpayers may also claim the Ethanol Blend Retailer Tax Credit for the same ethanol gallons and tax year. (Reference Iowa Code 422.11O)
Alternative Fuel Production Tax Credits (1)	The High Quality Jobs Program offers state tax incentives to business projects for the production of biomass or alternative fuels. Incentives may include an investment tax credit equal to a percentage of the qualifying investment, amortized over five years; a refund of state sales, service, or use taxes paid to contractors or subcontractors during construction; an increase of the state's refundable research activities credit; and a local property tax exemption of up to 100% of the value added to the property.
High Quality Jobs Program (1)	The High Quality Jobs (HQJ) program provides qualifying businesses assistance to off-set some of the costs incurred to locate, expand or modernize an Iowa facility. This flexible program includes loans, forgivable loans, tax credits, exemptions and/or refunds. The Iowa Economic Development Authority (IEDA) offers this program to promote growth in businesses, which employ Iowans in jobs defined as high-quality by state statute. State tax incentives to business projects for the production of biomass or alternative fuels. (Iowa Economic Development Authority, 2022)
Tax Exemptions	
Alternative Fuel Production Tax Credits (2)	The High Quality Jobs Program offers state tax incentives to business projects for the production of biomass or alternative fuels. Incentives may include an investment tax credit equal to a percentage of the qualifying investment, amortized over five years; a refund of state sales, service, or use taxes paid to contractors or subcontractors

	during construction; an increase of the state's refundable research activities credit; and a local property tax exemption of up to 100% of the value added to the property.
High Quality Jobs Program (2)	The High Quality Jobs (HQJ) program provides qualifying businesses assistance to off-set some of the costs incurred to locate, expand or modernize an Iowa facility. This flexible program includes loans, forgivable loans, tax credits, exemptions and/or refunds. The Iowa Economic Development Authority (IEDA) offers this program to promote growth in businesses, which employ Iowans in jobs defined as high-quality by state statute. State tax incentives to business projects for the production of biomass or alternative fuels. (Iowa Economic Development Authority, 2022)
Direct Payments	
None	N/A
Funding Programs	
Biofuel Infrastructure Grants	The Renewable Fuels Infrastructure Program provides financial assistance to qualified 70%-85% ethanol (E85) or dual 15% ethanol (E15) and biodiesel retailers. Cost-share grants are available to upgrade or install new E85 or dual E15 and biodiesel infrastructure. Three-year cost-share grants are available for up to 50% of the total cost of the total project, up to $30,000. Five-year cost-share grants are available for up to 70% of the total cost of the project, up to $50,000. Biodiesel distributors may apply for cost-share grants for infrastructure upgrades and installations at biodiesel terminal facilities. Facilities blending or dispensing blends ranging from 2% biodiesel (B2) to 98% biodiesel (B98) are eligible for up to 50% of the total project, up to $50,000. Facilities blending or dispensing B99 or B100 are eligible for up to 50% of the total project, up to $100,000.
Alternative Fuel Vehicle Demonstration Grant Authorization	The Iowa Department of Natural Resources (Department) may award demonstration grants to individuals who purchase vehicles that operate on alternative fuels, including but not limited to E85, biodiesel, compressed natural gas, electricity, solar energy, or hydrogen. Individuals may use the grants to conduct research connected with the

	fuel or vehicle. Grant funding to purchase the vehicle is available if the Department retains the title of the vehicle, the vehicle is used for research, and the proceeds from the eventual sale of the vehicle are used for additional research. Grants are subject to funding availability. (Reference Iowa Code 214A.19)
Iowa Renewable Fuels Infrastructure Program	The Iowa Renewable Fuels Infrastructure Program helps retail operators of motor fuel dispensing sites or fueling stations to convert their equipment to allow the expanded use of renewable fuels in Iowa. The program utilizes grant incentives to encourage these upgrades.
High Quality Jobs Program (3)	The High Quality Jobs (HQJ) program provides qualifying businesses assistance to off-set some of the costs incurred to locate, expand or modernize an Iowa facility. This flexible program includes loans, forgivable loans, tax credits, exemptions and/or refunds. The Iowa Economic Development Authority (IEDA) offers this program to promote growth in businesses, which employ Iowans in jobs defined as high-quality by state statute. State tax incentives to business projects for the production of biomass or alternative fuels.
Government Amendment Processes	
None	N/A
State Fleet AFV Requirements	
Alternative Fuel Vehicle Acquisition Requirements	At least 10% of new light-duty vehicles purchased by institutions under the control of the state fleet director, including the Iowa Department of Transportation, Board of Directors of Community Colleges, Board of Regents, Commission for the Blind, and Department of Corrections must be capable of operating on alternative fuels. Vehicles and trucks purchased and directly used for law enforcement and off-road maintenance work are exempt from this requirement. (Reference Iowa Code 8A.362, 216B.3, 260C.19A, 262.25A, 307.21 and 904.312A)
Blend Requirements	
E85 Fuel Exclusivity Contract Regulations	Any motor fuel franchisor must provide for the delivery of E85 as requested by the motor fuel dealer or allow the franchisee to purchase E85

	from another source. (Reference Iowa Code 323A)
Renewable Fuel Labeling Requirement	Biodiesel, biobutanol, and ethanol blend dispensers must be affixed with decals identifying the type of fuel blend. If fuel blends containing more than 10% ethanol are being dispensed, the decal must include the statement: "For Flexible Fuel Vehicles Only." The Iowa Department of Agriculture and Land Stewardship (Department) may approve applications to place a decal in a special location on a pump with special lettering or colors that are clear and conspicuous to the consumer. (Reference Iowa Code 214A.16)
Ethanol Blend Dispenser Requirement	An ethanol retailer selling a blend of at least 9% ethanol by volume must use gasoline storage and dispensing infrastructure that the Iowa Department of Natural Resources and state fire marshal have determined is compatible with the ethanol blend being dispensed. Exceptions may apply. (Reference Iowa Code 455G.31)
Biofuel Specifications	Ethanol-blended gasoline must conform to ASTM D4814, E85 must conform to ASTM D4806, and biodiesel-blended fuel containing at least 6%, but no more than 20%, biodiesel must conform to ASTM D7467. Additionally, biobutanol must be an agriculturally derived isobutyl alcohol that meets ASTM D7862 for butanol for blending with gasoline for use as a motor fuel. Gasoline blended with biobutanol must conform to ASTM D4814. The state defers to the U.S. Environmental Protection Agency for potential changes in specifications. (Reference Iowa Code 214A.2)
Alternative Fuel Tax	Alternative fuels used as vehicle fuel are taxed as follows: Compressed natural gas is subject to the state fuel excise tax of $0.31 per gasoline gallon equivalent, measured at 5.66 pounds (lbs.) or 126.67 cubic feet at a base temperature of 60 degrees Fahrenheit and a pressure of 14.73 lbs. per square inch; Liquefied natural gas is subject to the excise tax of $0.325 per diesel gallon equivalent (DGE), measured at 6.06 lbs.; Propane is subject to the excise tax of $0.30 per gallon; E85 is subject to the excise tax of $0.290 per gallon; Hydrogen is subject to the excise tax of $0.65 per DGE, measured at 2.49 lbs.; and Electricity is subject to the excise tax of $0.026 per kilowatt-hour of fuel delivered or placed into a

	battery or other energy storage device of an electric motor vehicle at any location in Iowa other than a residence. (Reference Iowa Code 452A.2 and 452A.86)
Biofuel Impact Studies Requirement	
Biofuel Quality Program	The Iowa Department of Agriculture and Land Stewardship must establish and administer programs to audit motor fuel facilities, including biofuel processing and production plants, to screen and test motor fuel, including renewable fuel, and to inspect motor fuel sold by dealers, including retail motor fuel dealers. Biofuels include ethanol, biobutanol, and biodiesel. Renewable fuel is defined as a combustible liquid derived from biomass or produced from a biogas source, such as biofuel and biofuel blended with gasoline. (Reference Iowa Code 214A.1 and 214A.2C)

APPENDIX F: Hugoton Plant

The Hugoton Plant, located in Hugoton, Kansas, was a project by the company Abengoa. Abengoa is an international biotechnology company, and is one of the largest ethanol producers in the United States, Brazil, and Europe. The Hugoton Plant was their first commercial-scale cellulosic ethanol facility, and used non-food agricultural residues like wheat straw, corn stover, milo stubble, and switchgrass as feedstocks. At total projected capacity, the plant could process 1000 tons/day of dry biomass into approximately 23 million gallons/year of cellulosic ethanol. The facility introduced a new enzymatic hydrolysis process at this commercial scale, after 30,000+ hours of testing at a pilot scale and 6,000+ hours of testing at a demonstration scale. Their new process converts the agricultural residues into sugars, then ferments, distills, and dehydrates them into denatured ethanol. In addition to the ethanol, the facility also housed a bioenergy plant, which could generate up to 21 MW of electricity per year— enough to power the entire facility. In the future, Abengoa aimed to use the location to produce additional co-products like bioplastics, biochemicals, and jet fuel. The plant was expected to create approximately 300 construction jobs and 65 full time jobs, with an annual payroll of over $4.5 million. Furthermore, the feedstocks were to mostly be harvested within a 50-mile radius of the facility, providing an estimated $17 million/year of additional income to local farmers. Given these conditions, Abengoa's Hugoton Plant received a $97 million grant from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), and a $132.4 million conditional loan guarantee from the U.S. Department of Energy's Loan Programs Office (Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy, n.d.). The Hugoton Plant finished construction in August 2014 and began processing fuel in September 2014, but in 2015, Abengoa Bioenergy filed for bankruptcy and the plant shut down. In 2016, the plant was sold to Synata Bio Inc. for $48.5 million. It was then sold to High Plains Bioenergy, now renamed Seaboard Energy (Neeley, 2021).

<table>
<tr><th colspan="2">Kansas State Level Policies (from AFDC, 2022)</th></tr>
<tr><td colspan="2">State Fuel Standard</td></tr>
<tr><td>None</td><td>N/A</td></tr>
<tr><td colspan="2">Tax Credits</td></tr>
<tr><td>Alternative Fuel Vehicle (AFV) Tax Credit</td><td>An income tax credit is available for 40% of the incremental or conversion cost for qualified AFVs, based on gross vehicle weight rating (GVWR) as outlined in the table below. following table:
<table>
<tr><td>GVWR</td><td>Credit</td></tr>
<tr><td>Less than 10,000 pounds (lbs.)</td><td>Up to $2,400</td></tr>
<tr><td>10,000 to 26,000 lbs.</td><td>Up to $4,000</td></tr>
<tr><td>Over 26,000 lbs.</td><td>Up to $40,000</td></tr>
</table></td></tr>
</table>

	Alternatively, a tax credit of 5% of the cost of the AFV, up to $750, is available for the purchase of an original equipment manufacturer AFV. Qualified AFVs include vehicles that operate on a combustible liquid derived from grain starch, oil seed, animal fat, or other biomass, or produced from a biogas source. This credit is allowed only to the first individual to take title of the vehicle. For motor vehicles capable of operating on E85, the individual claiming the credit must provide evidence of purchasing at least 500 gallons of E85 between the time the vehicle was purchased and December 31, of the following calendar year. Excess credits may be carried over for up to three years after the year in which the expenditures were made. The credit is only available to entities with corporate income tax liability. For more information, see the Alternative Fuel Tax Credit website. (Reference Kansas Statutes 79-32,201)
Alternative Fueling Infrastructure Tax Credit	An income tax credit is available for 40% of the total cost to install alternative fueling infrastructure. Qualified property must be directly related to the delivery of alternative fuel into the fuel tank of a motor vehicle propelled by such fuel. The tax credit may not exceed $100,000 per fueling station. Alternative fuels are defined as combustible liquids derived from grain starch, oil seed, animal fat, or other biomass, or produced from a biogas source. Excess credits may be carried over for up to three years after the year in which the expenditures were made. The credit is only available to entities with corporate income tax liability. For more information, see the Alternative Fuel Tax Credit website. (Reference Kansas Statutes 79-32,201)
Tax Exemptions	
Biofuel Production Facility Tax Exemption	Qualified equipment used for storing and blending petroleum-based fuel with biodiesel, ethanol, or other biofuel is exempt from state property taxes. The exemption begins at the time of installation at a fuel terminal, refinery, or biofuel production plant, and ends 10 taxable years following the year in which the equipment was installed. Equipment used only for denaturing ethyl alcohol is not eligible. (Reference Kansas Statutes 79-232 and 79-32,251)
Biofuel Blending Equipment Tax Exemption	Qualified equipment used for storing and blending petroleum-based fuel with biodiesel, ethanol, or other biofuel is exempt from state property taxes. The exemption begins at the time of installation at

	a fuel terminal, refinery, or biofuel production plant, and ends 10 taxable years following the year in which the equipment was installed. Equipment used only for denaturing ethyl alcohol is not eligible. (Reference Kansas Statutes 79-232 and 79-32,251)
Direct Payments	
Renewable Fuel Retailer Tax Incentive	A licensed retail motor fuel dealer may receive a quarterly incentive from the Kansas Retail Dealer Incentive Fund for selling and dispensing renewable fuels, including biodiesel. A qualified motor fuel dealer is eligible for up to $0.065 for every gallon of renewable fuel sold and up to $0.03 for every gallon of biodiesel sold, if the required threshold percentage is met. The threshold is determined by calculating the percent of total gasoline sales that are renewable fuel or biodiesel. For renewable fuel, the threshold increases incrementally on an annual basis from 10% in 2009 to 25% beginning on January 1, 2024. For biodiesel, the threshold increases incrementally on an annual basis from 2% in 2009 to 25% in 2025. Reference Kansas Statutes 79-34,171 through 79-34,176)
Funding Programs	
Cellulosic Ethanol Production Financing	The Kansas Development Finance Authority may issue revenue bonds to cover the costs of construction or expansion of a biomass-to-energy facility. A qualifying biomass-to-energy facility includes any industrial process plant that uses biomass to produce at least 500,000 gallons of cellulosic alcohol fuel, liquid or gaseous fuel, or other source of energy in a quantity with energy content at least equal to that of 500,000 gallons of cellulosic alcohol fuel. Expansion of an existing biomass-to-energy facility is defined as expansion of the facility's production capacity by a minimum of 10%. (Reference Kansas Statutes 74-8949b and 79-32,233)
Government Amendment Processes	
None	N/A
State Fleet AFV Requirements	

Flexible Fuel Vehicle (FFV) Acquisition Requirements	State agencies must purchase FFVs capable of operating on E85 fuel unless the desired vehicle model is not available with an E85-capable engine or the cost of the vehicle is at least $250 more than a comparable vehicle that does not use E85. When leasing motor vehicles, state agencies must lease FFVs unless no such vehicles are available for lease. Certain restrictions apply. (Reference Kansas Statutes 75-4617)
Biofuels Use Requirement	State-owned diesel-powered vehicles and equipment must use a biodiesel blend that contains at least 2% biodiesel (B2), where available, as long as the price of the biodiesel blend is not more than $0.10 per gallon as compared to the price of diesel fuel. Individuals operating state-owned motor vehicles must purchase fuel blends containing at least 10% ethanol (E10), as long as these fuel blends are not more than $0.10 per gallon as compared to the price per gallon of regular gasoline fuel. (Reference Kansas Statutes 75-3744a)
Blend Requirements	
E85 Tax Rate and Definition	The minimum motor vehicle fuel tax rate on E85 is $0.17 per gallon, compared to the conventional motor fuel tax rate of $0.24 per gallon. E85 is defined as an alternative fuel that is a blend of denatured ethanol and hydrocarbon and typically contains 85% ethanol by volume, but must contain at least 70% ethanol by volume, and complies with ASTM specification D5798-99. (Reference Kansas Statutes 79-3401 and 79-34,141)
Ethanol Blend Dispenser Requirement	A retail motor fuel dispenser that dispenses fuel containing more than 10% ethanol by volume must be labeled with the capital letter "E" followed by the numerical value representing the volume percentage of ethanol, such as E85, and end with the word "ethanol" as specified in Kansas Department of Agriculture guidelines (PDF) (Reference Kansas Administrative Regulations 99-25-10)
Biodiesel and Renewable Fuel Definitions	Biodiesel is defined as a renewable, biodegradable, mono alkyl ester combustible liquid fuel that is derived from vegetable oils or animal fats and meets the specifications adopted by rules and regulations of the Kansas Department of Agriculture pursuant to current law. The Kansas specification must meet the ASTM D6751-07 specification for biodiesel fuel (B100) blend stock for distillate fuels, but may be more

	stringent regarding biodiesel quality and usability. Renewable fuels are defined as combustible liquids derived from grain starch, oil seed, animal fats, or other biomass; or produced from a biogas source, including any non-fossilized, decaying, organic matter capable of powering spark ignition machinery. (Reference Kansas Statutes 79-34,170)
Biofuel Impact Studies Requirement	
None	N/A

APPENDIX G: Indian River Bioenergy Center

The Indian River Bioenergy Center, located in Vero Beach, Florida, was a joint venture between INEOS and New Planet Energy. INEOS is an international petrochemical company, operating in 29 different countries (INEOS, 2022). Meanwhile, New Planet Energy is a United States-based company that aims to develop sustainable solutions for municipal solid waste (MSW) and to produce biofuels. The facility was the first commercial-scale refinery in the United States to produce cellulosic ethanol from waste, and it used hybrid thermochemical-fermentation technology to create both cellulosic ethanol and electricity. The technology, supplied by INEOS, was feedstock-flexible and thus able to use construction waste, municipal solid waste, and forestry and agricultural waste. The facility was co-located beside a landfill and was able to process 250,000 tons/year of waste in order to produce 8 million gallons/year of cellulosic ethanol, as well as 6 MW of electricity/year. Of the 6 MW of electricity generated, 4 MW were used to power the facility and 2 MW were sold to the electric grid. Other benefits to the community included diverting 100,000 dry tons/year of waste directly from the landfill, creating 400 temporary design and construction jobs, creating 65 permanent plant jobs, and increasing the local economy by $4 million/year (Bioenergy Technologies Office & Office of Energy Efficiency & Renewable Energy, n.d.). The plant was mostly funded by a $50 million grant from the U.S. Department of Energy's 932 Integrated Biorefinery Program for design, construction, and commissioning, as well as a $75 million loan from the U.S. Department of Agriculture's 9003 Biorefinery Assistance Program. It also received $4.3 million from a local development agency called One North East, with around $2.4 million secured through the Tees Valley Industrial Program (Renewable Technology, n.d.). The facility began generating electricity in September 2012, and commercial production of cellulosic ethanol began in June 2013. However, by December 2013, the facility faced technological challenges and safety violations. In September 2014 they announced that they had completed major renovations and revamps to upgrade the facility. Ultimately, the facility was never able to recover and was sold in 2016. INEOS stated that the United States market for ethanol had changed from when they started, and that the technology and mission no longer aligned with their strategic objectives (Voegele, 2016).

Florida State Level Policies (from AFDC, 2022)	
State Fuel Standard	
None	N/A
Tax Credits	
None	N/A
Tax Exemptions	
None	N/A

Direct Payments	
None	N/A
Funding Programs	
Authorization for Alternative Fuel Infrastructure Incentives	Local governments may use income from the infrastructure surtax to provide loans, grants, or rebates to residential or commercial property owners to install electric vehicle supply equipment, propane fueling infrastructure, and natural gas fueling infrastructure, if a local government ordinance authorizing this use is approved by referendum. (Reference Florida Statutes 206.9951 and 212.055)
Provision for Renewable Fuels Investment	To create jobs and improve the state's general infrastructure, the Florida State Board of Administration may invest up to 1.5% of the net assets of the system trust fund in technology and growth investments of businesses operating in Florida, including businesses related to biofuels, renewable energy, and other related applications. (Reference Florida Statutes 215.47)
Government Amendment Processes	
Ethanol Production Credit	County governments are eligible to apply waste reduction credits towards their recycling goal, up to one-half of the goal, by using yard clippings, clean wood waste, or paper waste as feedstock for the production of clean-burning fuels such as ethanol. (Reference Florida Statutes 403.706)
Alternative Fuel Economic Development	To stimulate local economic development, landowners may apply to amend the local government comprehensive plan to expand existing uses of rural agricultural industrial centers to include facilities that prepare biomass materials that can be used for the production of fuel, renewable energy, bioenergy, or alternative fuel. In addition, permitting agencies may expedite applications and local comprehensive plan amendments submitted for projects resulting in the production of biofuels or construction of a biofuel processing facility. (Reference Florida Statutes 163.3177 and 403.973)
State Fleet AFV Requirements	
Fuel-Efficient Vehicle Acquisition and Alternative Fuel Use Requirements	When procuring new vehicles under a state purchasing plan, all Florida state agency, state university, community college, and local government fleets must select the vehicles with the greatest fuel efficiency available for a given use class, when fuel economy data is available. Exceptions may be made for emergency responder vehicles if these entities provide documentation. In addition, all state agencies must use ethanol and biodiesel blended fuels when available. State agencies administering central fueling operations for state-owned vehicles must purchase ethanol and biodiesel fuels to use in their vehicle fleet as much as possible. (Reference Florida Statutes 286.29)
Blend Requirements	
None	N/A

Biofuel Impact Studies Requirement	
Biofuels Promotion	The Florida Department of Management Services (DMS), in coordination with the Florida Department of Transportation (DOT), must conduct an analysis of fuel additives and biofuels DOT uses through its central fueling facilities. The DMS must also encourage other state government entities to analyze transportation fuel usage, including the types and percentages of fuels consumed, and report this information to the DMS. (Reference Florida Statutes 287.16)

APPENDIX H: Lakeview Facility

The Lakeview Facility is an in-progress project by Red Rock Biofuels located in Lakeview, Oregon. The United States-based company, Red Rock Biofuels, started in 2011 with a goal to create renewable jet fuel and diesel fuel while simultaneously finding solutions for the increasing problem of wildfires (Red Rock Biofuels, 2022). The Lakeview Facility will be the first facility in the world to create commercial-scale cellulosic jet and diesel fuels from wood waste. The facility uses existing technology and processes, but combines them in new ways, integrated gasification, Fischer-Tropsch, and hydroprocessing technologies. This new integration scheme theoretically makes the Fischer-Tropsch processes of refining, which has long been commercialized, economically viable at a larger scale. The Lakeview Facility aims to produce ~15.1 million gallons/year of renewable cellulosic jet and diesel fuel from ~166,000 dry tons/year of wood waste. They also plan to make 3.6 million gallons/year of naphtha (Lane, 2018), a solvent used in gasoline conversion (Rennie, 2018). Currently, the Lakeview Facility has contracts with three vendors supplying 95,300 dry tons/year of feedstocks (Lane, 2020), including plans to obtain wood slash from neighboring industrial forest lands owned by Green Diamond Resource Company (Hughes, 2021). Ultimately the facility aims to harvest most of its feedstocks within a 125-mile radius. Contracts have also been signed for fuel offtake, with plans for 100% of the jet fuel to be sold to FedEx and Southwest Airlines. The project aims to bring in at least 500 construction jobs, 31 direct manufacturing jobs, and 120 feedstock processing and transportation jobs (Dinh & Manternach, 2019). While the facility is not explicitly co-located with other infrastructure, the site lies in an area surrounded by forest and thus by feedstocks. Lakeview also has fairly good access to railways, with new tracks being laid for the project, as well as new gas pipes being built into the existing Ruby Pipeline system in the area (Town of Lakeview Oregon, 2020). Because of their interest in using renewable jet fuel for the military, the U.S. Department of Defense gave a $4.1 million grant to the facility (USAspending.gov, n.d.), paired with a $70 million joint award from the U.S. Department of Energy, U.S. Department of Agriculture, and the U.S. Navy through the Defense Production Act (USDA Release No. 0156.15, 2015; Office of Energy Efficiency & Renewable Energy, 2014). The project also received $245 million in state bonds, signed by 2018 Oregon Governor Kate Brown (Hughes, 2021). Though the Lakeview Facility originally planned to be in production by 2021, COVID, increased materials costs, and problems with suppliers led to slower progress. On April 21, 2021, the company declared bankruptcy and construction halted (Jester, 2021). In 2022, the town manager of Lakeview reported that she was told that major work on the Lakeview Facility is on hold until at least 2023 (Jester & Winter, 2022), though a small crew is still working on testing processes at the plant (Winter, 2021).

Oregon State Level Policies (from AFDC, 2022)	
State Fuel Standard	
Oregon Clean Fuels Program	Launched in 2016, the Oregon Department of Environmental Quality's Clean Fuels Program is designed to decrease the amount of greenhouse gases created during the life cycle (i.e., the production, processing, transportation, and consumption) of fuel used in Oregon. Clean fuels have lower carbon emissions,

	or carbon intensity, which help improve air quality and public health. The clean fuel standards are the annual average carbon intensity that a regulated party must comply with. There is a standard for gasoline and gasoline substitutes and one for diesel and diesel substitutes. The baseline year for the program is 2015 and represents 10 percent ethanol blended with gasoline and 5 percent biodiesel blended with diesel. The rule requires a 10 percent reduction in average carbon intensity from 2015 levels by 2025. (Department of Environmental Quality, 2022)
Tax Credits	
None	N/A
Tax Exemptions	
Rural Renewable Energy Development Zone	The incentive is the standard (3- to 5-year) exemption on qualified property available in any enterprise zone, except that in a RRED Zone it is only for renewable energy activities (which would also be eligible in an enterprise zone). The total amount of property (among one or more projects) that can qualify is subject to a locally-set cap with each RRED Zone. That cap can be no greater than $250 million in initial market value of each project.
Biofuels Production Property Tax Exemption	Property used to produce biofuels, including ethanol and biodiesel, may be eligible for a property tax exemption if it is located in a designated Rural Renewable Energy Development Zone. The Oregon Business Development Department must receive and approve an application from a qualified rural area to designate the area as a Rural Renewable Energy Development Zone. For more information, see the Business Oregon Renewable Energy website. (Reference Oregon Revised Statutes 285C.350 - 285C.370)
Direct Payments	
None	N/A
Funding Programs	
Alternative Fuel Loans	The Oregon Department of Energy administers the Small-Scale Local Energy Loan Program which offers low-interest loans for qualified projects. Eligible alternative fuel projects include fuel production facilities, dedicated feedstock production, fueling infrastructure, and fleet vehicles. Loan recipients must complete a loan application and pay a loan application fee. The Energy Loan Program is not currently accepting new loan applications (verified February 2020). For more information, including application forms and interest rate and fee information, see the Energy Loan Program website. (Reference Oregon Revised Statutes 470)
Energy Loan Program	Oregon's Small-Scale Local Energy Loan Program has made more than 860 loans since we began lending in 1980.

	Oregon's energy loan program offers fixed-rate, long-term loans for qualified projects that invest in energy conservation, renewable energy, alternative fuels, or create products from recycled materials. (Oregon Department of Energy, 2022)
Government Amendment Processes	
None	N/A
State Fleet AFV Requirements	
Zero Emission Vehicle (ZEV) Deployment (1)	The Oregon Department of Energy (ODOE) will monitor state ZEV adoption goal progress for registered vehicles, new vehicle purchases, and the state fleet. The state established the following goals for vehicle registrations: • By 2020, 50,000 vehicles will be ZEV; • By 2025, 250,000 vehicles will be ZEV; and • By 2030, 25% of vehicles will be ZEV. In addition, the state established the following goals for new vehicle purchases: • By 2030, 50% of all new vehicle purchases will be ZEV; and • By 2035, 90% of all new vehicle purchases will be ZEV. By 2029, all state fleet vehicles should be ZEVs. ODOE must submit a biannual report by September 15 on the status of ZEV adoption. If ZEV adoption goals are not met, ODOE report must include strategies for increased adoption rates. (Reference Oregon Revised Statutes 283.327 and 283.398)
Blend Requirements	
Alternative Fuel Vehicle (AFV) Parking Space Regulation	An individual is not allowed to park a motor vehicle within any parking space specifically designated for public parking and fueling of AFVs unless the motor vehicle is an AFV fueled by electricity, natural gas, methanol, propane, gasoline blended with at least 85% ethanol (E85), or other fuel the Oregon Department of Energy approves. Eligible AFVs must also be in the process of fueling or charging to park in the space. A person found responsible for a violation is subject to traffic violation penalties. (Reference Oregon Revised Statutes 811.587)
Renewable Fuels Mandate	All gasoline sold in the state must be blended with 10% ethanol (E10). Gasoline with an octane rating of 91 or above is exempt from this mandate, as is gasoline sold for use in certain non-road applications. Gasoline that contains at least 9.2% agriculturally derived ethanol that meets ASTM specification D4806 complies with the mandate. For the purpose of the mandate, ethanol must meet ASTM specification D4806. The governor may suspend the renewable fuels mandate for ethanol if the Oregon Department of Energy finds that a sufficient amount of ethanol is not available. All diesel fuel sold in the state must be blended with at least 5% biodiesel (B5). For the purpose of this mandate, biodiesel is defined as a motor vehicle fuel derived from vegetable oil, animal fat, or other non-petroleum resources, that is designated

<table>
<tr><td></td><td>as B100 and complies with ASTM specification D6751. Renewable diesel qualifies as a substitute for biodiesel in the blending requirement. In addition, diesel fuel blends sold between October 1 and February 28 may contain additives to prevent congealing or gelling. At any time, the Oregon Department of Energy may request a certificate of fuel analysis for biodiesel sold at any non-retail and wholesale biodiesel dealer. Reference Oregon Revised Statutes 646.913 - 646.923 and Oregon Administrative Rules 603-027-0410 and 603-027-0420)</td></tr>
<tr><td colspan="2">Biofuel Impact Studies Requirement</td></tr>
<tr><td>Zero Emission Vehicle (ZEV) Deployment (2)</td><td>The Oregon Department of Energy (ODOE) will monitor state ZEV adoption goal progress for registered vehicles, new vehicle purchases, and the state fleet. The state established the following goals for vehicle registrations:
• By 2020, 50,000 vehicles will be ZEV;
• By 2025, 250,000 vehicles will be ZEV; and
• By 2030, 25% of vehicles will be ZEV.
In addition, the state established the following goals for new vehicle purchases:
• By 2030, 50% of all new vehicle purchases will be ZEV; and
• By 2035, 90% of all new vehicle purchases will be ZEV.
By 2029, all state fleet vehicles should be ZEVs. ODOE must submit a biannual report by September 15 on the status of ZEV adoption. If ZEV adoption goals are not met, ODOE report must include strategies for increased adoption rates.
(Reference Oregon Revised Statutes 283.327 and 283.398)</td></tr>
<tr><td>Support for Renewable Natural Gas (RNG)</td><td>The Oregon Public Utility Commission (PUC) will develop rules for RNG distribution programs for both small and large utilities. Rules must include reporting requirement guidelines and a rate recovery costs process. The PUC must establish rate caps for small natural gas utilities.
The PUC has established voluntary RNG target distribution goals for large utilities that participate in the RNG program under the following schedule:
<table>
<tr><td>Calendar Years</td><td>Percent RNG</td></tr>
<tr><td>2020-2024</td><td>5%</td></tr>
<tr><td>2025-2029</td><td>10%</td></tr>
<tr><td>2030-2034</td><td>15%</td></tr>
<tr><td>2035-2039</td><td>20%</td></tr>
<tr><td>2040-2044</td><td>25%</td></tr>
<tr><td>2045-2050</td><td>30%</td></tr>
</table>
(Reference Oregon Oregon Revised Statutes 757.396)</td></tr>
<tr><td>Clean Transportation Fuel Standards</td><td>The Oregon Department of Environmental Quality (DEQ) administers the Oregon Clean Fuels Program (Program), which</td></tr>
</table>

	requires fuel producers and importers to register, keep records of, and report the volumes and carbon intensities of the fuels they provide in Oregon. Phase 2 of the Program, implemented in 2016, requires fuel suppliers to reduce the carbon content of transportation fuels. In 2020, a new goal was implemented to reduce the carbon content of transportation fuels by 20% below 2015 levels by 2030, and 25% below 2015 levels by 2035. DEQ must conduct rulemaking for the Program to support greater plug-in electric vehicle (PEV) adoption. DEQ must also develop a method to aggregate and monetize all eligible PEV credits in the Program to assist in achieving the state goal of 50,000 registered PEVs in Oregon by 2020. For more information, see the DEQ Oregon Clean Fuels Program website. (Reference Executive Order 20-04, 2020, Oregon Revised Statutes 468A.266, and Oregon Administrative Rules 340-253)
Biofuels Program Impact Studies	The Oregon Department of Energy (ODOE) must conduct periodic impact studies related to the biofuels industry in the state. These studies should evaluate such criteria as: jobs created; current and projected feedstock availability; amount of biofuels blends produced and consumed in the state; cost comparison of biofuels blends and petroleum fuel; environmental impacts; and the extent to which Oregon producers import biofuels or biofuels feedstocks from outside the state. ODOE issued the first Biofuels Impact Study in 2010 and will conduct a study every two years through January 1, 2025. (Reference Oregon Revised Statutes 469B.400)

APPENDIX I: Proposed Lewis County Facility

Washington State Level Policies (from AFDC, 2022)	
State Fuel Standard	
Clean Fuel Standard (E3SHB 1091)	The Washington Clean Fuel Standard began the rulemaking process in July 2021. Rules will be proposed in Summer 2022, and adopted in Winter 2022. Program enforcement will begin in January 2023. The CFS aims to decrease state greenhouse gas emissions by 4.3 million metric tons/year by 2038. It will require fuel suppliers to reduce the carbon intensity of their transportation fuels to 20% below 2017 levels by: ● Improving the efficiency of their fuel production processes ● Producing and/or blending low-carbon biofuels into the fuel they sell ● Purchasing credits generated by low-carbon fuel providers, including electric vehicle charging providers
Low Carbon Fuel Standard	The Washington Department of Ecology will develop rules to establish a Clean Fuels Program (Program) that reduces the overall carbon intensity of transportation fuels used in the state by 20% below 2017 levels by 2035. The Program standards must be based on the carbon intensity of gasoline, gasoline substitutes, diesel, and diesel substitutes. The Program must go into effect no later than January 1, 2023. (Reference House Bill 1091, 2021)
Tax Credits	
None	N/A
Tax Exemptions	
Alternative Fuel Vehicle (AFV) Retail Sales and Use Tax Exemption	The retail sales and state use tax of 6.5% does not apply to the sale or lease of new or used passenger vehicles, light-duty trucks, and medium-duty passenger AFVs. AFVs powered by natural gas, propane, hydrogen, and electricity are eligible. Vehicles must not have a selling price plus trade-in property value that exceeds $45,000 for new vehicles and $30,000 for used vehicles. The maximum eligible amount for used purchased or leased vehicles is $16,000. The maximum

	eligible amounts for new purchased or leased vehicles are as follows: Newly Purchases or Leased Year — Maximum Amount Through July 31, 2021 — $25,000 August 1, 2021 - July 31 2023 — $20,000 August 1, 2023 - July 31 2025 — $15,000 For more information, see the Renewable Energy/Green Incentives section of Washington Department of Revenue's Incentives Programs website. (Reference Revised Code of Washington 82.12.9999)
Natural Gas Tax Exemptions	Compressed, liquefied, and renewable natural gas used as a transportation fuel are exempt from public utility taxes. In addition, natural gas distribution businesses are eligible for an exemption for machinery and equipment used to produce natural gas for transportation fuel. This exemption is available quarterly as a remittance. (Reference Revised Code of Washington 82.08.02565 and 82.16.310)
Biodiesel Feedstock Tax Exemption	Waste vegetable oil, specifically cooking oil gathered from restaurants or commercial food processors, used by an individual to produce biodiesel for personal use is exempt from state sales and use taxes. The purchaser must provide the seller with an exemption certificate from the Washington Department of Revenue. (Reference Revised Code of Washington 82.08.0205 and 82.12.0205)
Direct Payments	
None	N/A
Funding Programs	
Green Transportation Grant Program	The Washington State Department of Transportation (WSDOT) offers grants for projects that reduce the carbon intensity of the Washington

Newly Purchases or Leased Year	Maximum Amount
Through July 31, 2021	$25,000
August 1, 2021 - July 31 2023	$20,000
August 1, 2023 - July 31 2025	$15,000

<table>
<tr><td></td><td>transportation system, including fleet electrification, modification or replacement of facilities to facilitate fleet electrification and hydrogen fueling, upgrades to electrical transmission and distribution systems, and construction of charging and fueling infrastructure. To be eligible, a transit authority must provide matching funding for that project that is at least equal to 20% of the total cost of the project. For more information, including funding availability and program dates, see the WSDOT Green Transportation Capital Grants (Reference Revised Code of Washington 47.66.120)</td></tr>
<tr><th colspan="2">Government Amendment Processes</th></tr>
<tr><td>None</td><td>N/A</td></tr>
<tr><th colspan="2">State Fleet AFV Requirements</th></tr>
<tr><td>Fleet Electric Vehicle (EV) Procurement Requirements</td><td>State executive and small-cabinet agency fleets must procure electric vehicles (EVs) to replace light-, medium-, and heavy- duty internal combustion engine (ICE) vehicles once they reach the end of their useful life. Fleets must achieve the following procurement requirements:
<table>
<tr><td></td><td colspan="3">Percentage of Procured Vehicles that Must be EVs</td></tr>
<tr><td>Year</td><td>Light Duty</td><td>Medium Duty</td><td>Heavy Duty</td></tr>
<tr><td>2025</td><td>40%</td><td>No requirement</td><td>No requirement</td></tr>
<tr><td>2030</td><td>75%</td><td>30%</td><td>50%</td></tr>
<tr><td>2035</td><td>100%</td><td>55%</td><td>75%</td></tr>
<tr><td>2040</td><td>100%</td><td>100%</td><td>100%</td></tr>
</table>
When EVs are not available for medium- and heavy-duty vehicles, fleets must prioritize the lowest-emission, cost-effective option available, and may procure plug-in hybrid vehicles and hydrogen fuel cell electric vehicles.
(Reference Executive Order 21-04,2021)</td></tr>
</table>

Biodiesel Use Requirement	At least 20% of all diesel fuel used to fuel state agency vehicles, vessels, and construction equipment must be biodiesel. The Washington Department of Enterprise Services (WDES) must assist state agencies by coordinating the purchase and delivery of biodiesel if requested, using long-term contracts if necessary, to secure a sufficient and stable supply of biodiesel. For state agencies complying with the U.S. Environmental Protection Agency's ultra-low sulfur diesel (ULSD) mandate, at least 2% biodiesel (B2) must be used as an additive to ULSD for lubricity, provided that the use of a lubricity additive is appropriate and that performance and cost are comparable with other available lubricity additives. All agencies using biodiesel must submit annual consumption reports to WDES. (Reference Revised Code of Washington 43.19.642 and 43.19.646)
Alternative Fuel Use Requirement	All state agencies must, to the extent practicable, use 100% biofuels or electricity to operate all publicly owned vehicles. Agencies must prioritize all-electric vehicles (EVs) when leasing or purchasing new vehicles, and all trips that may feasibly use EVs must employ them. For vehicle classes without EV model options, agencies must prioritize the most cost-efficient, low-emission vehicle option available. Agencies may substitute natural gas or propane for electricity or biofuel if the Washington State Department of Commerce (Department) determines that electricity and biofuel are not reasonably available. Practicability and measures of compliance are defined in rules adopted by the Department. The governor has established a cross-agency Governing Council, which must adopt and implement standards, measures, targets, and tools to support agencies in reducing greenhouse gas emissions and prioritizing EV adoption. In addition, all local government agencies must, to the extent practicable, use 100% biofuels or electricity to operate all publicly owned vehicles. Transit agencies using compressed natural gas and engine retrofits that would void vehicle warranties are exempt from this requirement. To allow the motor vehicle fuel needs of state and local government to be satisfied by Washington-produced biofuels, the Washington Department of Enterprise Services and local governments may contract in advance and execute contracts with public or private producers and suppliers for the purchase of appropriate biofuels. Agencies may substitute natural gas or propane in vehicles if the Department determines that biofuels and

	electricity are not reasonably available. Practicability and measures of compliance are defined in rules adopted by the Department. (Reference Executive Order 18-01, 2018, Washington Administrative Code 194-28 and 194-29, and Revised Code of Washington 43.19.647 and 43.19.648)
Low Carbon Fuel and Fuel-Efficient Vehicle Acquisition Requirement	Washington state agencies must consider purchasing low carbon fuel vehicles or converting conventional vehicles to use low carbon fuels when financially comparable over the vehicle's useful life. Low carbon fuels include hydrogen, biomethane, electricity, or natural gas blends of at least 90%. State agencies must achieve an average fuel economy of 36 miles per gallon (mpg) for passenger vehicle fleets in motor pools and leased conventional vehicles. State agencies must also purchase low carbon fuel vehicles or, when purchasing new conventional vehicles, achieve an average fuel economy of 40 mpg for light-duty passenger vehicles and 27 mpg for light-duty vans and sport utility vehicles. When calculating average fuel economy, emergency response vehicles, passenger vans with a gross vehicle weight rating of 8,500 pounds or greater, off-road vehicles, low carbon fuel vehicles, and vehicles driven less than 2,000 miles per year are excluded. (Reference Revised Code of Washington 43.19.622)
Blend Requirements	
Renewable Fuel Standard	At least 2% of all diesel fuel sold in Washington must be biodiesel or renewable diesel. This requirement will increase to 5% 180 days after the Washington State Department of Agriculture (WSDA) determines that in-state feedstocks and oil-seed crushing capacity can meet a 3% requirement. Renewable diesel is defined as a diesel fuel substitute produced from non-petroleum renewable sources, including vegetable oils and animal fats, meets the federal registration requirements for fuels and fuel additives and ASTM specification D975. At least 2% of the total gasoline sold in the state must be denatured ethanol. The ethanol requirement increases if the Washington Department of Ecology determines that this increase will not jeopardize continued attainment of federal Clean Air Act standards, and WSDA

	determines that the state can economically support the production of higher ethanol blends. All state agencies with jurisdiction over renewable fuel infrastructure, specifically storage, blending, and dispensing equipment, are required to expedite related application and permitting processes. The governor may suspend these requirements by Executive Order if the standard is temporarily technically or economically infeasible, or poses a significant risk to public safety. (Reference Revised Code of Washington 19.112.010 and 19.112.110 -19.112.180)
Biofuel Blend Dispenser Labeling Requirement	Pumps dispensing ethanol or biodiesel blends must have a label that specifies the percentage of ethanol or biodiesel present in the fuel. Ethanol pumps distributing between 1% and 10% must include a label stating that the fuel "contains up to 10% ethanol" and those distributing blends greater than 10% must be labeled with the capital letter E, followed by the numerical value volume of ethanol and the word "ethanol." Pumps dispensing biodiesel blends of 5% (B5) or less must include a label stating that the fuel "may contain up to five percent biodiesel" and those distributing blends greater than 5% must be labeled with the capital letter B, followed by the numerical value volume of biodiesel and the words "biodiesel" or "biodiesel blend." (Reference Revised Code of Washington 19.112.020, and Washington Administrative Code 16-662-115)
E85 Definition	E85 motor fuel is defined as an alternative fuel that is a blend of ethanol and hydrocarbon, of which the ethanol portion is 75-85% denatured fuel ethanol by volume and complies with the most current ASTM specification D5798. (Reference Revised Code of Washington 19.112.010)
Biodiesel Definition	Biodiesel fuel is defined as a monoalkyl ester of long chain fatty acids derived from vegetable oils or animal fats for use in compression-ignition engines and meets the requirements of the ASTM specification D6751. (Reference Revised Code of Washington 19.112.010 and 43.19.643)
Alternative Fuel Vehicle Labeling Requirement	Every alternative fuel automobile, truck, motorcycle, motor home, or off-road vehicle must bear a reflective placard from the National Fire Protection Association indicating that the vehicle is powered by an alternative fuel. Alternative fuels include propane and natural gas. (Reference

	Revised Code of Washington 46.37.467)
Biofuel Impact Study Requirement	
Biofuel Quality Program	The Washington State Department of Agriculture (WSDA) Biofuels Quality Program tests and assesses biofuel quality and quantity to resolve any quality issues before the product reaches the consumer. WSDA samples biofuel throughout the state, monitors and tracks the quality of biofuel, and works with producers and manufacturers to help supply the highest biofuel quality fuel available to consumers. The goal of the program is to create equity in the biofuel marketplace for refiners, suppliers, distributors, and retailers, and protect consumers. (Reference Revised Code of Washington 19.112.005 -19.112.080)
Miscellaneous	
Alternative Fuel Vehicle (AFV) Emissions Inspection Exemption	AFVs powered exclusively by electric, natural gas, and propane vehicles are exempt from state emissions control inspections. Plug-in hybrid electric vehicles that obtain a U.S. Environmental Protection Agency fuel economy rating of at least 50 miles per gallon during city driving are also exempt from these inspections. (Reference Revised Code of Washington 46.16A.060)
Alternative Fuel Vehicle (AFV) Car Share Pilot Program	The Washington State Department of Transportation (WSDOT) will develop a pilot program to provide AFV use opportunities to underserved and low-income communities and to those without easy access to transportation corridors. (Reference Revised Code of Washington 47.04.355)
Alternative Fuel Vehicle (AFV) Technical Assistance and Education Program	The Washington State University (WSU) Energy Program must establish and administer a technical assistance and education program on the use of AFVs for public agencies, including state and local governments. For more information, visit the WSU Energy Program Green Transportation Program website. (Reference Revised Code of Washington 28B.30.903)
Biodiesel Storage Regulations	Underground storage tank (UST) regulations apply to all biodiesel blends with the exception of 100% biodiesel (B100). If a UST owner increases the percentage of biofuel in a petroleum UST, they must prove that all UST materials are compatible with that product. UST owners must

<table>
<tr><td></td><td>submit an Alternative Fuel Installation or Conversion Checklist when the percentage of ethanol in gasoline is greater than 10% or the biodiesel percentage in diesel is greater than 20%. For more information, see the Department's Biodiesel in Underground Storage Tanks (PDF) fact sheet. (Reference Washington Administrative Code 173-360)</td></tr>
<tr><td>Zero Emission Vehicle (ZEV) Sales Requirements and Low Emission Vehicle (LEV) Standards</td><td>Washington adopted the California motor vehicle emissions and compliance requirements specified in Title 13 of the California Code of Regulations. The Washington Department of Ecology adopted rules to implement these emissions standards for passenger cars, light-duty trucks, and medium-duty passenger vehicles, known as the Clean Car Law. For more information, see the Washington Clean Car Standards website. (Reference Revised Code of Washington 70.120A.010 and 70.120A.020 and Washington Administrative Code 173-423-010 - 173-423-150)</td></tr>
<tr><td>Alternative Fuel Vehicle Annual Fee</td><td>Owners of natural gas vehicles (NGVs) and propane powered vehicles are required to pay an annual license fee, based on gross vehicle weight rating (GVWR), instead of motor fuel excise taxes. The fee is calculated as follows:
<table>
<tr><th>GVWR</th><th>Fee</th></tr>
<tr><td>Less than 10,000 pounds (lbs.)</td><td>$45</td></tr>
<tr><td>10,001 - 18,000 lbs.</td><td>$80</td></tr>
<tr><td>18,001 - 28,000 lbs.</td><td>$110</td></tr>
<tr><td>28,001 - 36,000 lbs.</td><td>$150</td></tr>
<tr><td>More than 36,000 lbs.</td><td>$250</td></tr>
</table>
To determine the actual annual license fee imposed per registration year, multiply the appropriate dollar amount given in the above schedule by the motor vehicle fuel tax rate in cents per gallon effective on July 1 of the preceding calendar year, and divide the resulting amount by $0.12. There is an additional $5 handling fee for each license issued.

(Reference Revised Code of Washington 82.38.075)</td></tr>
</table>

Biofuels Production and Distribution Contracts	Conservation districts, public development authorities, municipal utilities, and public utility districts may enter crop purchase contracts to produce, sell, and distribute biodiesel produced from Washington feedstocks, cellulosic ethanol, and cellulosic ethanol blended fuels for utility and public use. Additionally, municipal utilities and public utility districts may produce and distribute biodiesel, ethanol, and ethanol blended fuels. (Reference Revised Code of Washington 35.21.465, 35.92.440, 54.04.190, and 89.08.570)
Renewable Natural Gas and Renewable Hydrogen Fuel Sales Regulations	Public utility districts are authorized to sell renewable natural gas and renewable hydrogen to facilities that condense or dispense natural gas or renewable hydrogen for use as a motor fuel. Renewable natural gas is defined as methane gas or other hydrocarbons derived from organic materials. Renewable hydrogen is defined as hydrogen produced using renewable resources as the source of the hydrogen and the source for the energy input into the production process. (Reference Revised Code of Washington 54.04.190)
State Emissions Reductions Requirements	Washington State must limit greenhouse gas (GHG) emissions to achieve the following reductions: • By 2020, reduce overall GHG emissions in the state to 1990 levels; • By 2035, reduce overall GHG emissions in the state to 25% below 1990 levels; and • By 2050, reduce overall emissions to 50% below 1990 levels or 70% below the state's expected emissions that year. Every other year, the Washington Departments of Ecology and Commerce must report to the governor and legislature on the total GHG emissions in the state for the previous two years. For more information, see the Washington Department of Ecology Climate Change and the Environment website. (Reference Revised Code of Washington 70A.45.020)