ASPHALT PLANT RENEWABLE PROPANE PROOF OF CONCEPT AND LCA DEVELOPMENT

Final Report

Oregon Department of Transportation

ASPHALT PLANT RENEWABLE PROPANE PROOF OF CONCEPT AND LCA DEVELOPMENT

by

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16. Abstract: A recent analysis of Oregon DOT activities found that the largest source of greenhouse gas emissions comes from asphalt concrete pavement (ACP) production. An average of 65,200 MT CO2e is released into the atmosphere each year from the production of ACP used by ODOT. One of the key recommendations from the aforementioned research study was to substitute renewable fuels for fossil fuels at ACP-production plants. In September 2022, ODOT partnered with the Asphalt Pavement Association of Oregon (APAO) and an Oregon-based asphalt contractor to test the viability of using renewable propane at a mobile asphalt plant. The project provided an ideal comparison between fossil and renewable propane since the contractor used conventional (fossil) propane before and after the test section, the weather was consistent, and the paving type and tonnage were identical among the shifts. The contractor reported no noticeable differences between conventional and renewable propane – except for the price. The major objective of this study was to perform a life-cycle assessment (LCA) for renewable propane to determine its environmental impact on asphalt production. The outputs from the renewable propane LCA were incorporated into another asphalt LCA tool (Emerald ECO label) to quantify the impact of using renewable propane on the CO2 emissions of a typical asphalt plant in Oregon. The outputs allowed for an apples-to-apples comparison between fossil propane and renewable propane. These outcomes will enable asphalt plant operators and asphalt customers across the nation to make more informed decisions on where, or how, to focus sustainability efforts.

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Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	millimeters squared	mm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.093	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	m^2	meters squared	1.196	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	kilometers squared	km^2	km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
	NOTE: Volumes greater than 1000 L shall be shown in m^3.								
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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1.0 INTRODUCTION

The Oregon Department of Transportation (hereinafter, "ODOT" or "Agency") is responsible for constructing and maintaining Oregon's statewide transportation system – a network of 4,052 miles of highway and 1,733 bridges along with numerous park-and-ride facilities, rest-stops, railroads, and airports [1]. The Oregon Transportation Commission, ODOT's policy board with members appointed by the governor, approved a Strategic Action Plan (SAP) that directs the Agency to ensure a transportation system "that is modern, reliable, and serves all Oregonians in an efficient, environmentally responsible, and safe manner" [2]. A key component of the SAP is to reduce greenhouse gas (GHG) emissions, both transportation-system user emissions (e.g., transportation electrification) and emissions from ODOT's operations (e.g., embodied carbon of purchased materials).

ODOT's Sustainability Program administered a contract with Good Company – an Oregon-based sustainability consulting firm – to inventory GHG emissions from ODOT's operations. This initial inventory measured ODOT's carbon footprint by calculating all Scope 1 and Scope 2 emissions, as well as a select few Scope 3 emission categories. Calculations used activity data from fiscal years (FY) 2016 – 2019, which were reported on an annual basis as well as an average across the four years. This inventory is referred to as the "FY 16-19 GHG Inventory" in this document.

The FY 16-19 GHG Inventory found that, on average, 117,500 MT CO2e come from ODOT's annual procurement of asphalt concrete pavement (ACP), concrete products, and cement, as well as steel products and fuel used by contractors during construction [3]. This amount is equivalent to over 26,000 gasoline-powered passenger vehicles driven for a year [4]. The single largest source of GHGs for ODOT comes from ACP production since it is significantly the most commonly used material for pavement construction and maintenance in Oregon. An average of 65,200 MT CO2e is released into the atmosphere each year from ODOT's use of ACP [3].

An advisory group of internal and external subject-matter experts agreed upon 40 recommendations for ODOT to pursue to reduce its operational carbon footprint. One of the more impactful recommendations was to substitute renewable fuels for fossil fuels at industry plants [3].

In September 2022, ODOT partnered with the Asphalt Pavement Association of Oregon (APAO) and Rocky Mountain Construction, an Oregon-based asphalt contractor, to test the viability of using renewable propane at a mobile asphalt plant. The project provided an ideal comparison between fossil and renewable propane since the contractor used conventional (fossil) propane before and after the test section, the weather was consistent, and the paving type and tonnage were identical among the shifts. The contractor reported no noticeable differences between conventional and renewable propane, a successful proof of concept.

Also, in 2022, ODOT applied for and was awarded funding through the Federal Highway Administration's (FHWA) Climate Challenge [5]. One of the projects ODOT used the funding for was to develop a life cycle inventory (LCI) of the renewable propane used at the previously mentioned asphalt plant, with the intention being the LCI could be used for a comparative life cycle assessment (LCA) between renewable and fossil fuels specifically used in ACP production. The outputs from the renewable propane LCA were incorporated into another asphalt LCA tool (Emerald ECO label) to quantify the impact of using renewable propane on the CO2 emissions of a typical asphalt plant in Oregon [6]. The outputs allowed for an apples-to-apples comparison between fossil propane and renewable propane when used at a mobile asphalt plant.

This research report discusses the LCI development and comparative asphalt production LCA results. These outcomes will enable asphalt plant operators and asphalt customers across the nation to make more informed decisions on where, or how, to focus sustainability efforts.

1.1 Key Objectives of the Study

The study's main goals are to:

- Identify the impact of using renewable propane (FOG [fats, oils, greases] and camelina-based) on asphalt concrete mixture production emissions.
- Quantify the impact of increased recycled asphalt pavement (RAP) content on asphalt plant emissions.
- Compare the impact of increased RAP and renewable propane use on asphalt plant emissions.
- Assess the major factors that control the A1-A3 emissions of asphalt materials.

2.0 METHODOLOGY, ANALYSIS, AND RESULTS

In this study, the impact of using renewable propane at mobile asphalt plants on asphalt production emissions was quantified by using life cycle assessment (LCA) methods. The results of the fuel LCA conducted for renewable propane by the Renewable Energy Group (REG), Inc. were modified for the pilot production case mentioned in the previous section to achieve realistic carbon emission values for asphalt production in Oregon. Those modified values were used in the Emerald ECO label tool to quantify the impact of using renewable propane on the CO2 emissions for aggregate drying (drum heating) and binder heating during asphalt production. Finally, based on the calculated percentage reduction in carbon emissions, the impact of using renewable fuels on the overall annual Oregon DOT emissions was quantified by integrating the results of this study with results from a previous ODOT research project [3].

2.1 MODIFYING THE REG FUEL LCA RESULTS FOR OREGON

In 2018, REG petitioned the Environmental Protection Agency (EPA) to approve a pathway for producing renewable petroleum gas (LPG) from fats, oils, greases, and biogenic waste (called FOG). REG's facility in Geismar, Louisiana, produces naphtha and LPG fuel products by using a process that involves hydrotreating with grid electricity, natural gas, and hydrogen. REG submitted the data related to the production of the LPG to the EPA. EPA conducted an analysis to calculate the life cycle of greenhouse gas emissions associated with the fuel production pathway. EPA published its final report with the results of its fuel life cycle assessment (LCA) in 2018 and concluded that LPG produced from biogenic waste FOGs through the REG Geismar process qualifies as an advanced biofuel according to the EPA and Clean Air Act (CAA) implementing regulations [7]. To have the EPA accept a renewable fuel as an advanced biofuel, it needs to reduce GHG emissions by at least 50 percent when compared to its fossil counterpart.

EPA's fuel LCA had the following components:

- **Feedstock transport:** A conservative assumption of 300-mile transportation of feedstock from restaurants and meat plants by a heavy-duty truck was followed.
- **Feedstock pretreatment:** Biogenic waste FOGs were processed to remove natural minerals to prevent them from deactivating the downstream hydrotreating catalysts. Electricity and natural gas were used for the process.
- **Fuel production:** The REG fuel production process is in the category of a hydrotreating process, which was already analyzed for March 2010 and 2013 Renewable Fuel Standard (RFS) rules and the April 2017 REG Geismar determination. The final results for renewable propane production emissions were reported in [7]. This study uses those values to calculate the cradle-to-gate emission values for renewable propane production.
- **Fuel distribution:** The biofuel transportation from the production facility to the distribution terminal was assumed to include 26 miles by barge, 360 miles by pipeline, and 25 miles by truck. This is a general assumption used by the EPA for all renewable fuel LCAs. The same analysis also assumed that the biodiesel was transported 50 miles by truck from the terminal to the distribution station. Emissions factors were calculated by using those distances and modes of transportation.

In this study, the transportation path after the REG Geismar terminal was modified to reflect the distance between the terminal and the mobile asphalt plant in Crescent, Oregon (the location of the pilot asphalt production plant). Figure 1 shows the actual transportation path for the renewable fuel used for the pilot production in Crescent, Oregon. The renewable fuel was first moved to NGL Supply Company in Mississippi via four cargo tanks loaded on four trucks from the REG terminal in Geismar, Louisiana (a distance of 147 miles). The weights of the renewable propane in four cargo tanks were 4,357, 8,551, 8,590, and 8,614 gallons. The cargo tanks were loaded on a freight train to be transported to Eugene, Oregon (a distance of 3,740 miles), where they were loaded on trucks by the Star Tank Lines company to be delivered to the portable asphalt plant in Crescent, Oregon (a distance of 101 miles).

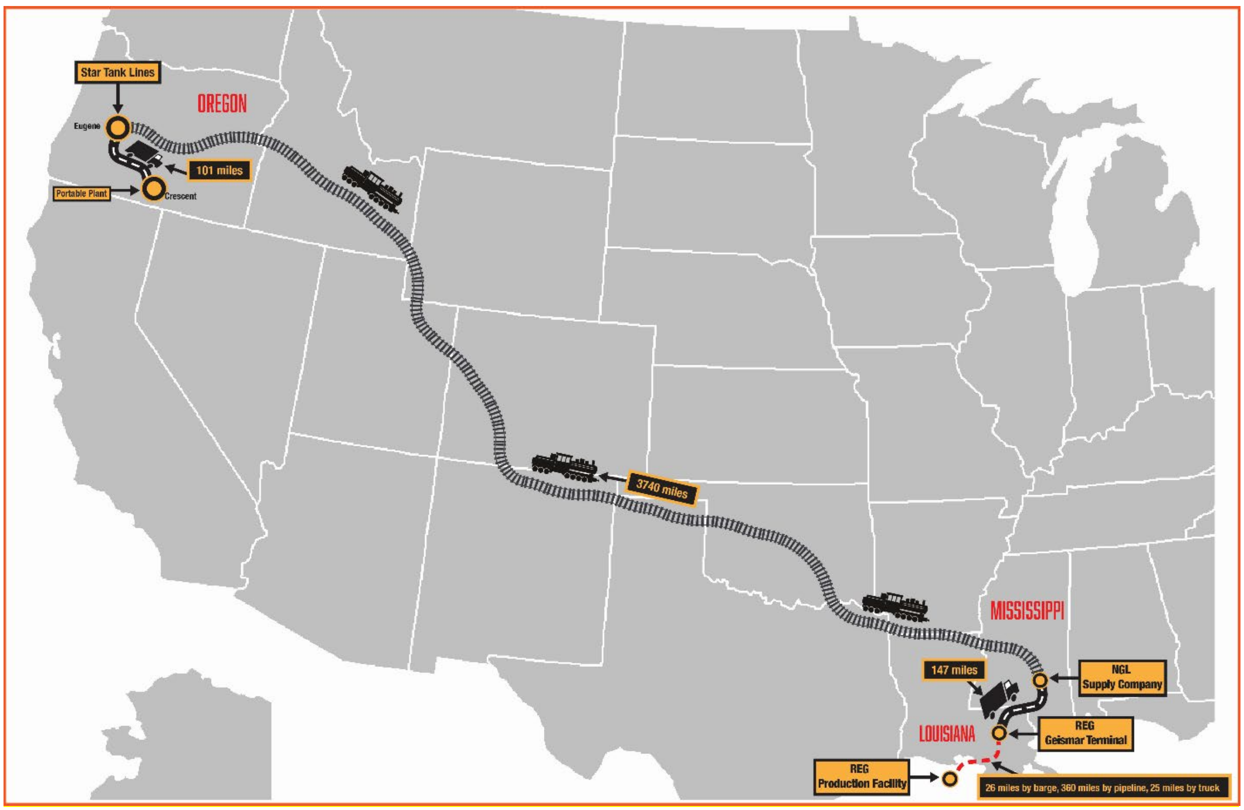


Figure 1. The transportation path for the renewable propane used for the pilot asphalt production in Crescent, Oregon.

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) models, a tool that examines the life-cycle impacts of vehicle technologies, fuels, products, and energy systems, were used to determine each transportation step's carbon intensity (CI) [8]. The CI value for the truck transportation for 50 miles already included in the REG results was replaced with the 147-mile truck transportation distance (actual distance between the terminal and the distribution station) CI values calculated using the GREET models. Then, the CI values for the 3,740-mile freight train and 101-mile truck transportation were included using the GREET models.

- **Fuel use (tailpipe):** The LPG non-carbon dioxide emissions factors developed for the March 2010 RFS rule were used in the REG Geismar fuel LCA to calculate the tailpipe emissions for renewable propane. Details are described in [7].

The calculated CO2 emission results for every fuel LCA step outlined above are given in Figure 2. It can be observed that the "feedstock pretreatment and fuel production" step has the most significant emissions, while the tailpipe emissions are low for renewable propane. The total CO2 emissions from the 3,740-mile train transportation of all propane in four cargo tanks were calculated to be 1.95 gCO2eq/MJ by using the GREET models for a diesel-powered freight train. This number would have been 0.72 gCO2eq/MJ and 1.15 gCO2eq/MJ for renewable diesel and electric-powered freight trains, respectively. However, it should be noted that renewable diesel and electric-powered freight trains are not currently common in the U.S., but this reality might change in the near future.

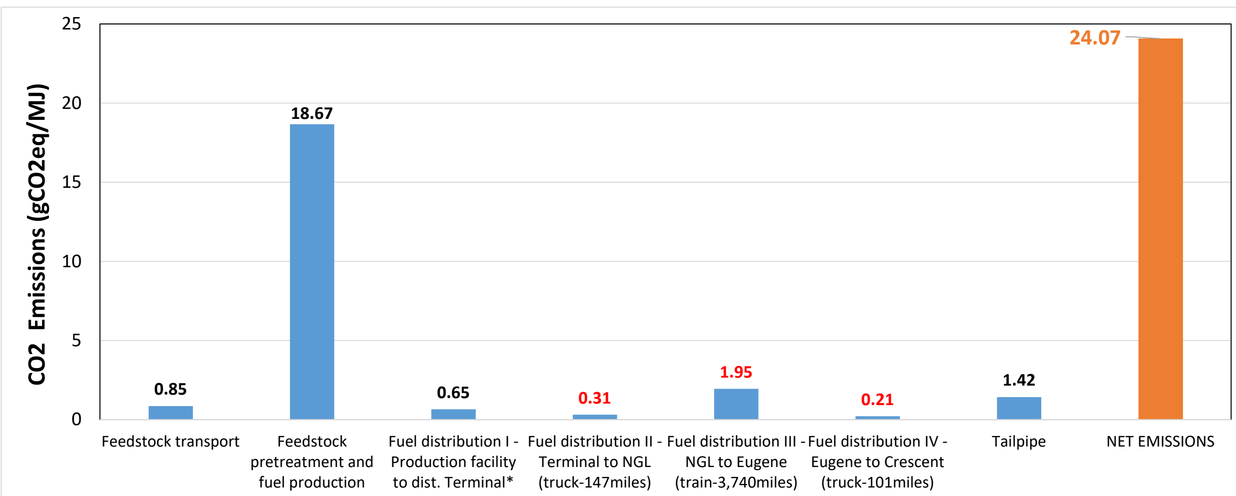


Figure 2. CO2 emissions for renewable propane for the Crescent, Oregon pilot study.

In Figure 3, the results of the renewable propane LCA for REG Geismar were compared to the results for Martinez Renewables, LLC [9]. For this comparison, the EPA assumptions for renewable fuel LCA were followed, and the emissions released during fuel transportation to Oregon were not included. Those typical fuel transportation assumptions are stated under the fuel distribution bullet above (first paragraph). It can be observed from the comparison plot that all stages have close numbers except the tailpipe stage (also called fuel use). The reason for the difference is the difference in the dataset and model used for the tailpipe emission calculations. REG Geismar LCA study was conducted in 2018, while the Martinez Renewables, LLC study was conducted in 2023. The more recent data and models available in GREET 2022 [8] were used for the Martinez study, which resulted in lower CO2 emission values. However, in this study, the higher 1.42 gCO2eq/MJ number from the earlier REG study was used to reflect a higher CI and be more conservative when comparing emissions.

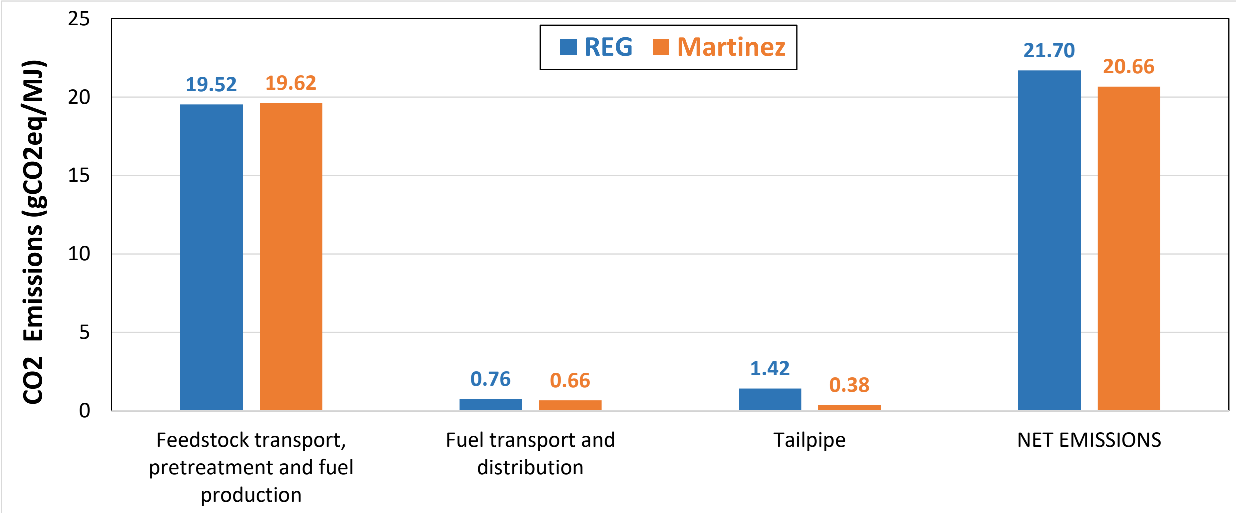


Figure 3. EPA's renewable propane CO2 emissions comparison for REG and Martinez companies.

2.2 THE IMPACT OF USING RENEWABLE PROPANE ON ASPHALT PLANT PRODUCTION EMISSIONS

In this phase of the study, the Emerald Eco-Label, NAPA's verified Environmental Product Declaration (EPD) tool, was used to quantify the impact of using renewable propane on asphalt production emissions. Analyses were conducted for the following asphalt mix type with 20% RAP commonly used in Oregon for roadway construction. There are two ongoing ODOT research studies focusing on increasing RAP content to 40% in Oregon [10, 11]. For this reason, a 40% RAP production case was also simulated in Emerald Eco-Label to determine its impact on production emissions. The 20% and 40% RAP cases were simulated for both renewable and fossil fuel cases to quantify the impact of all those factors on production emissions. The research study conducted by Coleri et al. [12] showed that, for Oregon asphalt mixtures, a binder content increase of 0.3% is required to increase the RAP content of the asphalt mixture by 10% to avoid any premature cracking failures. Based on the findings of that research study, the cases with 20% RAP were simulated with 6% total binder content, while the 40% RAP cases were simulated with a 6.6% binder content.

An ongoing effort by various oil companies is to produce renewable fuels from a crop called Camelina. 40% of this crop is oil and can be used for fuel production, while the remaining components can be used as animal meal, which further reduces its environmental impact [13]. The crop does not require significant water and can be grown virtually anywhere (even in areas with limited sunlight). Due to all those benefits, the renewable propane produced from the camelina oil has a significantly smaller CI. The fuel LCA conducted by the EPA for the camelina propane by the Sustainable Oils Company indicated that the CI would be 11.4 gCO2eq/MJ. This number can be directly compared to the numbers given in Figure 3 (21.7 gCO2eq/MJ for REG and 20.66 gCO2eq/MJ for Martinez). Details of the study can be accessed in this report [13]. Although Camelina-based renewable propane is not commonly produced and used in the U.S., it might become a low-carbon alternative in the near future, according to the comments from several stakeholders contacted during this study. For this reason, asphalt production LCA analysis for Camelina-based renewable propane was also included in this study in addition to renewable propane - REG Geismar-pilot production fuel produced from FOG and fossil propane. It should be noted that this study did not consider the land-use effect on the calculated emissions, which is expected to increase the reported 11.4 gCO2eq/MJ emission value. However, the impact of land use on fuel LCA was not considered in any of the studies provided in this report, and it is still a controversial concept. For this reason, EPA is also not requiring the inclusion of the land use concept in fuel LCAs yet.

The properties of the asphalt mixtures and other details used for the asphalt LCA are given as follows:

- Level 3 mix with PG64-22 binder and dense gradation and 1/2 inch NMAS
- 20% vs 40% RAP (two cases)
- 0 mile RAP truck distance - initial processing or storage location is on-site
- Natural Stone-Quarry Rock from the Asphalt Pavement Association of Oregon (APAO) source
- 6% binder content (Virgin+RAP binder) for the 20% RAP mix and 6.6% binder content for the 40% RAP mix
- 50-mile distance for binder transportation from the terminal
- No binder additives
- No mix additives
- Production with i) renewable propane - REG Geismar-pilot production fuel produced from FOG versus ii) renewable propane – Camelina-based versus iii) fossil propane.

The production fuels used for asphalt binder heating, aggregate drum heating, water and electricity use, and plant equipment diesel use were entered into the Emerald Eco-Label tool. At the portable asphalt plant in Crescent, Oregon, propane was used to heat the drum and the asphalt binder oil tanks. The cases for renewable fuel-FOG (pilot project case), renewable fuel-Camelina, and fossil propane were simulated for both 20% and 40% RAP cases. For the fossil propane case, 83.2 gCO2eq/MJ CI value was used for the analysis. This CI value was adapted from a fuel LCA study conducted by Baldwin et al. and sponsored by the Propane Education and Research Council, USDOE Office of Energy Efficiency and Renewable Energy (EERE) [14]. The total Global Warming Potential (GWP) values for all simulated cases are shown in Figure 4. Figure 5 shows the GWP values separated into the Material extraction and supply (A1), Transportation to plant (A2), and Asphalt mix production (A3) components.

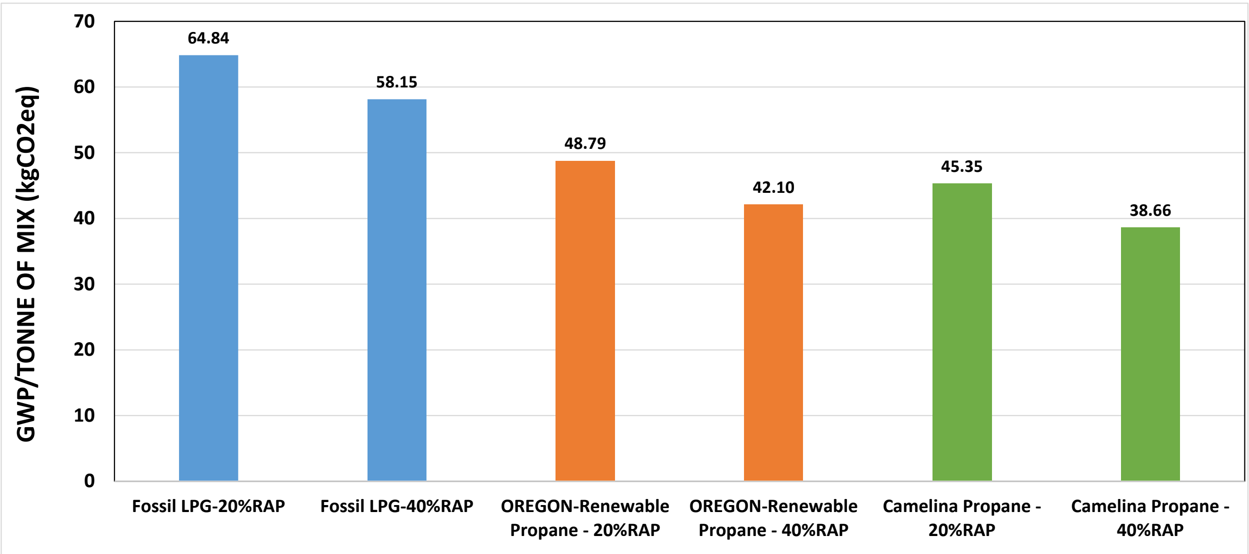
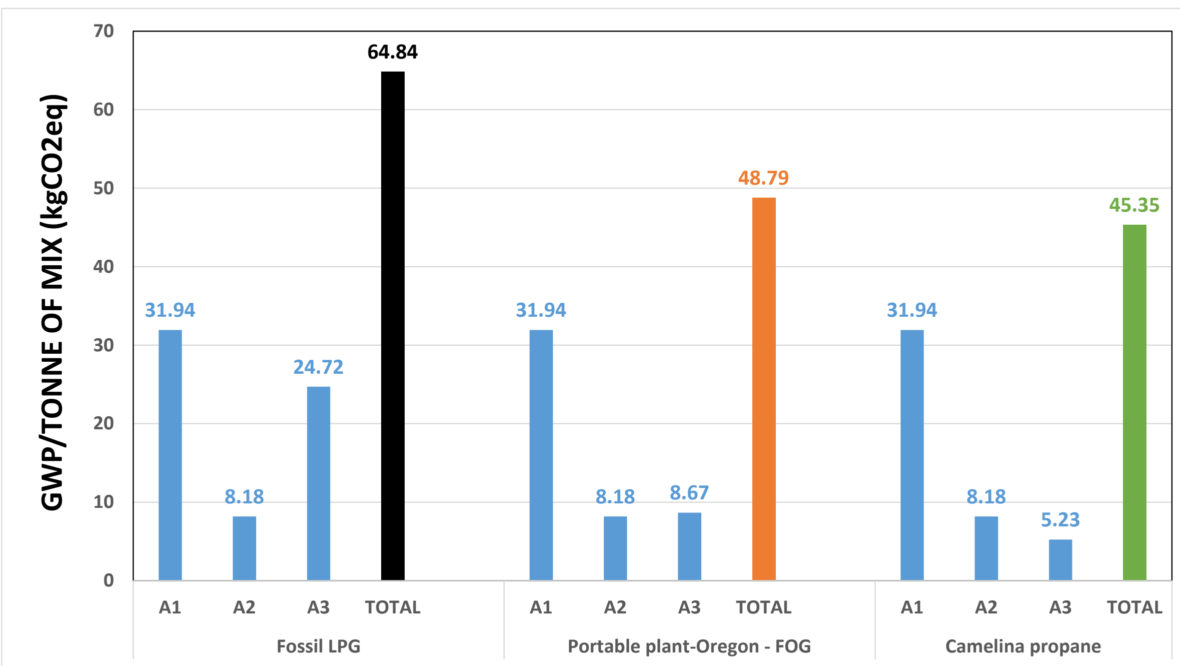
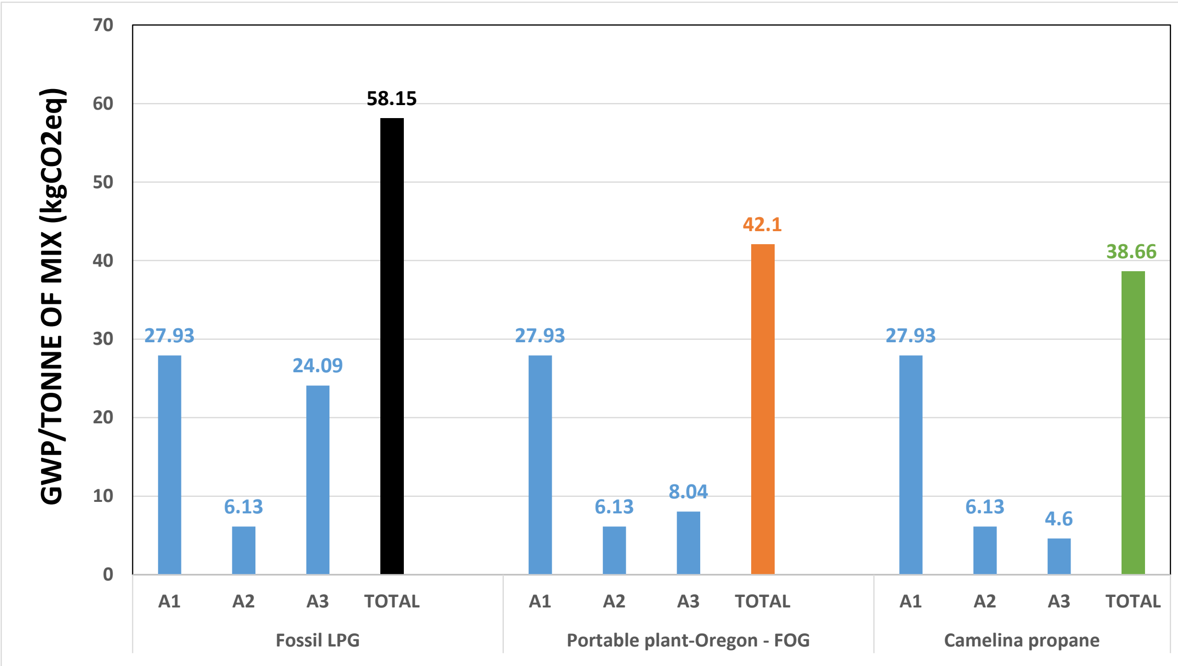


Figure 4. Total production GWP values for all simulated cases.



(a)



(b)

Figure 5. GWP values separated for Material extraction and supply (A1), Transportation to plant (A2), and Asphalt mix production (A3) components. (a) 20% RAP cases (b) 40% RAP cases.

It can be observed from Figure 4 that using renewable propane-FOG creates a 24.8% {[(64.84-48.79)/64.84]x100} reduction in GWP values for the 20% RAP asphalt mixes that are commonly used in Oregon. This reduction percentage increased to 27.6% when the 40% RAP asphalt mix results were used. When the Camelina renewable propane results are compared to the fossil propane, these percentages increased to 30% and 33.5% for the 20% and 40% RAP cases, respectively. These results suggested that using renewable propane just for drying the aggregates (drum) and heating the asphalt binder can significantly reduce the overall GWP of asphalt mixture production.

When only the asphalt mix production stage (A3) is considered (Figure 5), a 65% reduction (from 24.72 gCO2eq/MJ to 8.67 gCO2eq/MJ) in GWP was observed when renewable propane-FOG was used instead of fossil propane. This percentage increased to 78.8% when renewable propane-camelina was used. These results clearly show the significance of using renewable fuels for asphalt mix production to reduce GHG emissions and environmental impact.

According to the results presented in Figure 4, increasing RAP content from 20% to 40% (without sacrificing long-term pavement performance) can lead to a 10.3%, 13.7%, and 14.8% reduction in GWP of the plant production process for the fossil propane, renewable propane-FOG, and renewable propane-Camelina cases, respectively. By increasing the RAP content to 40% and also using the Camelina-based renewable propane, in the long run, it can be possible to reduce the GWP of asphalt mix production from 64.84 gCO2eq/MJ to 38.66 gCO2eq/MJ (a 40.4% reduction in GWP).

2.3 THE IMPACT OF USING RENEWABLE PROPANE ON OVERALL OREGON DOT EMISSIONS

A recent analysis of Oregon DOT activities found that the largest source of greenhouse gas emissions comes from asphalt concrete pavement (ACP) production since it is significantly the most commonly used pavement construction material in Oregon. According to the report [3], an average of 65,200 MT CO_2e is released into the atmosphere each year from the production of ACP used by ODOT, while the total CO_2 emissions across all analyzed sources was 182,592 MT. This result suggested that about 36% of ODOT's annual GHG emissions are from asphalt mixture production. According to the findings reported in the previous section, switching from fossil propane to renewable-FOG propane can create about a 24.8% reduction in production emissions. If this same percentage reduction is assumed to be the case for other plants, including plants powered by natural gas, 65,200MT can be reduced to 49,030MT. This translates into an 8.8% reduction in overall annual ODOT emissions. This percentage increases to 10.7% when Camelina-based renewable propane is used for asphalt mix production. These results suggested that using renewable propane significantly reduces ODOT's annual GHG emissions. However, it should be noted that these analyses are just for using renewable propane for drum and binder heating. Using renewable fuels at other stages of material extraction, material supply, and transportation can result in additional reductions in GHG emissions.

3.0 CONCLUSIONS

The major conclusions of the study are listed below:

- Renewable propane produced from FOG has a CI (21.7 gCO2eq/MJ), which is almost one-fourth of fossil propane (83.2 gCO2eq/MJ). Renewable propane produced from Camelina has a CI (11.4 gCO2eq/MJ) that is almost one-eight of fossil propane. These significantly lower CI values for renewable fuels suggest that using renewable fuel options can create significant reductions in GHG emissions for the pavement life cycle (including construction, material production, use phase, and others).
- Using renewable propane-FOG creates a 24.8% reduction in GWP values for the 20% RAP asphalt mixes that are commonly used in Oregon. This reduction percentage increased to 27.6% when the 40% RAP asphalt mix results were used. When the Camelina renewable propane results are compared to the fossil propane, these percentages increased to 30% and 33.5% for the 20% and 40% RAP cases, respectively. These results suggested that using renewable propane (or other renewable fuels) just for drying the aggregates (drum) and asphalt binder can significantly reduce the overall GWP of asphalt mixture production.
- When only the asphalt mix production stage (A1) is considered (Figure 5), a 65% reduction (from 24.72 gCO2eq/MJ to 8.67 gCO2eq/MJ) in GWP was observed when renewable propane-FOG was used instead of fossil propane. This percentage increased to 78.8% when renewable propane-camelina was used.
- Increasing RAP content from 20% to 40% (without sacrificing long-term pavement performance) can lead to a 10.3%, 13.7%, and 14.8% reduction in GWP of the plant production process for the fossil propane, renewable propane-FOG, and renewable propane-Camelina cases, respectively.
- By increasing the RAP content to 40% and also using the Camelina-based renewable propane, in the long run, it can be possible to reduce the GWP of asphalt mix production from 64.84 gCO2eq/MJ to 38.66 gCO2eq/MJ (a 40.4% reduction in GWP).
- Using FOG-based renewable propane can create an 8.8% reduction in overall annual ODOT emissions. This percentage increases to 10.7% when Camelina-based renewable propane is used for asphalt mix production. These results suggested that using renewable propane significantly reduces ODOT's annual CO2 emissions. However, it should be noted that these analyses are just for using renewable propane for drum and binder heating. Using renewable fuels at other stages of material extraction, material supply, and transportation can result in additional reductions in GHG emissions.

3.1 Future Work

The results of this study point out the importance of renewable fuels in reducing the carbon footprint of asphalt pavements. However, the study just focused on portable asphalt plants and propane. Since the majority of the asphalt plants are stationary and use natural gas, the impact of using renewable natural gas on the overall GHG emissions for asphalt mixture production should be evaluated in a future study. A future study should also quantify the impact of using renewable diesel and electricity to power construction and plant vehicles on the overall GHG emissions. These findings, along with the findings from this study, can help state DOTs make more accurate and reliable plans for reducing the environmental impact of their organizations.

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