# Final Report – Logistics Optimization Models Employing First Mile-Last Mile Analysis

# Southeast Partnership for Advanced Renewables from Carinata (SPARC)

**July 2021**

**PREPARED FOR**

**Southeast Partnership for Advanced Renewables from Carinata**

# Southeast Partnership for Advanced Renewables from Carinata (SPARC)

# Final Report – Logistics Optimization Models Employing First Mile-Last Mile Analysis

**Submitted to:**

USDA-NIFA Grant #2016-11231

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July 2021

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| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| **4. Title and Subtitle**<br>Southeast Partnership for Advanced Renewables from Carinata (SPARC) – Final Report – Logistics Optimization Models Employing First Mile-Last Mile Analysis | | **5. Report Date**<br>July 2021<br>**6. Performing Organization Code** |
| **7. Author(s)**<br>Robert Hooker, Seckin Ozkul | | **8. Performing Organization Report No.** |
| **9. Performing Organization Name and Address**<br>Monica Wooden Center for Supply Chain Management & Sustainability, Muma College of Business, University of South Florida (USF) | | **10. Work Unit No.**<br>**11. Contract or Grant No.** |
| **12. Sponsoring Agency Name and Address**<br>Southeast Partnership for Advanced Renewables from Carinata (SPARC) | | **13. Type of Report**<br>Final Report on Logistics Optimization Models Employing First Mile-Last Mile Analysis<br>**14. Sponsoring Agency Code** |
| **15. Supplementary Notes** | | |

**16. Abstract**

The overall goal of this project was to perform a logistics optimization analysis for the supply chain of Carinata in order to produce jet fuel, diesel, and naphtha. The research provides first mile-last mile logistics optimization of carinata bioproduct supply chains. This project utilized the United States (US) DOT's Volpe National Transportation Systems Center Fuel Transportation Optimization Tool (FTOT) software to optimize logistics costs, environmental impact, and determine optimal routes and modes between supply chain facilities such as: raw material producers, handlers, crushers, bio refineries and end users/customers. During the FTOT process, several steps to the modelling of logistics optimization such as setting origins and destinations (OD), locating potential processing points and identifying optimal transportation modes and routes according to a certain set of constraints. The models reported reveal different movements of carinata co-products through their own respective supply chains.

| 17. Key Words | | 18. Distribution Statement | |
|---|---|---|---|
| Supply chain management, logistics, resilience, Carinata, Fuel Transportation Optimization Tool (FTOT), SPARC | | | |
| **19. Security Classif. (of this report)** | **20. Security Classif. (of this page)** | **21. No. of Pages**<br>56 (Total) | **22. Price** |

**Form DOT F 1700.7** (8-72) Reproduction of completed page authorized

## ACKNOWLEDGEMENTS

The authors express their sincere appreciation to the Southeast Partnership for Advanced Renewables from Carinata (USDA-NIFA Grant #2016-11231) and the USDOT Volpe Center team for input and assistance in making this effort possible.

## EXECUTIVE SUMMARY

Brassica carinata (Ethiopian mustard), a nonfood oilseed brassica, is a dedicated feedstock for renewable jet fuel, diesel and other bi-products. In the southeastern United States carinata can be produced as a cool season crop covering millions of acres of winter fallow land. In addition, the meal from carinata seed can provide a high-protein feed source for livestock. The economic growth potential generated by the creation of this bio-economy is positive.

In order to utilize carinata as a renewable jet fuel source, in the Southeastern United States, supply chain cost and routing estimates, among other performance metrics, needed to be determined. This was accomplished with the analysis performed by Ozkul, Hooker, Mardani, Philippidis (2020). A separate follow on study (Hooker, Ozkul, Mardani, and Philippidis 2020) examined the resilience of multiple carinata supply chains to most-likely disruptions capable of disrupting each network. The present study was performed to extend beyond prior optimization analysis (Ozkul et al. 2020) and assist in developing highly refined, first mile-last mile (FMLM) analysis of multiple carinata supply chains. FMLM analysis is important for gaining greater levels of precision for logistics optimization, which can result in cost and routing adjustments to prior established networks. The results could impact the timing of production, shipment, stakeholder selection, and other key variables necessary for an efficient bio-economy.

A multi-method approach was utilized. First, a combined needs and planning analysis for all co-products in the SPARC effort with geographical and operations-based logistics optimization utilizing the USDOT Volpe Transportation Center's Freight and Fuel Transportation Optimization Tool (FTOT) was performed (Ozkul et al. 2020). The scenarios tested were originally developed with the guidance of the SPARC partners, and are consistent with those discussed in prior research (Ozkul et al. 2020; Hooker et al. 2020). These partners included ARA, CAAFI, and NuSeed (formerly, Agrisoma). In each scenario, a multitude of supply chain (SC) facilities are involved. These SC facilities included raw material producers (RMP), processors (PROC) and end users/destinations (DEST). Once the scenarios were finalized per commercial partner needs, FTOT coding and runs were performed by the research team.

The scenarios developed provided the basis from which to assess the FMLM implications over the geographic footprint covered. These are discussed in detail within this report. More specifically, comparisons of costs, material moved, VMT, fuel burn, and Co2 emissions between the base scenarios and FMLM refinements, along with managerial conclusions, are provided.

# 1 INTRODUCTION

Brassica carinata (Ethiopian mustard), a nonfood oilseed brassica is a dedicated feedstock for renewable jet fuel, diesel and other co-products. In the southeastern United States carinata can be produced as a cool season crop covering millions of acres of winter fallow land. In addition, the meal from carinata seed can provide a high-protein feed source for livestock.

A prior study determined the supply chain and logistics costs across several carinata-based supply chain networks (Ozkul et al. 2020). The previous study highlighted different supply chain alternatives and their respective optimized logistics costs to assist decision makers in determining how investments could be made to ensure the growth of carinata throughout its supply chain. The purpose of the current study is to build upon prior research and develop more refined analysis of first mile-last mile (FMLM) impacts on logistics optimization scenarios. The optimization modelling tool that was used for this study was USDOT Volpe Transportation Center's Freight and fuel Transportation Optimization Tool (FTOT), a policy tool that is being repurposed to perform this in-depth bottoms-up analysis.

## 1.1. BACKGROUND

The Fuel Transportation Optimization Tool (FTOT) was utilized for the purposes of this research. FTOT assumes a three-step supply chain linked via different transportation modes such as roadway (truck), rail, seaborne/marine, etc.

1. Raw material producers (RMP)
2. Processors: Crushers and Biorefineries (PROC)
3. End User Destinations (DEST)

## 1.2. PROJECT OBJECTIVES

The specific project objectives included:

1- Re-assessment of four baseline carinata supply chains determined to be most-likely from prior research

2- Using FTOT, model scenarios and identify optimal transportation modes and routes according to given sets of constraints within the FMLM context

### 1.3. REPORT ORGANIZATION

Chapter one of this report includes the introduction and background regarding the carinata supply chain/logistics optimization. Chapter two comprise literature review, followed by chapter three, which includes the methodology. Chapter four includes scenario development and FTOT runs, and chapter 5 includes FTOT run results. Chapter 6 summarizes the findings and conclusions and Chapter 7 includes the references used.

# 2 LITERATURE REVIEW

The process of determining how the carinata supply chain functions is more than a matter of feasibility. In developing optimization models, Ozkul et al. (2020) determined the best combination of supply chain network nodes from a wide array of feasible locations. The best combination of facilities were the combinations that produced the minimum total costs. This was done using an optimization program that considers capital, operating, and logistics costs from all potential locations simultaneously.

Locating nodes and optimizing the supply chain network for logistics costs represents an important step in planning. Bottlenecks, congestion points and other inadequacies are an accepted and accounted for part of transportation and logistics. However, greater accuracy in the form of FMLM analysis was determined to be needed since studies such Bergmann et al. (2020) showed that last mile alone can account for up to 28% of the total cost of transportation, and this value does not include the first mile component, which also adds approximately 10-12% of the total cost of transportation. As knowledge within SPARC developed, smaller routes between nodes could be connected to the network to provide a better depiction of optimization scenarios (Ozkul et al. 2020). These can result in diversions in shipping routes and costs—examined in the present study—that can have profound impacts.

Techniques like those used in this study, such as linear programming (LP), integer programming (IP), and mixed-integer linear programming (MILP), have long been used to practically implement the simplex algorithm for transportation problems and other supply chain management problems (Tittmann et al., 2010). LPs are systems of equations comprising of an objective function that describes some characteristic that will be optimized, and a series of constraints that restrict variables in the objective function. For transportation problems, the objective function usually represents minimized total costs. Variables describe the amount of material transferred between nodes. Constraints describe rules for how material is allowed to interact with nodes along the supply chain (Anderson et al., 1994).

MILP transportation problems are similarly organized but include variables and constraints to make some nodes optional, based on a fixed cost that is only added to the total costs if the node is used by the model (Bradley, 1977). LP and the related techniques have many applications as they optimize an entire supply chain at once, providing the ability to consider material transfers at several locations, or across specific routes, simultaneously.

LP techniques have been widely used by those studying supply chain transportation to describe overall transportation systems, and to determine the price dynamics between different modes of transportation (Soysal et al., 2012). Similar research has used LP transportation techniques to model the wheat supply chain and potential changes to operations of the Columbia and Snake River System (Jessup et al., 1998).

Several studies have focused on siting facilities associated with production of biofuels in the United States, as new biofuels facilities can present a significant disruption to existing supply chains. A similar model was used by the WGA to assess total biofuels production in the Western United States (Skog et al., 2009). In 2016, a study focused on logistical feasibility for oilseeds grown in Kansas as a biofuels feedstock was performed. This study follows Ozkul et al. (2020) and Hooker et al. (2020) in applying a single-step MILP, from production points modelled as county centroids to potential crusher locations, to selected optimal oilseed crusher locations (Luna Meiners, 2016).

# 3 METHODOLOGY

In assessing FMLM, this study extended the logistics optimization (Ozkul et al. 2020), the purpose of which was to develop a model to translate baseline product scenarios into geospatially explicit results including, but not limited to the following:

- How biorefineries may be sized and spatially distributed
- End-to-end route optimization over a national intermodal network
- Transportation costs associated with each movement
- CO2 emissions associated with transport of feedstock and fuel

A multi-method approach was utilized in this analysis. First, a combined needs and planning analysis for all co-products in the SPARC effort with geographical and operations-based logistics optimization utilizing the U.S. DOT Volpe Center Freight and Fuel Transportation Optimization Tool (FTOT) was performed (Ozkul et al. 2020; Hooker et al. 2020). Discussions with multiple SPARC stakeholders occurred, to include capabilities assessments of the latest version of FTOT available during the analysis window, and ways of balancing such capabilities with needs. The overarching four-stage analytical approach is described in Fig. 3.1.

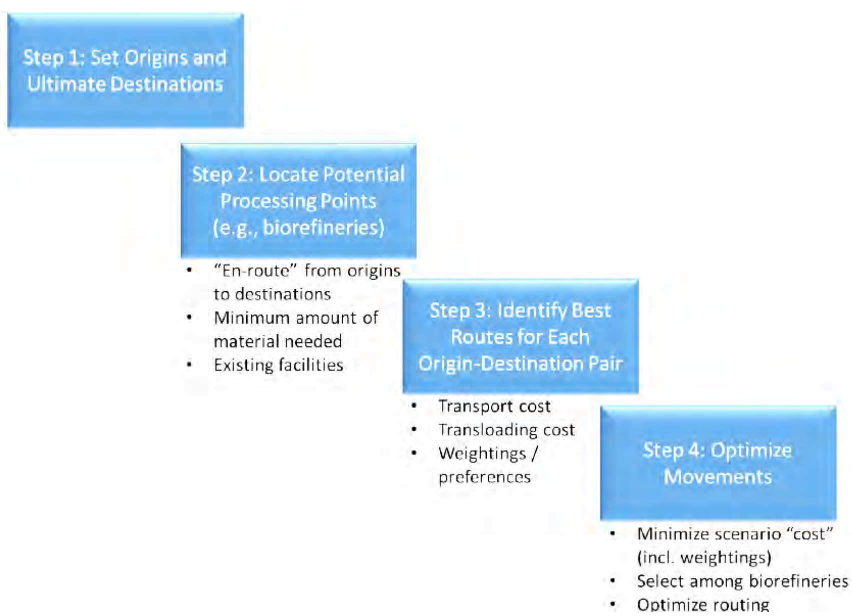



**Fig. 3.1. Analytical Approach of Fuel Transportation Optimization Tool (Adapted from Lewis et al., 2015)**

FTOT v2020.x was utilized for the FMLM analysis. FTOT is a "geospatially explicit scenario testing tool" integrating a Geographic Information System (GIS) with optimizer modules (Lewis et al., 2015). These include ESRI ArcGIS 10.6.1, Python 2.7, the FTOT GitHub data repository, data visualization for graphical outputs (Tableau), and six additional Python modules (i.e., Pint, PULP, COIN-OR, LXML, NetworkX, and ImageIO). XML configuration files are used for initial data input and combined with data from the Alternative Fuels Production Assessment Tool (AFPAT). AFPAT was co-developed by the Massachusetts Institute of Technology (MIT), the FAA, Volpe, and Metron Aviation. It has been updated by MIT and Volpe, with input on data values (e.g, feedstock yields) from researchers at Washington State University, Pennsylvania State University, Idaho National Laboratory, and Oak Ridge National Laboratory (Lewis et al., 2015). AFPAT assembles peer reviewed data on typical yields for various feedstocks, related conversion pathways, conversion efficiencies for particular crops and pathways, and product slate information, as well as notional capital costs for small, medium, and large facilities of each conversion process type (Galligan, 2018).

ESRI ArcMap is a geospatial information system (GIS) that determines potential routing and associated costs between origins and destinations, computed as scenario runs. PuLP is a linear programming optimization model solver which connects ArcMap with the Computational Infrastructure for Operations Research (COIN-OR) module. COIN-OR represents a collection of optimization models for mixed integer programming, including simplex and branch and cut solvers (CLP and CBC, respectively). Functionally, they are used for selecting candidate biorefinery locations, as well as optimize feedstock and fuel across each model pathway. Collectively, these models assess costs across the network links, including transportation costs per ton-mile for road, rail, and waterway. They also include costs per origin-destination pair in pipeline, transloading costs, and additional preferences, such as weighting. FTOT can use sets of geospatially defined endpoint destinations for analysis. The GIS modelling relies upon two layers including commercial airports, as well as DoD facilities (Defense Fuel Supply Points). These layers currently include a non-exhaustive list of around 80 commercial airports and over 50 DFSPs, as per DLA-Energy data. The data flow schematic featured in Fig. 3.2 demonstrates the relationship between each element of the optimizer tool process.

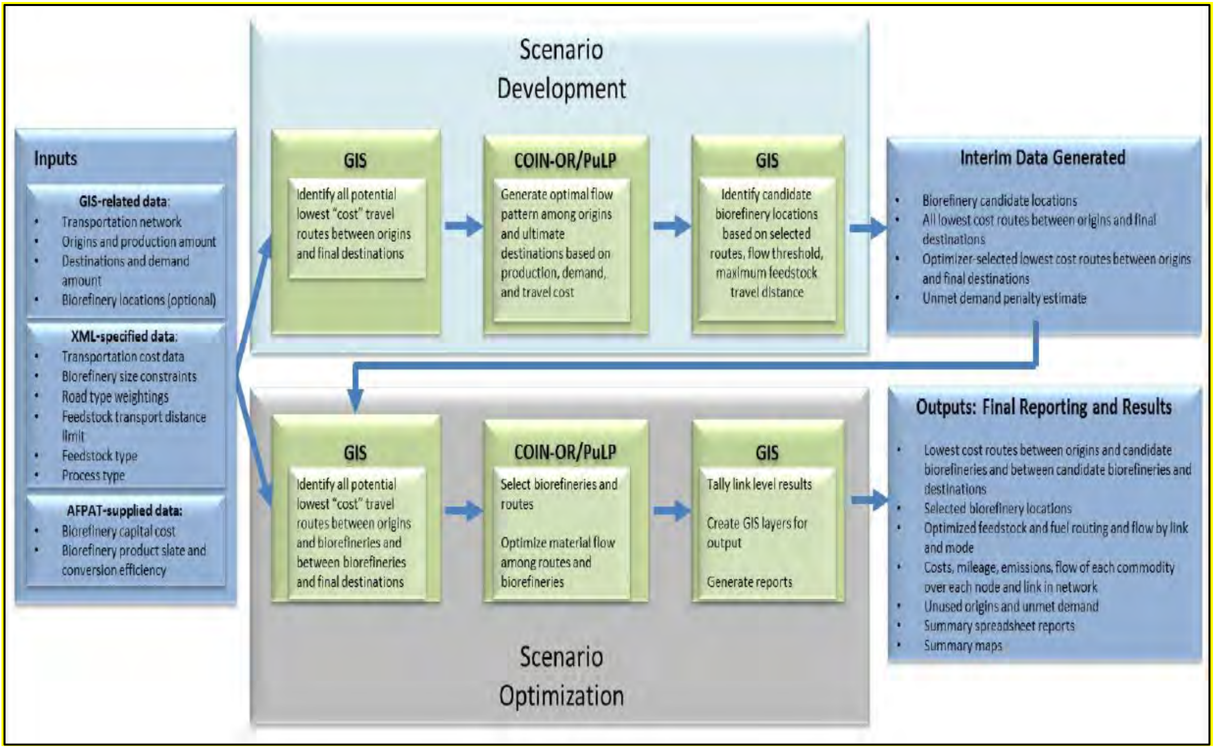



**Fig. 3.2. Analytical Data Flow Schematic for FTOT (Adapted from Lewis et al., 2015)**

FTOT adopts a three-level supply chain linking intermodal road, rail, pipeline, and/or waterway. These stages include: (1) Agricultural production/crop location and co-located pre-processor/aggregation points; (2) Biorefineries which convert feedstocks into fuel, and: (3) Destinations for final SPARC co-products. This is depicted in Figure 3.3. Transport legs can independently function as multimodal or in single mode and may involve multiple co-products.

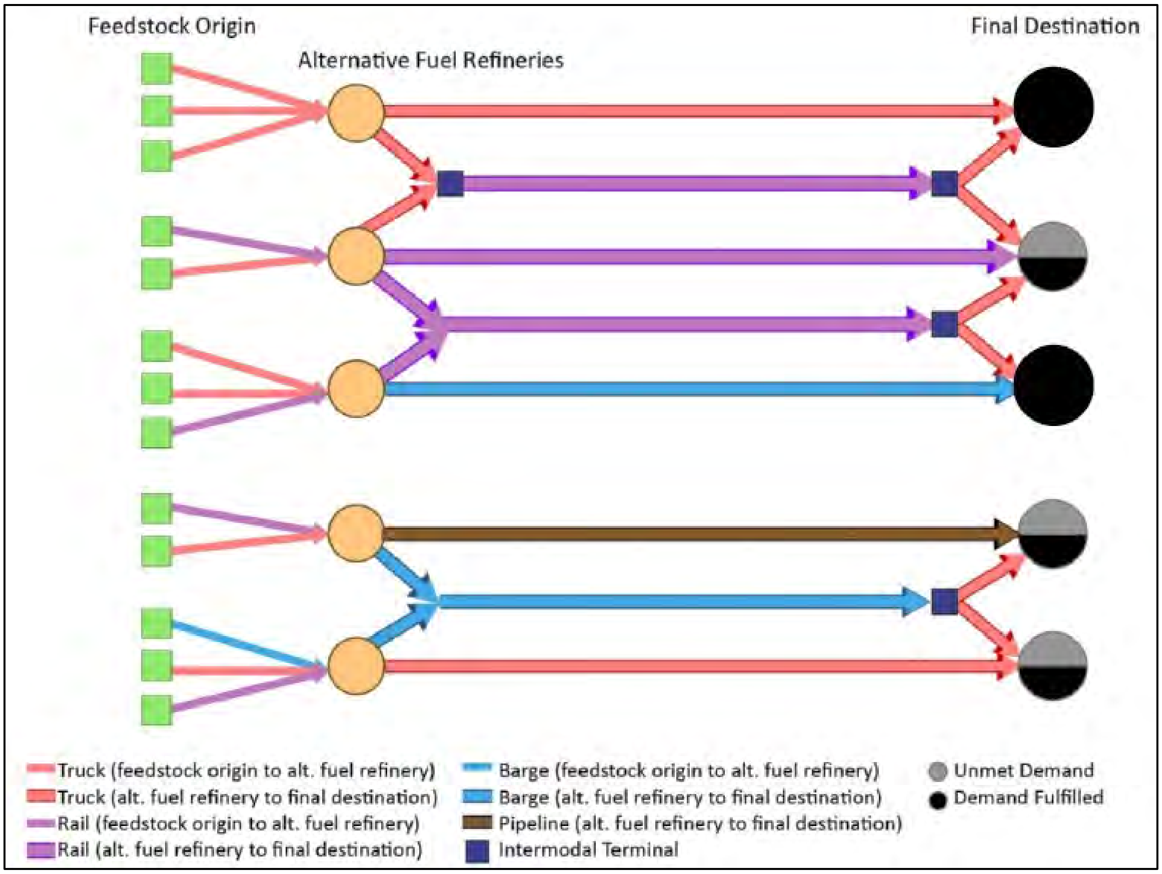



**Fig. 3.3. Levels and Modal Structure of Optimized Network (Adapted from Lewis et al., 2015)**

The previously mentioned intermodal network is built upon multiple data sources. Input data using FTOT can be grid format, county-level, and/or other geospatial data relating to feedstock origins and production amounts. Roadway networks are adapted from the Federal Highway Administration's (FHWA) Freight Analysis Framework (FAF). Railway networks were developed by the Federal Railroad Administration (FRA). FTOT makes use of both Class I and non-Class I railroads by default and are customizable via input data. Waterways are constructed from the Navigable Waterway Links data developed by the United States Army Corps of Engineers and the US DOT Bureau of Transportation Statistics (BTS). FTOT also features the ability to utilize pipeline infrastructure for transporting oil. Intermodal Terminal Facilities are built from data developed by the BTS and consist of over 3,000 facilities across the U.S (Figure 3.4). For the purposes of this research, biorefineries were input as known entities, capable of being handled by FTOT. Location, capacity, and facility names of fixed biorefinery locations were sought and incorporated into the scenarios. The fixed biorefineries were flagged within the biorefinery GIS shapefile with the value of 1 in the “prefunded” field. All prefunded biorefineries have a construction cost of zero, as they are already built. A lower bound would be required if making the decision to invest in new biorefinery facilities, however. The GIS module calculated the optimal pathways to the fixed biorefineries from the pre-processors and from the biorefineries to the destinations. The routes to/from all biorefineries, fixed and candidate locations, with the PuLP optimizer handling the processing.

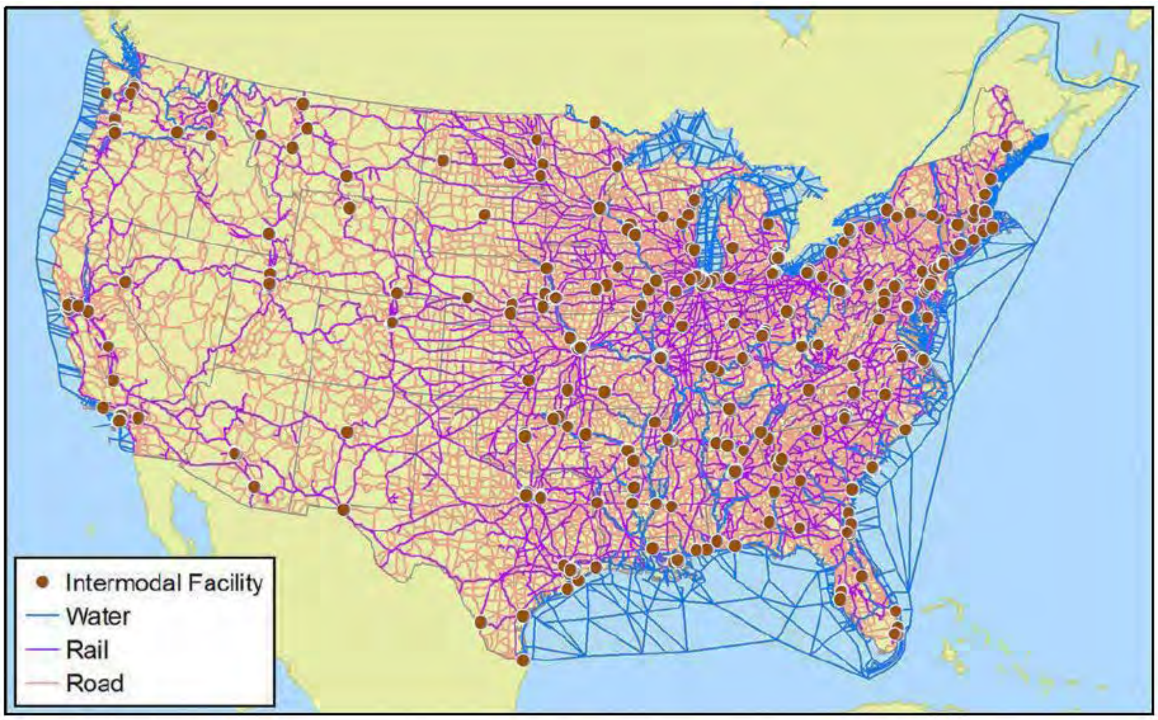



**Fig. 3.4. Intermodal Facilities and Rail, Road, and Water Networks (Adapted from Lewis et al., 2015)**

# 4 SCENARIO DEVELOPMENT AND FTOT RUNS

In this chapter, the details of scenario development and FTOT runs are provided. In total, four scenarios are presented within this chapter. These four scenarios were selected with SPARC stakeholder input on the basis of likelihood of adoption considering the latest developments at the time of analysis. While the scenarios run represent fresh analysis, they are more refined extensions of scenarios optimized in prior research (i.e., Ozkul et al. 2020, and elements of Hooker et al. 2020). Therefore, these scenarios will be referred to using the numbering scheme adopted from prior research. Specifically, FMLM Scenarios 1, 3, 5, and 8 are analysed and compared against their baseline optimization models from prior research. All scenarios assess various aspects of FMLM and econometric analysis for key decision makers.

## 4.1 SCENARIO 1

### *4.1.1 RAW MATERIAL PRODUCERS (RMPS)*

For Scenario 1, six optimal raw material producers including MOBILE, BATROUGE, JACKSONVILLE, KISSIMMEE, ATLANTA and CRGLLMONTGO were considered. These RMPs are presented in Fig. 4.1.


**Fig. 4.1. RMP Locations for Scenario 1**

### *4.1.2. PROCESSORS*

Under the processors involved in Scenario 1, there are crushers and biorefineries. The biorefinery is represented by VALDOSTA and the crusher is represented by EXPRSGRNMS. The locations and names of these processors are presented in Fig. 4.2.


**Fig. 4.2. Biorefinery and Crusher Locations for Scenario 1**

### *4.1.3. End users/Destinations*

Scenario 1 composed of the following end users/destinations SAVGULFSTR, MCO, CHEVCA, SWGAETH, TATELYLE and ADM. The locations and names of these end users/destinations are presented in Fig. 4.3.


**Fig. 4.3. End Users/Destinations for Scenario 1**

### *4.1.4. Scenario 1 - Summary*

Figs. 4.4 and 4.5 represent all of the supply chain (SC) components involved in running Scenario 1 along with the commodities they handle/process. These facilities were coded into ArcGIS per their geo-locations and using the rest of the data supplied through XML files, FTOT logistics optimization runs were performed.

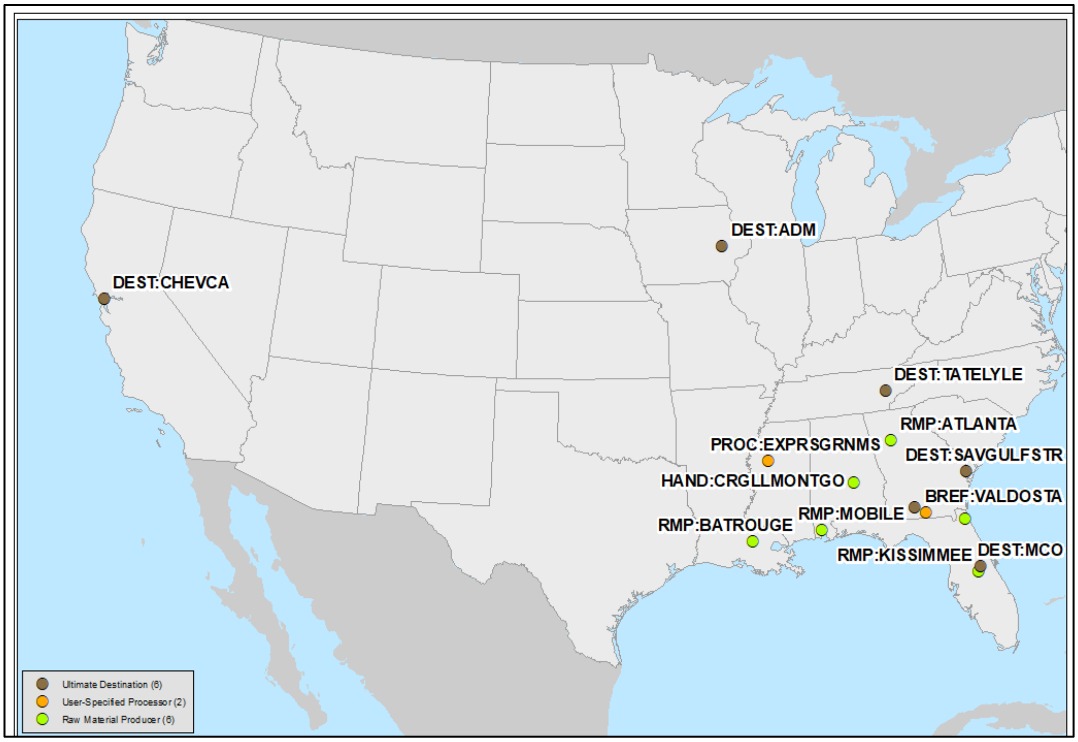



**Fig. 4.4. The Name and Graphical Locations of all Facilities for Scenario 1**

*Raw material producers*

| Facility name | Commodity |
|---|---|
| MOBILE | grease |
| BATROUGE | |
| JACKSONVILLE | |
| KISSIMMEE | |
| ATLANTA | |
| CRGLLMONTGO | Carinata oil seed |

*Processers (Biorefinery and Crusher)*

| Facility name | Commodity |
|---|---|
| VALDOSTA_ Biorefinery | Carinata oil crude |
| | grease |
| | jet |
| | diesel |
| | naphtha |
| EXPRSGRNMS_ Crusher | Carinata oil seed |
| | Carinata oil crude |

*End user*

| Facility name | Commodity |
|---|---|
| SAVGULFSTR | Jet |
| MCO | |
| CHEVCA | Diesel |
| SWGAETH | Naphtha |
| TATELYLE | |
| ADM | |

**Fig. 4.5. Facilities Based on Commodities Information for Scenario 1**

## 4.2 SCENARIO 3

### *4.2.1 RAW MATERIAL PRODUCERS*

For Scenario 3, five optimal raw material producers including PRTWLLHOUSTON, AUSTIN, ELLTROUTLUFKIN, LAFAYETTE, and CRGLLMONTGO were considered. These RMPs are presented in Fig. 4.6.

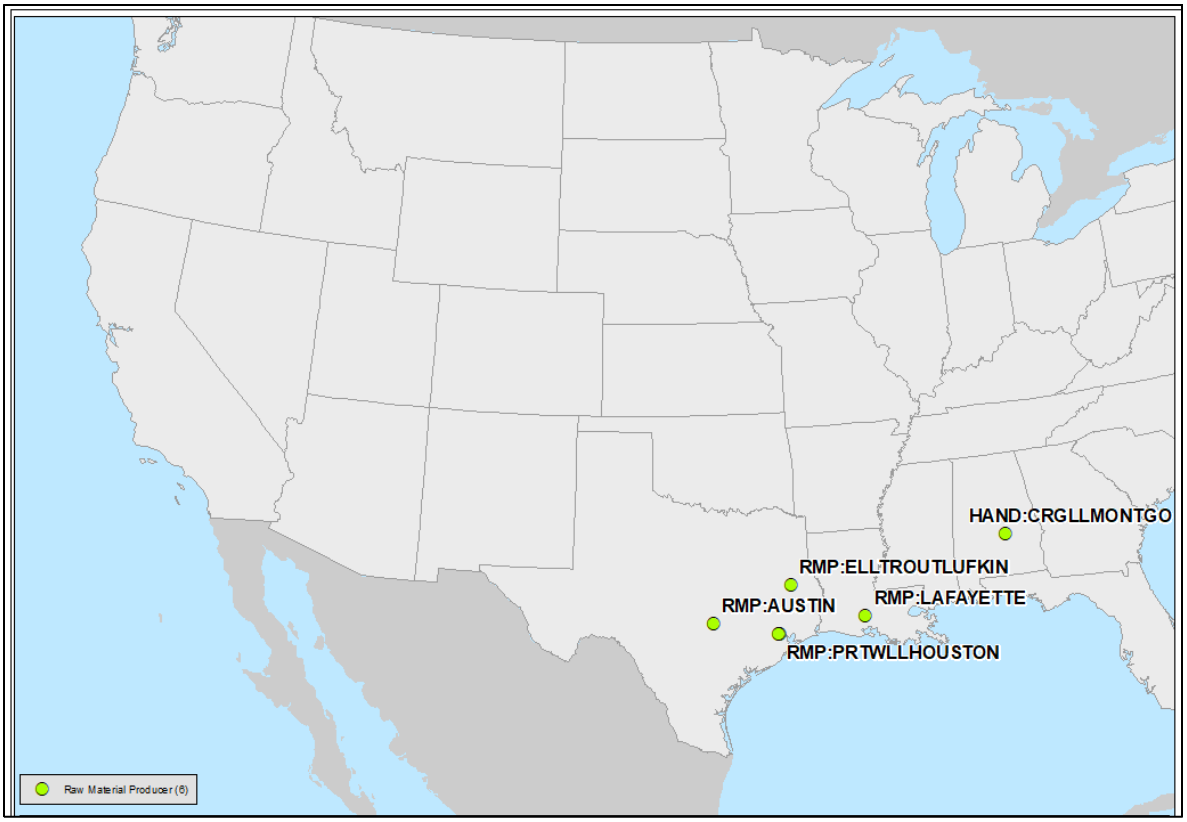



**Fig. 4.6. RMP Locations for Scenario 3**

### *4.2.2. Processors*

Under the processors involved in Scenario 3, there are crushers and biorefineries. The biorefinery is represented by CHVRNMS and the crusher is represented by CRGLLMONTGO. The location and name of these processor are presented in Fig. 4.7.


**Fig. 4.7. Biorefinery and Crusher Locations for Scenario 3**

### 4.2.3. *END USERS/DESTINATIONS*

Scenario 3 composed of the following end users/destinations LAX, CHEVCA, SWGAETH, TATELYLE, and ADM. The locations and names of these end users/destinations are presented in Fig. 4.8.

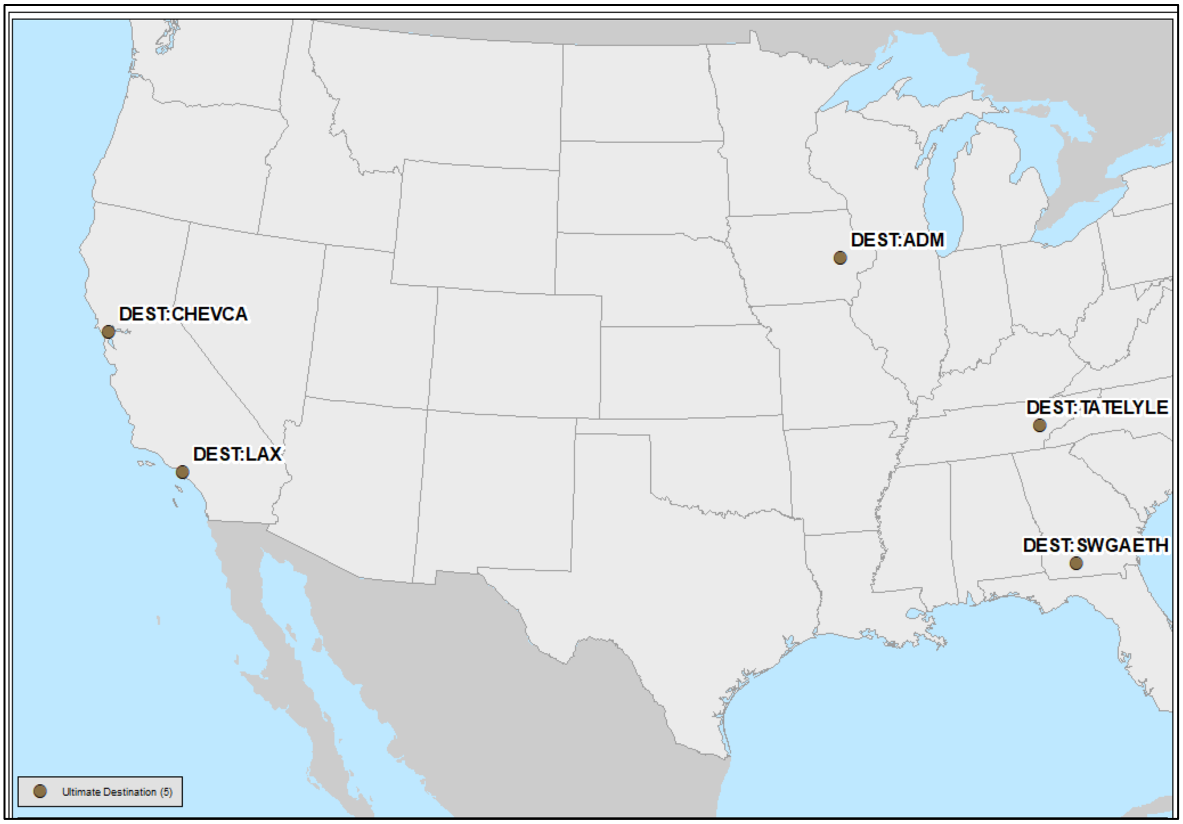



**Fig. 4.8. End Users/Destinations for Scenario 3**

### *4.2.4. Scenario 3* - Summary

Figs. 4.9 and 4.10 represent all of the SC components involved in running Scenario 3 along with the commodities they handle/process. These facilities were coded into ArcGIS per their geo-locations and using the rest of the data supplied through XML files, FTOT logistics optimization runs were performed.

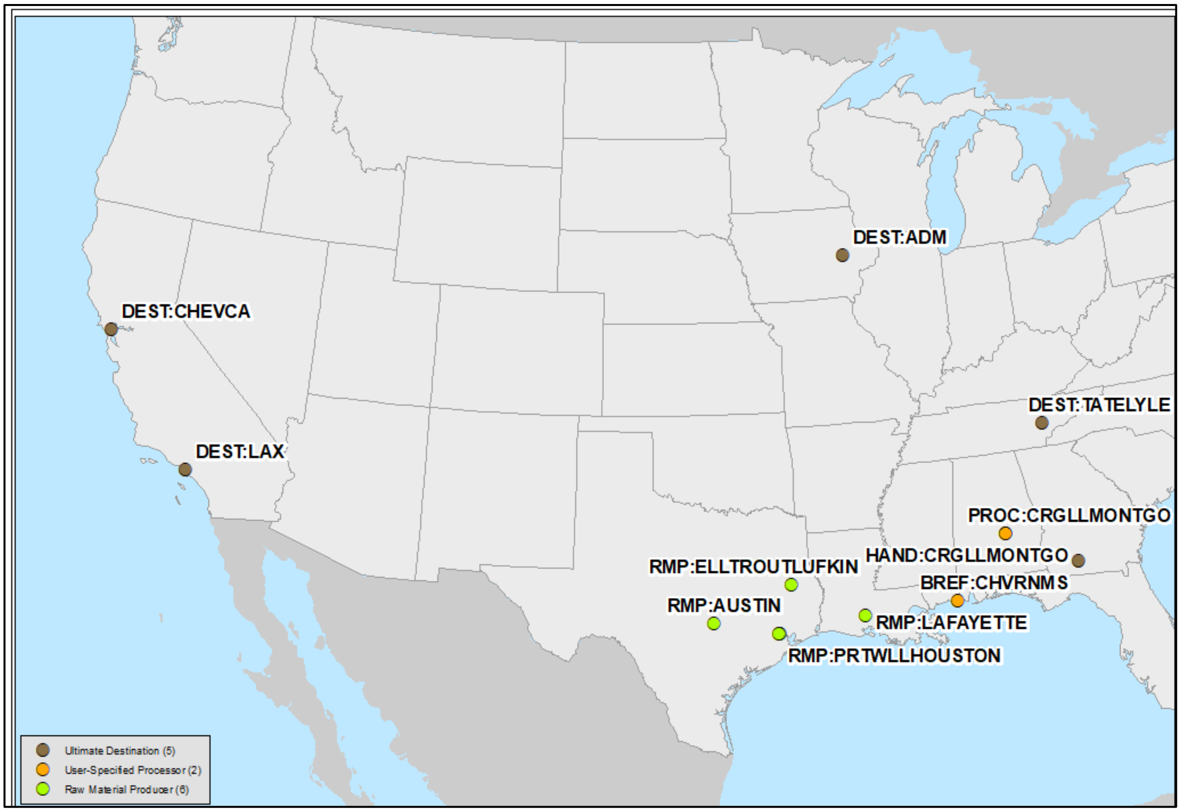



**Fig. 4.9. The Name and Graphical Locations of all Facilities for Scenario 3**

*Raw material producers*

| Facility name | Commodity |
|---|---|
| PRTWLLHOUSTON | grease |
| AUSTIN | |
| ELLTROUTLUFKIN | |
| LAFAYETTE | |
| CRGLLMONTGO | Carinata oil seed |

*Processers (Biorefinery and Crusher)*

| Facility name | Commodity |
|---|---|
| CHVRNMS_ Biorefinery | Carinata oil crude |
| | grease |
| | jet |
| | diesel |
| | naphtha |
| CRGLLMONTGO_ Crusher | Carinata oil seed |
| | Carinata oil crude |

*End user*

| Facility name | Commodity |
|---|---|
| LAX | Jet |
| CHEVCA | Diesel |
| SWGAETH | Naphtha |
| TATELYLE | |
| ADM | |

**Fig. 4.10. Facilities Based on Commodities Information for Scenario 3**

## 4.3 SCENARIO 5

### *4.3.1 Raw material producers*

For Scenario 5, six optimal raw material producers including MOBILE, BATROUGE, JACKSONVILLE, KISSIMMEE, ATLANTA and CRGLLMONTGO were considered. These RMPs are presented in Fig. 4.11.

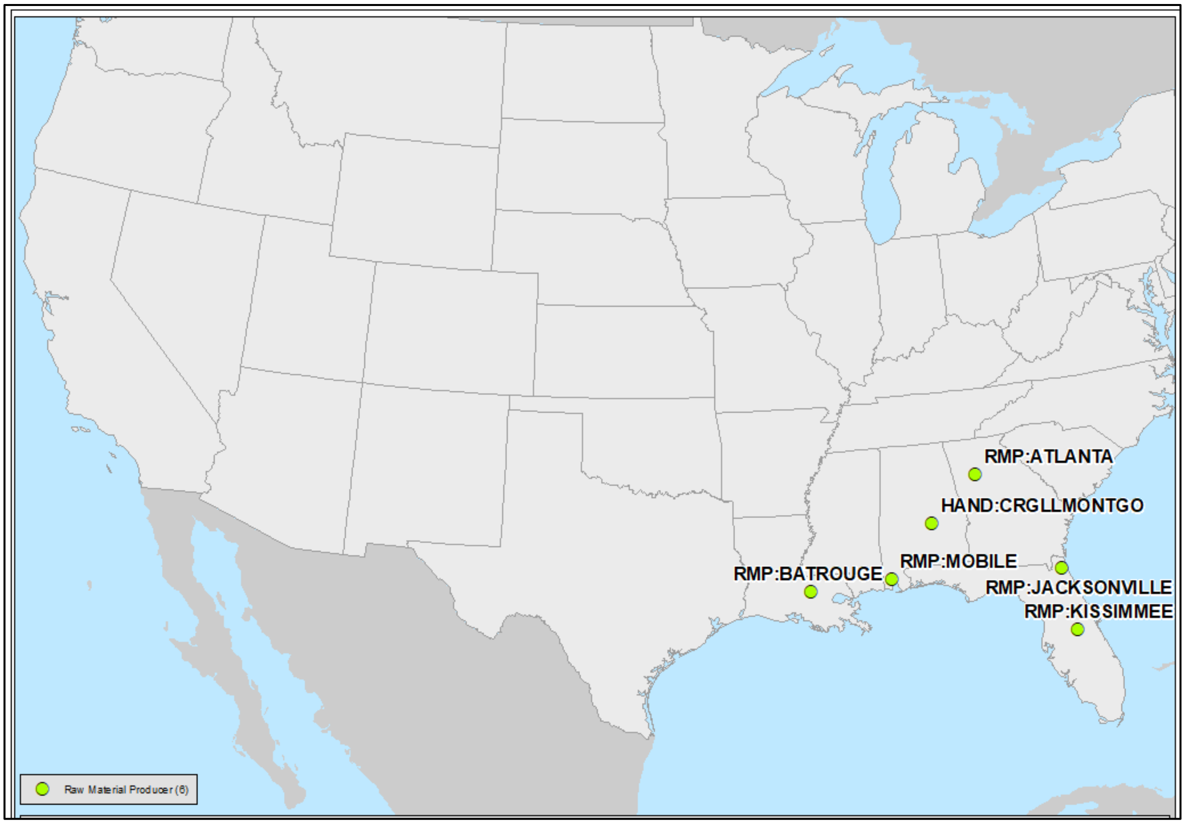



**Fig. 4.11. RMP Locations for Scenario 5**

### *4.3.2. Processors*

Under the processors involved in Scenario 5, there are crushers and biorefineries. The biorefinery is represented by SUNSHINETPA and the crusher is represented by EXPRSGRNMS. The location and name of these processors are presented in Fig. 4.12.

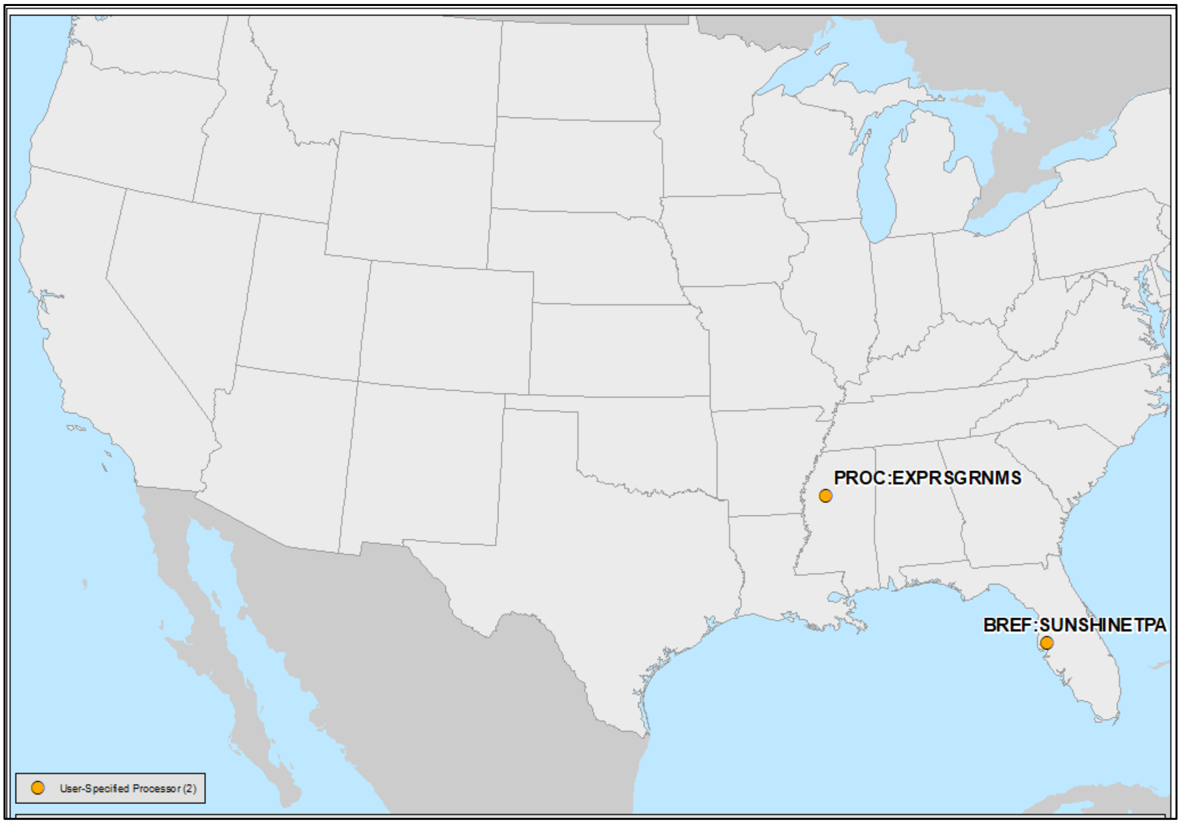



**Fig. 4.12. Biorefinery and Crusher Locations for Scenario 5**

### *4.3.3. End users/Destinations*

Scenario 5 is composed of the following end users/destinations TPA, LAX, CHEVCA, and DSM. The locations and names of these end users/destinations are presented in Fig. 4.13.

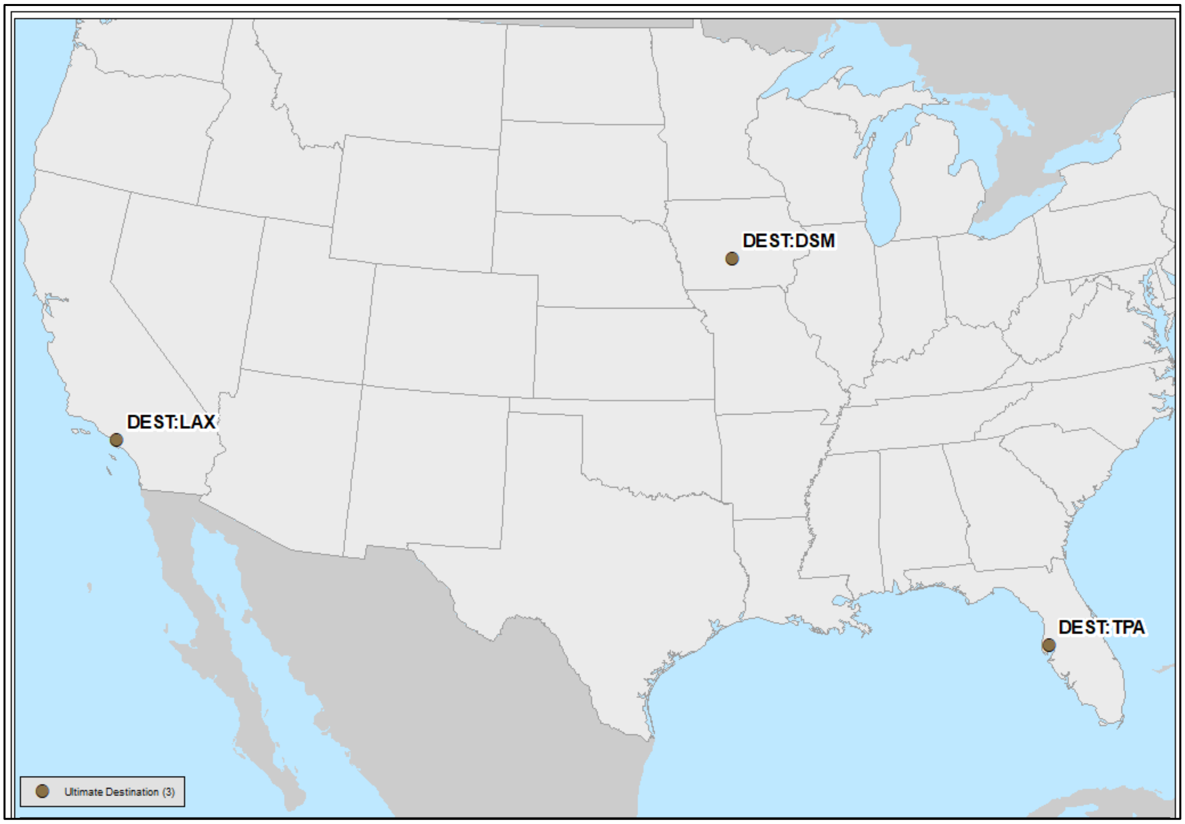



**Fig. 4.13. End Users/Destinations for Scenario 5**

### *4.3.4. Scenario 5 - Summary*

Figs. 4.14 and 4.15 represent all of the SC components involved in running Scenario 5 along with the commodities they handle/process. These facilities were coded into ArcGIS per their geo-locations and using the rest of the data supplied through XML files, FTOT logistics optimization runs were performed.

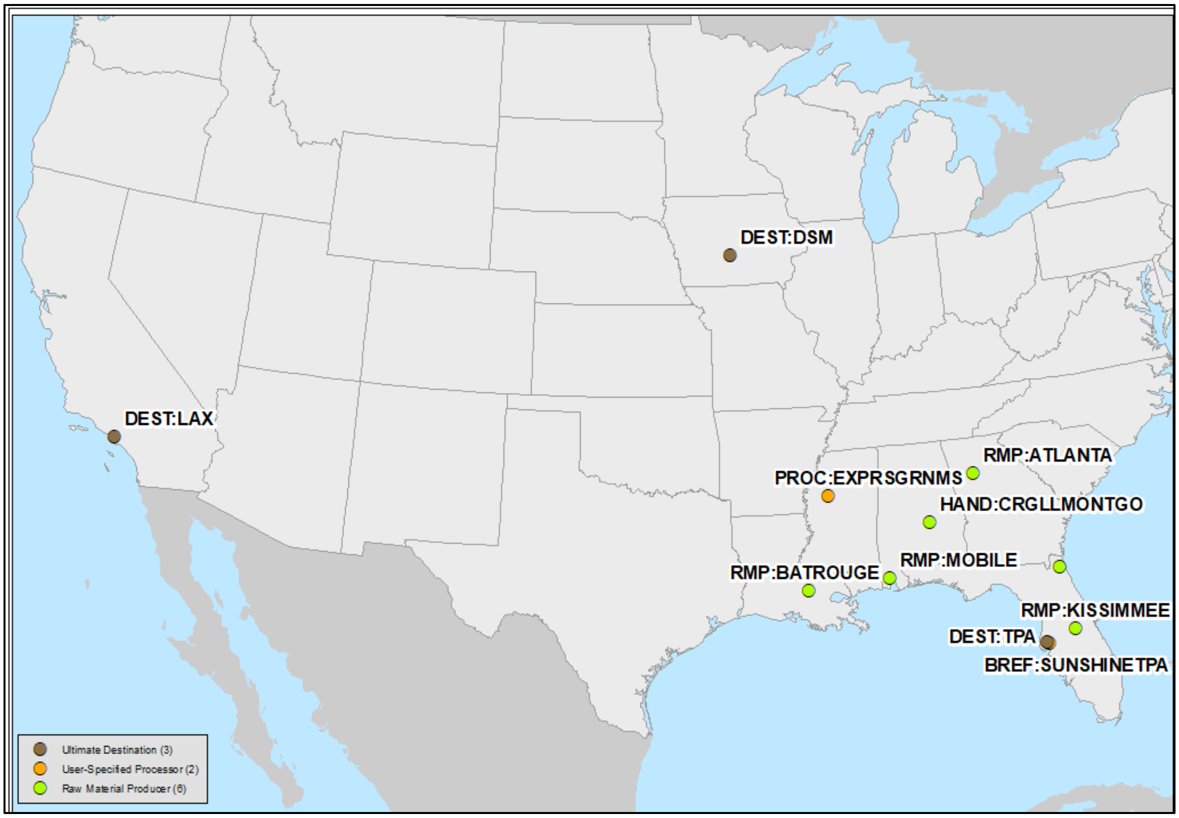



**Fig. 4.14. The Name and Graphical Locations of all Facilities for Scenario 5**

*Raw material producers*

| Facility name | Commodity |
|---|---|
| MOBILE | grease |
| BATROUGE | |
| JACKSONVILLE | |
| KISSIMMEE | |
| ATLANTA | |
| CRGLLMONTGO | Carinata oil seed |

*Processers (Biorefinery and Crusher)*

| Facility name | Commodity |
|---|---|
| SUNSHINETPA _ Biorefinery | Carinata oil crude |
| | grease |
| | jet |
| | diesel |
| | naphtha |
| EXPRSGRNMS _ Crusher | Carinata oil seed |
| | Carinata oil crude |

*End user*

| Facility name | Commodity |
|---|---|
| TPA | Jet |
| LAX | Diesel |
| DSM | Naphtha |

**Fig. 4.15. Facilities Based on Commodities Information for Scenario 5**

## 4.4 SCENARIO 8

### *4.4.1 RAW MATERIAL PRODUCERS*

For Scenario 8, six optimal raw material producers including MOBILE, BATROUGE, JACKSONVILLE, KISSIMMEE, ATLANTA and CRGLLMONTGO were considered. These RMPs is presented in Fig. 4.36.

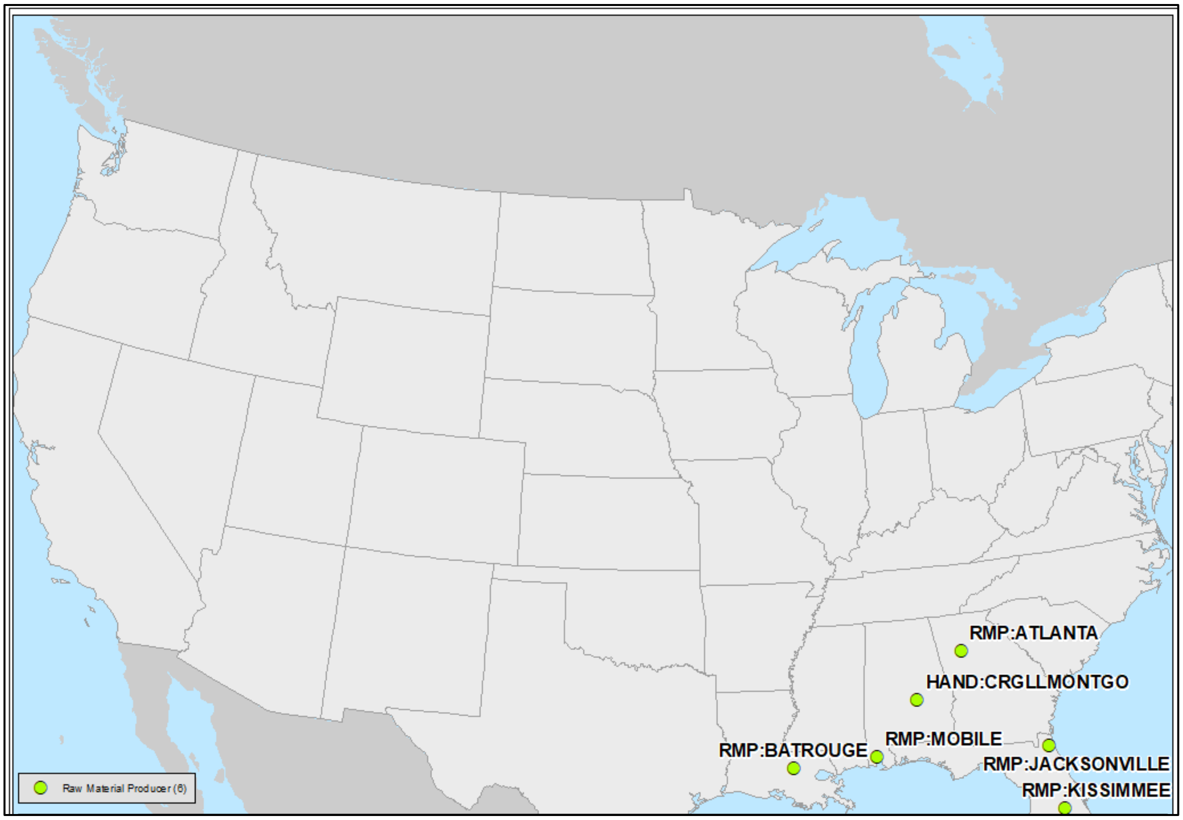



**Fig. 4.36. RMPs Locations for Scenario 8**

### *4.4.2. Processors*

Under the processors involved in Scenario 8, there are crushers and biorefineries. The biorefinery is represented by REGGEISMARLA and the crusher is represented by EXPRSGRNMS. The location and name of these processors are presented in Fig. 4.37.

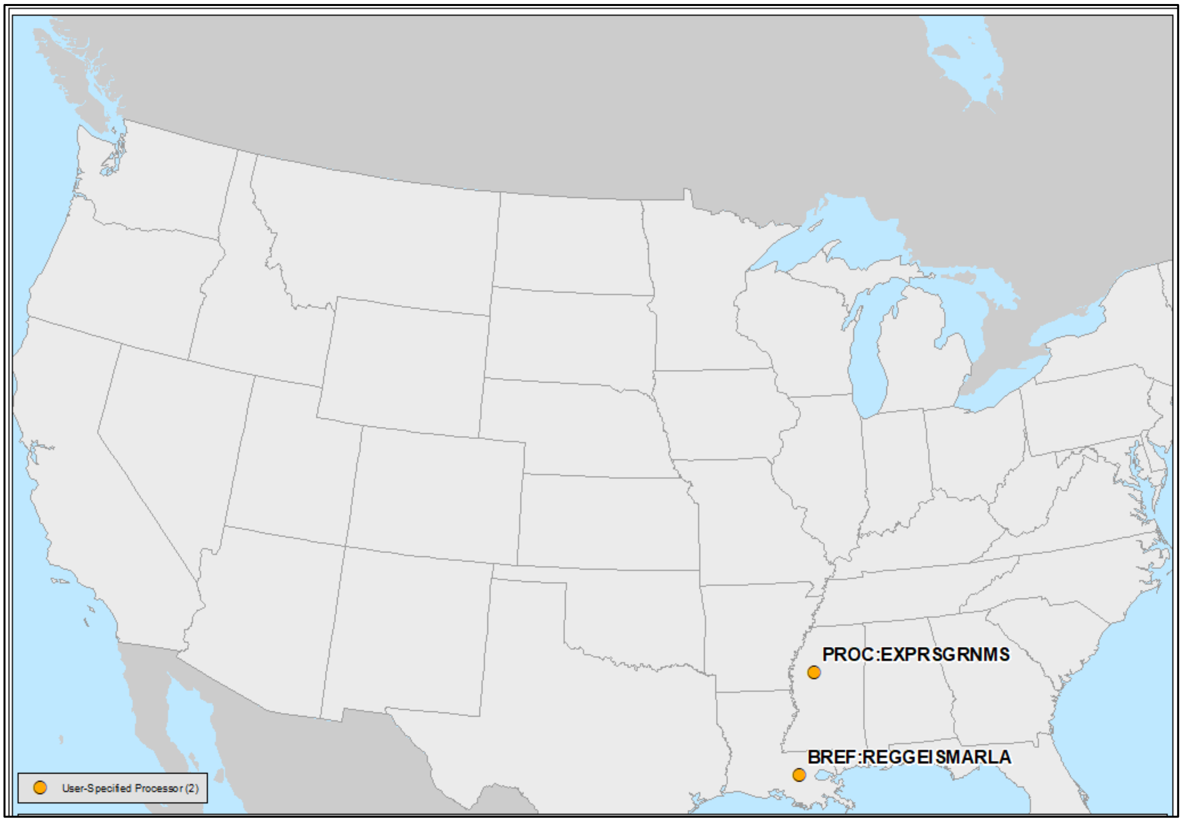



**Fig. 4.37. Biorefinery and Crusher Locations for Scenario 8**

### *4.4.3. End users/Destinations*

Scenario 8 composed of the following end users/destinations IAH, DFW and VCV. The location and names of this end users/destinations are presented in Fig. 4.38.


**Fig. 4.38. End Users/Destinations for Scenario 8**

### *4.4.4. Scenario 8 - Summary*

Figs. 4.39 and 4.40 represent all of the SC components involved in running Scenario 8 along with the commodities they handle/process. These facilities were coded into ArcGIS per their geo-locations and using the rest of the data supplied through XML files, FTOT logistics optimization runs were performed.

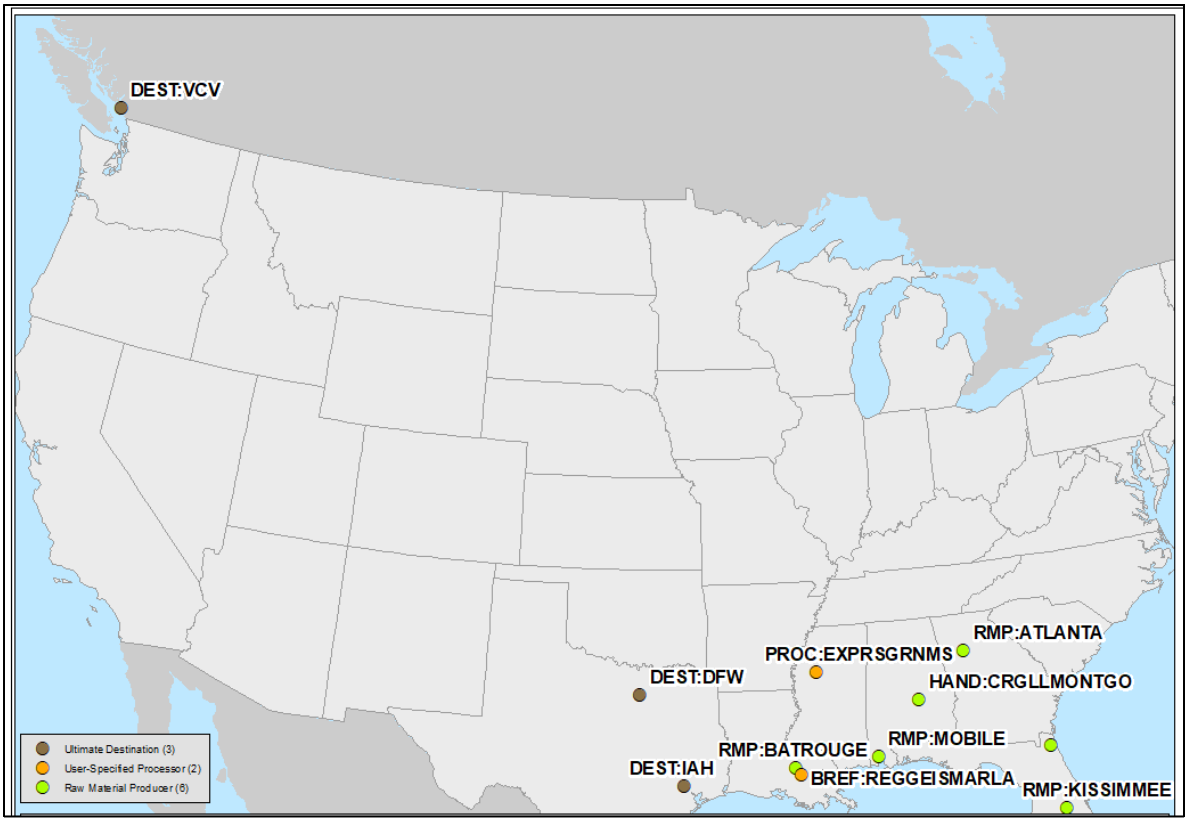



**Fig. 4.39. The Name and Graphical Locations of all Facilities for Scenario 8**

*Raw material producers*

| Facility name | Commodity |
|---|---|
| MOBILE | grease |
| BATROUGE | |
| JACKSONVILLE | |
| KISSIMMEE | |
| ATLANTA | |
| CRGLLMONTGO | Carinata oil seed |

*Processers (Biorefinery and Crusher)*

| Facility name | Commodity |
|---|---|
| REGGEISMARLA_ Biorefinery | carinata oil crude |
| | grease |
| | jet |
| | diesel |
| | naphtha |
| EXPRSGRNMS _ Crusher | Carinata oil seed |
| | Carinata oil crude |

*End user*

| Facility name | Commodity |
|---|---|
| IAH | Jet |
| DFW | Jet |
| VCV | Diesel |
| VCV | Naphtha |

**Fig. 4.40. Facilities Based on Commodities Information for Scenario 8**

# 5 FTOT RUN RESULTS

In this chapter, the logistics optimization results for the scenarios described in section 4 are provided. A comparison between baseline (2019) and FMLM (2020) models is provided for each scenario. This is done to demonstrate any aggregate changes in costs, emissions, or miles travelled once FMLM inputs are factored into the models. Additionally, optimal FMLM modelling routes by both commodity and mode are provided.

## 5.1 OPTIMIZATION RESULTS OF SCENARIO 1

This subsection summarizes the FMLM optimization results obtained for Scenario 1.

### *5.1.1 Optimal Routing by Commodity and Mode – Scenario 1*

Six RMPs were involved in the development of Scenario 1, namely, MOBILE, BATROUGE, JACKSONVILLE, KISSIMMEE, ATLANTA and CRGLLMONTGO. Two kinds of commodities including carinata-oil-seed and grease were handled at these RMPs for Scenario 1. Processors included VALDOSTA and the crusher facility, EXPRSGRNMS. Six kinds of commodities including Carinata-oil-crude, Carinata-oil-seed, diesel, grease, jet and naphtha were handled at this processor for Scenario 1. Three end users/destinations were involved in the development of Scenario 1, namely, SUNSHINETPA, CHEVCA, and REGGEISMARLA. Three kinds of commodities including, diesel, jet and naphtha were sent to these end users/destinations for Scenario 1.

Detailed maps of these RMP, processor, and end user/destination locations can be seen in the preceding report (Ozkul et al. 2020), as well as this study. Current versions of FTOT allow for the commodities to be broken down across various routes within the larger optimization model. This data is exported into a data visualization tool. Color-coded routing across the entire network depicts the optimal solution routes by commodity. Figure 5.1 details the optimal solution routes by commodity. When compared with the campaign model results from 2019 (Ozkul et al. 2020), a large increase in the number of miles travelled is noted when accounting for FMLM connections.

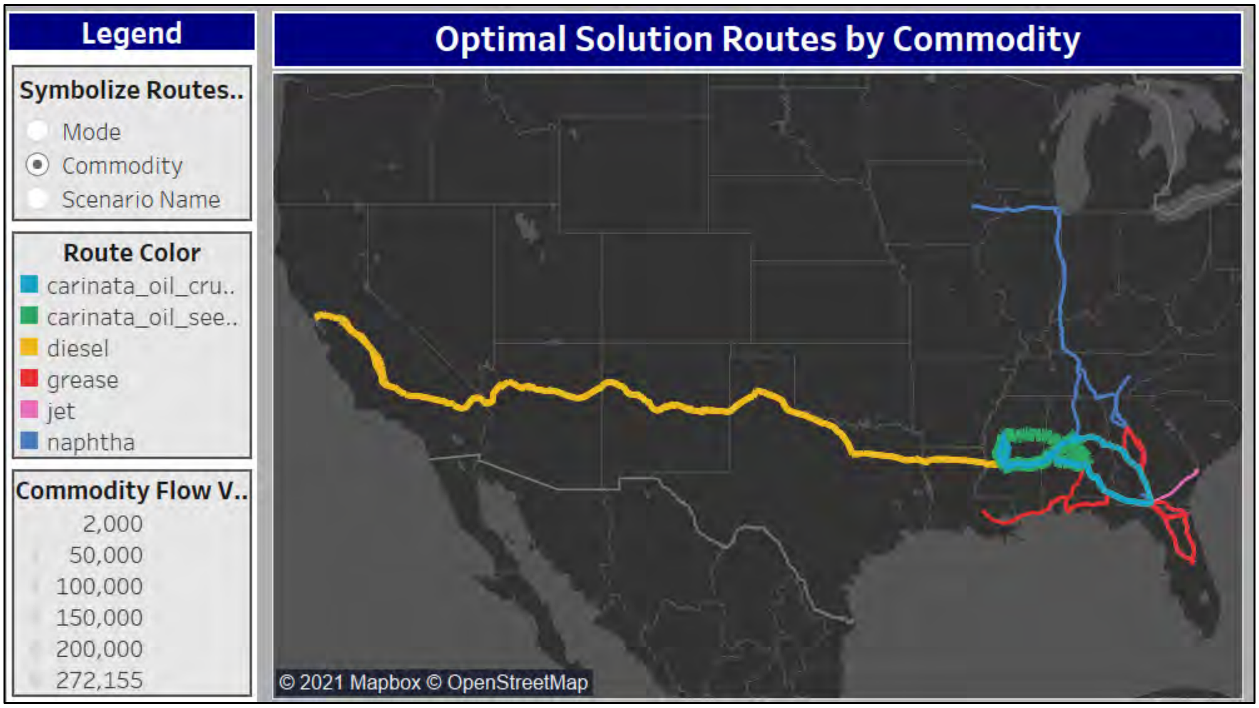



**Fig. 5.1. Optimal Solution Routes by Commodity for Scenario 1**

The optimal solution routes by transportation mode are depicted in Figure 5.2. All modes previously utilized in the baseline model (Ozkul et al. 2020) were used, including rail, road, and water. The optimized routing indicates that while road is used to a greater extent to connect nodes to intermodal facilities such as railyards, rail itself is still the predominant transport mode.

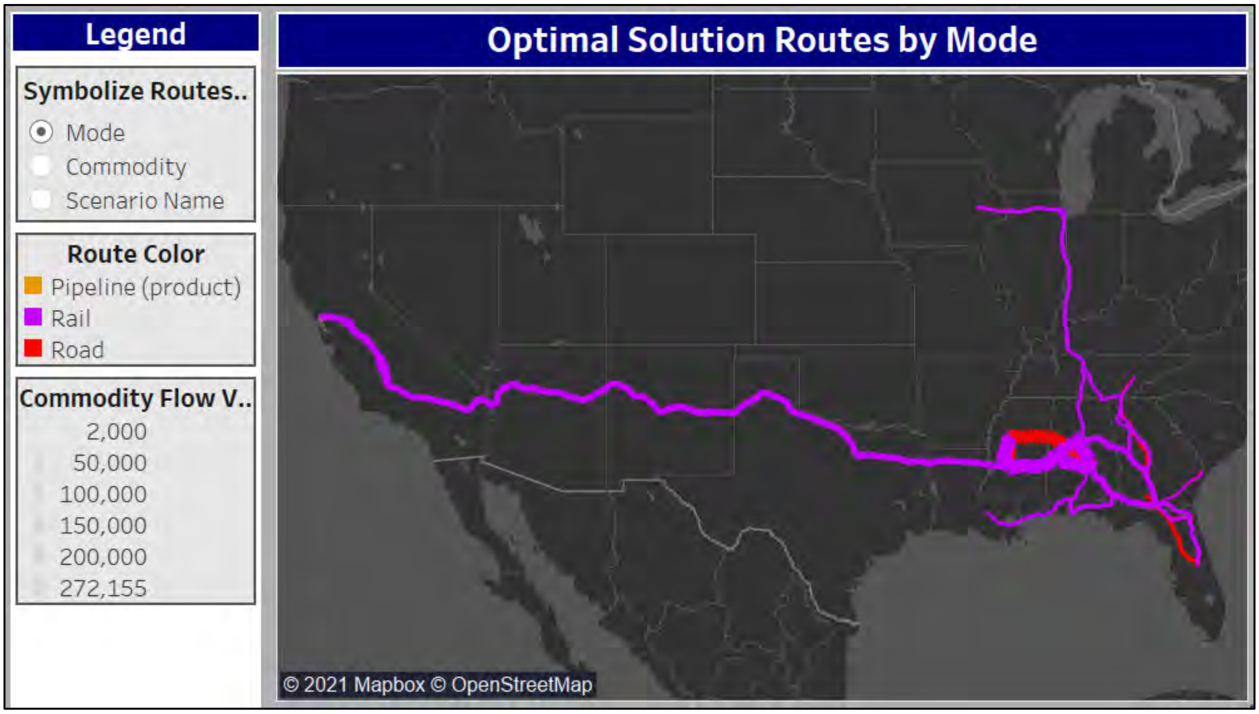



**Fig. 5.2. Optimal Solution Routes by Mode for Scenario 1**

Questions from the prior, baseline analysis regarding the absence of pipeline routing was addressed with the 2020 analysis. Just in the prior analysis, FTOT is configured to leverage stakeholder inputs and use a variety of databases and algorithms to programmatically determine the optimal solution. The 2020 models contained additional programming combined with newer capabilities within FTOT to reveal a small portion of pipeline utilized in FMLM Scenario 1. This occurs near end-user/destination CHEVCA, in the San Francisco area, and is illustrated in Figure 5.3. This represents the sole FMLM scenario utilizing pipeline.

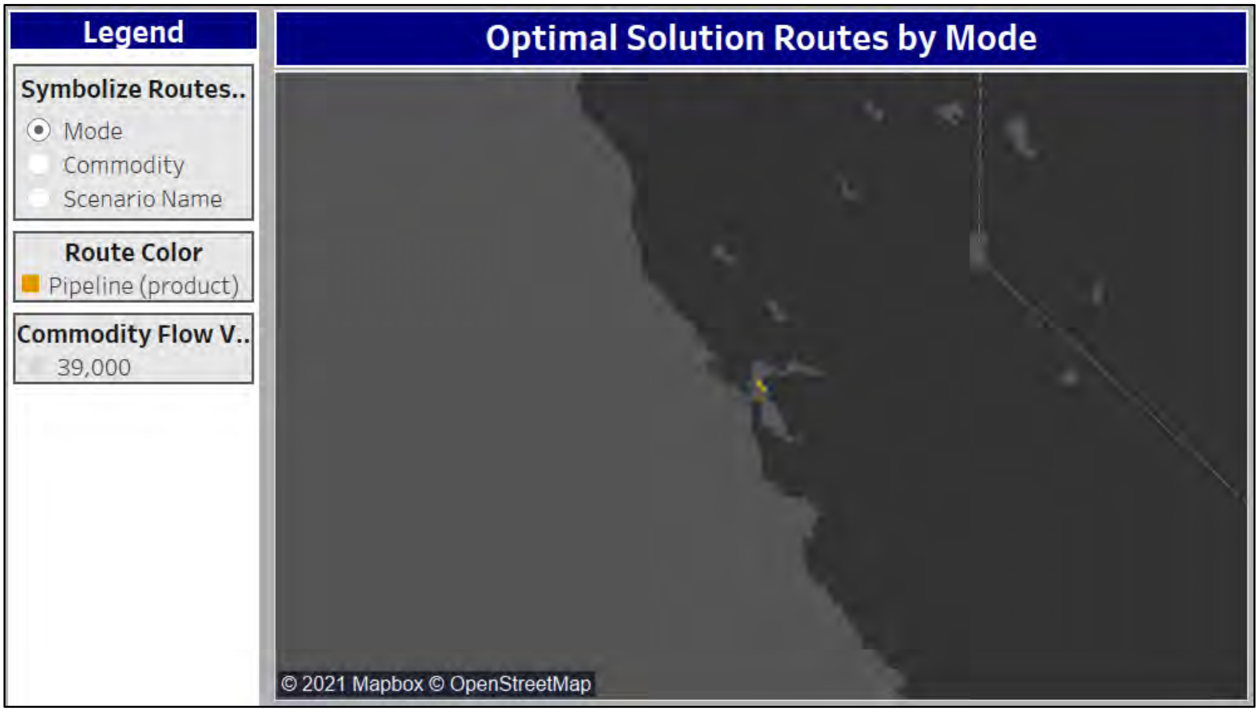
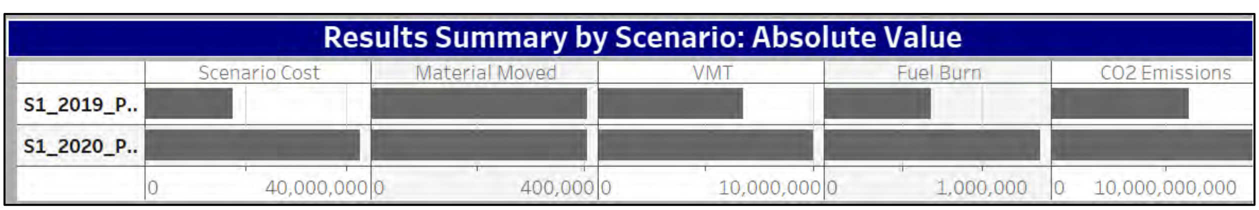



**Fig. 5.3. Optimal Solution Routes by Mode Highlighting Pipeline Usage for Scenario 1**

### *5.1.2. Summary of Conclusions from Optimization Metrics Comparison – Scenario 1*

Aggregated comparison metrics between the original baseline model (i.e., 2019) versus the FMLM model (e.g., 2020) appear in Tables 5.1 and 5.2. Specifically, total scenario cost, material moved, vehicle miles travelled (VMT), fuel burn, and $CO_2$ emissions were analysed. Actual metrics, along with illustrative bar charts are provided. Overall, the FMLM analysis resulted in substantial increases in all metrics, with the exception of material moved.

**Table 5.1. Summary of Key Metrics Comparing Baseline to FMLM – Scenario 1**




Historically, FMLM can result in 40% increases in overall costs for transporting products. Although, in SPARC's case, many coproducts are being transported across a large geographic area that includes many processing elements between the RMP and end-user/destination locations.

As a result, the % component of FMLM increase in total transportation cost (USD) of 59.2%, while substantial, does not represent a complete surprise. Particularly, given a 32.4% increase in VMT, and a resulting 35.9% increase in $CO_2$ emissions.

**Table 5.2. Summary of Differences Across Costs, CO2 Emissions, and VMT from Baseline to FMLM – Scenario 1**

| | **Total Transportation Dollar Cost (USD)** | **Total $CO_2$ Emissions (kg)** | **Total Vehicle Miles Travelled (VMT)** |
|---|---|---|---|
| **Scenario 1 (2019)** | 17,424,374.84 | 12,024,394,051.52 | 6,758,595.83 |
| **Scenario 1 (2020)** | 42,715,139.20 | 18,761,158,129.09 | 10,004,750.94 |
| **% Component of FMLM** | 59.2% | 35.9% | 32.4% |

## 5.2 OPTIMIZATION RESULTS OF SCENARIO 3

This subsection summarizes the FMLM results obtained by running Scenario 3.

### *5.2.1 Optimal Routing by Commodity and Mode – Scenario 3*

Five RMPs were involved in the development of Scenario 3, namely, PRTWLLHOUSTON, AUSTIN, ELLTROUTLUFKIN, LAFAYETTE, and CRGLLMONTGO. Two kinds of commodities including carinata-oil-seed and grease were handled at these RMPs for Scenario 3. Processors included a crusher and biorefinery represented by CRGLLMONTGO and CHVRNMS, respectively. Six kinds of commodities including Carinata-oil-crude, Carinata-oil-seed, diesel, grease, jet and naphtha were handled at these processors. Scenario 3 is comprised of the following end users/destinations: LAX, CHEVCA, SWGAETH, TATELYLE, and ADM. Three kinds of commodities including diesel, jet and naphtha were sent to these end users/destinations for Scenario 3. Locations of each of the RMPs, processors, and end users/destinations are illustrated earlier within this report. Figure 5.4 highlights the optimal solution routes, color-coded by commodity across the entire network.

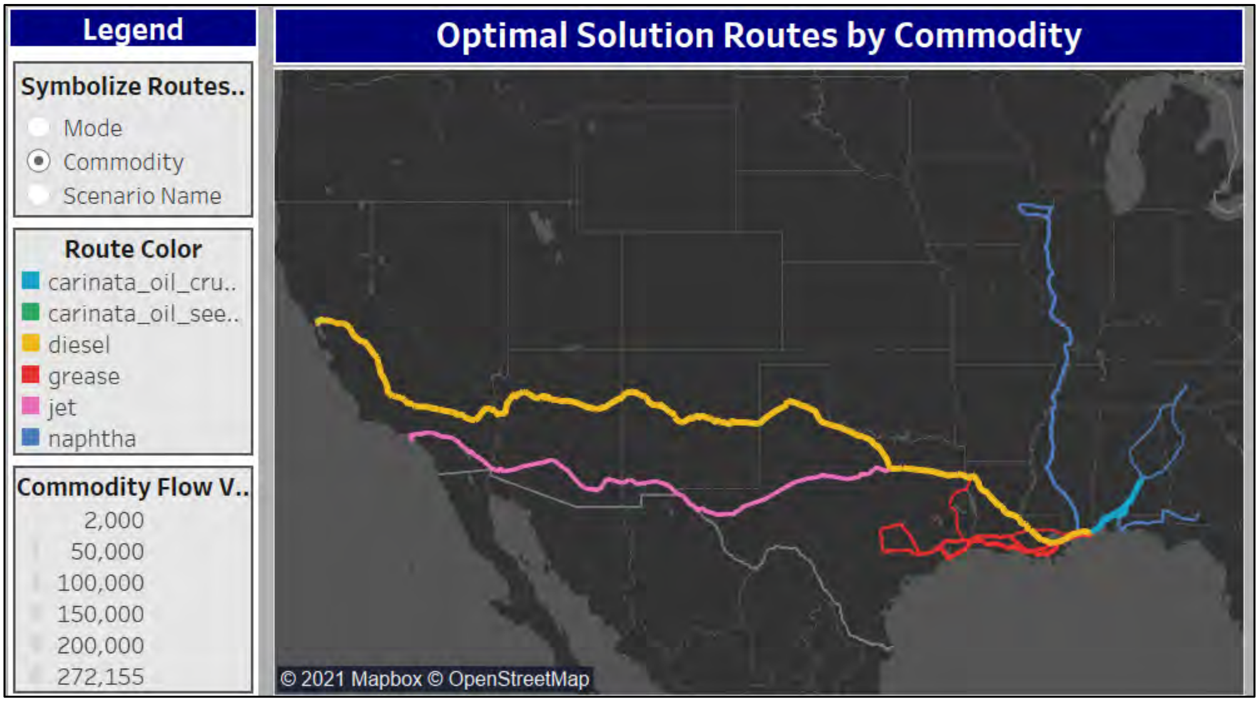



**Fig. 5.4. Optimal Solution Routes by Commodity for Scenario 3**

When compared with the baseline optimization model for Scenario 3 (Ozkul et al. 2020), the FMLM routing model incorporates far greater usage of road for transporting materials between all nodes of the network. This is depicted in Figure 5.5. These road extensions occur within Texas, Louisiana, Georgia, and Iowa, and indicate transloading points that previously weren't calculated by FTOT in the baseline model of Scenario 3. In fact, the baseline scenario did not utilize any road network. Additionally, FMLM Scenario 3 creates two parallel rail lines that originate within the state of Texas and continue to LAX and CHEVCA end users/destinations. In the baseline scenario, this split occurred within the state of California. The thickness of the rail route from Texas to CHEVCA indicates a greater volume being shipped to the CHEVCA end user/destination than along the route to LAX.

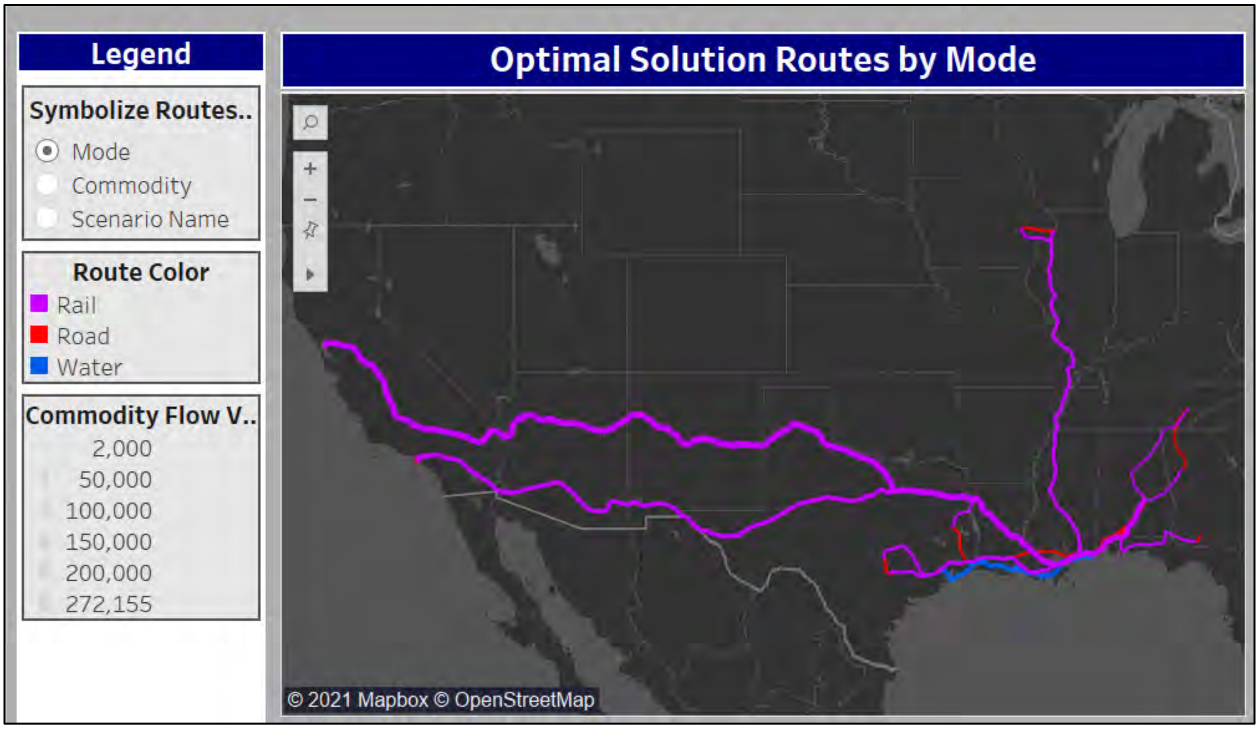



**Fig. 5.5. Optimal Solution Routes by Mode for Scenario 3**

### *5.2.2. Summary of Conclusions from Optimization Metrics Comparison – Scenario 3*

The location of the routing split in transportation of product to CHEVCA and LAX results in increases in scenario costs, VMT, fuel burn, and $CO_2$ emissions (Table 5.3). The greater use of road and intermodal costs also contribute to these across the board increases.

**Table 5.3. Summary of Differences Across Costs, CO2 Emissions, and VMT from Baseline to FMLM – Scenario 3**

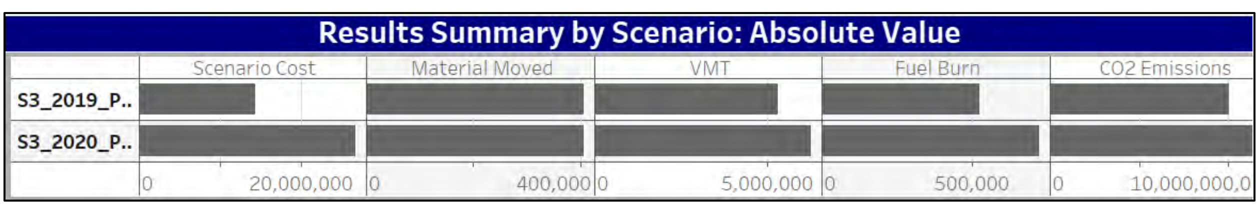



Table 5.4 reports the specific percentage increases and values for Total Transportation Dollar Cost (USD), Total CO2 Emissions (kg), and Total Vehicle Miles Travelled (VMT). Given the contributing factors highlighted above, FMLM optimization revealed a 15.2% increase in VMT, as well as a 17.3% increase in CO2 Emissions. However, FMLM increased the total transportation

cost over the network by 46.2%. This is higher than the estimated 40% average increase for FMLM analysis.

**Table 5.4. Summary of Differences Across Costs, CO2 Emissions, and VMT from Baseline to FMLM – Scenario 1**

| | Total Transportation Dollar Cost (USD) | Total $CO_2$ Emissions (kg) | Total Vehicle Miles Travelled (VMT) |
|---|---|---|---|
| **Scenario 2019** | 14,361,139.08 | 10,049,647 | 5,324,116.25 |
| **Scenario 2020** | 26,736,699.00 | 12,146,689 | 6,278,081.44 |
| **% Component of FMLM** | 46.2% | 17.3% | 15.2% |

## 5.3 OPTIMIZATION RESULTS OF SCENARIO 5

This subsection summarizes the FMLM optimization results obtained for Scenario 5.

### *5.3.1 Optimal Routing by Commodity and Mode – Scenario 5*

Six RMPs were involved in the development of FMLM Scenario 5. These include MOBILE, BATROUGE, JACKSONVILLE, KISSIMMEE, ATLANTA and CRGLLMONTGO. Two kinds of commodities consisting of carinata-oil-seed and grease were handled at these RMPs for Scenario 5. Two processors were involved in the development of Scenario 5. SUNSHINETPA and EXPRSGRNMS represent a biorefinery and crusher, respectively. Six kinds of commodities including Carinata-oil-crude, Carinata-oil-seed, diesel, grease, jet and naphtha were handled at these processors for FMLM Scenario 5. Three end users/destinations were involved in the development of Scenario 5, namely, TPA, LAX, and DSM. Three kinds of commodities to include diesel, jet and naphtha were sent to these end users/destinations for Scenario 5.

Detailed maps of these RMP, processor, and end user/destination locations are provided within an earlier section of this study. The latest version of FTOT allows for the commodities to be segmented across various routes within the larger optimization model. This data is exported into a data visualization tool for further analysis. Color-coded routing across the entire network depicts the optimal solution routes by commodity. Figure 5.6 demonstrates the optimal solution routes by commodity. The longest distance travelled between logistics network nodes are in the transport of diesel and naphtha to end users/destinations LAX and DSM, respectively.

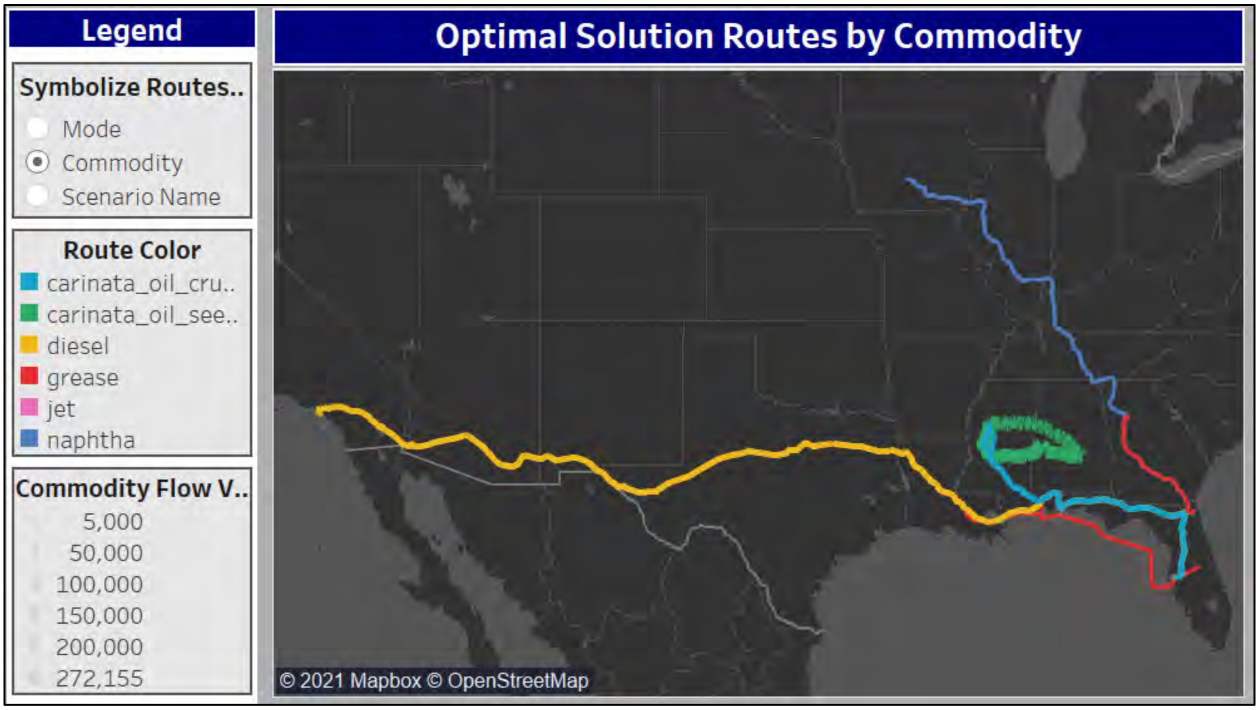



**Fig. 5.6. Optimal Solution Routes by Commodity for Scenario 5**

The routing by transportation mode is illustrated in Figure 5.7. Rail, road, and water modes were utilized, as in the baseline models (Ozkul et al. 2020). Rail remained the predominant mode used for transporting over long distances between nodes of the logistics network. However, the FMLM modelling revealed the addition of new road routes. Specifically, heavy use of road transport was used within Mississippi and Alabama. Additionally, road transport is added along the Interstate 4 corridor from Winter Haven, to Port Tampa Bay, and onto end user/destination, TPA. Port Tampa Bay is serving as an intermodal connection for rail, road, and marine transport.

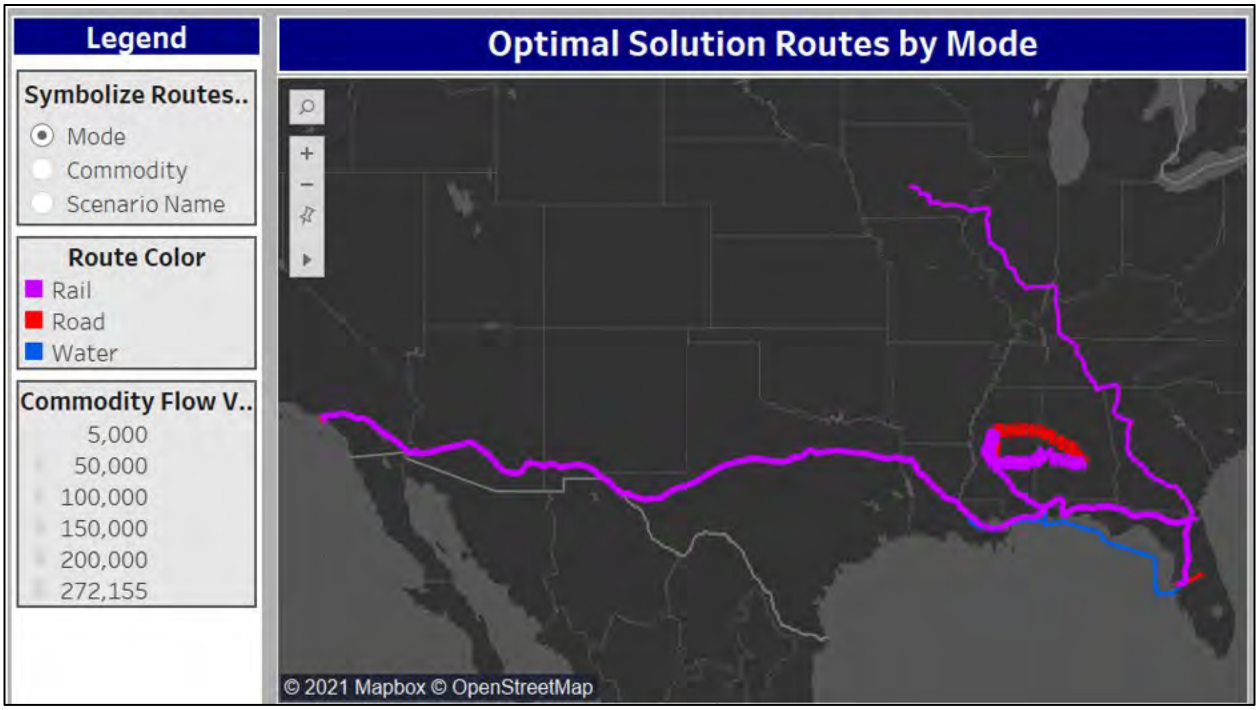
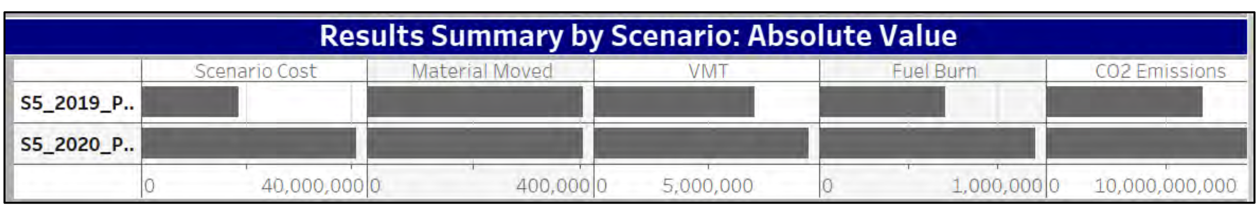



**Fig. 5.7. Optimal Solution Routes by Mode Highlighting Pipeline Usage for Scenario 5**

### *5.3.2. Summary of Conclusions from Optimization Metrics Comparison – Scenario 5*

Comparative metrics for the baseline scenario and FMLM logistics optimization models appear in Tables 5.5 and 5.6. Again, the FMLM model shows increases in costs, VMT, fuel burn, and emissions.

**Table 5.5. Summary of Key Metrics Comparing Baseline to FMLM – Scenario 5**




In further comparing the aggregated costs between the baseline scenario and FMLM logistics optimization model, it is determined that FMLM results in a 54.6% increase in expenses related to transporting the bio-coproducts through their various stages of production to the end user/destination locations. This is in part due to the 25% increase in the total VMT realized by directly connecting nodes to respective modes of transportation. In previous baseline tests, FTOT attempted to identify the lowest cost mode of transportation within a 5 mile radius from specific nodes. In reality, rail lines do not directly connect with processors, for example. Within the FMLM analysis, FTOT directly connects nodes to these actual transportation routes. This results in additional VMT, transload expenses, and other factors being included in the analysis. Thus, a more accurate estimate is provided by the FMLM optimization. Finally, total CO2 emissions for the FMLM model increased by 27.1% overall in Scenario 5.

**Table 5.7. Summary of Differences Across Costs, CO2 Emissions, and VMT from Baseline to FMLM – Scenario 5**

| | Total Transportation Dollar Cost (USD) | Total $CO_2$ Emissions (kg) | Total Vehicle Miles Travelled (VMT) |
|---|---|---|---|
| **Scenario 5 (2019)** | 18,582,210.75 | 13,093,702 | 7,069,906.69 |
| **Scenario 5 (2020)** | 40,894,298.44 | 17,948,208 | 9,431,901.46 |
| **% Component of FMLM** | 54.6% | 27.1% | 25.0% |

## 5.4 OPTIMIZATION RESULTS OF SCENARIO 8

This subsection summarizes the FMLM optimization results obtained for Scenario 8.

### *5.4.1 Optimal Routing by Commodity and Mode – Scenario 8*

Six RMPs are involved in the development of Scenario 8, namely, MOBILE, BATROUGE, JACKSONVILLE, KISSIMMEE, ATLANTA, and CRGLLMONTGO. Two kinds of commodities including carinata-oilseed and grease were handled at these RMPs for Scenario 8. Two processors were involved in the development of Scenario 8, namely, REGGEISMARLA (Biorefinery) and EXPRSGRNMS (Crusher). Five kinds of commodities including Carinata-oil-crude, Carinata-oil-seed, grease, diesel, jet and naphtha were handled at these processors for Scenario 8. Three end users/destinations were involved in the development of Scenario 8, namely, IAH, DFW, and VCV. Three kinds of commodities including diesel, jet and naphtha were sent to these end users/destinations for Scenario 8. Optimized routing solutions by commodity are depicted in the color-coded graphic, below (Figure 5.8). The longest route by commodity, in this case diesel and naphtha, is the logistics network segment from biorefinery REGGEISMARLA to end user/destination VCV.

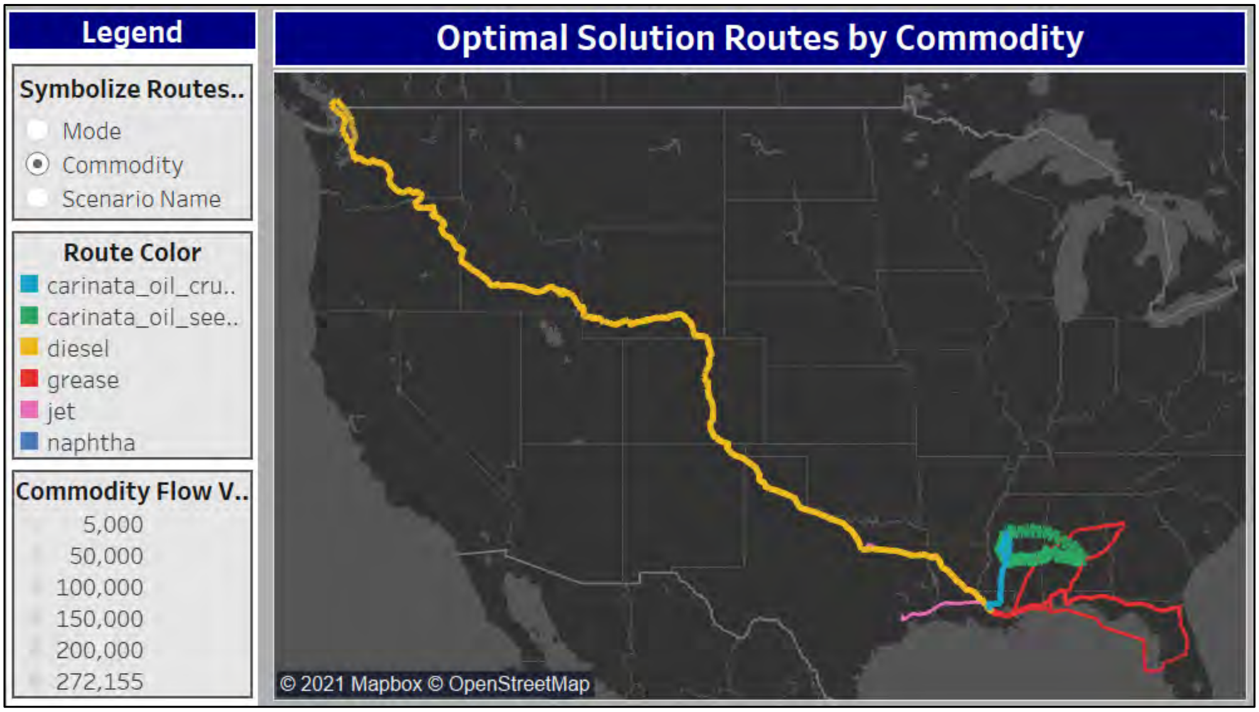
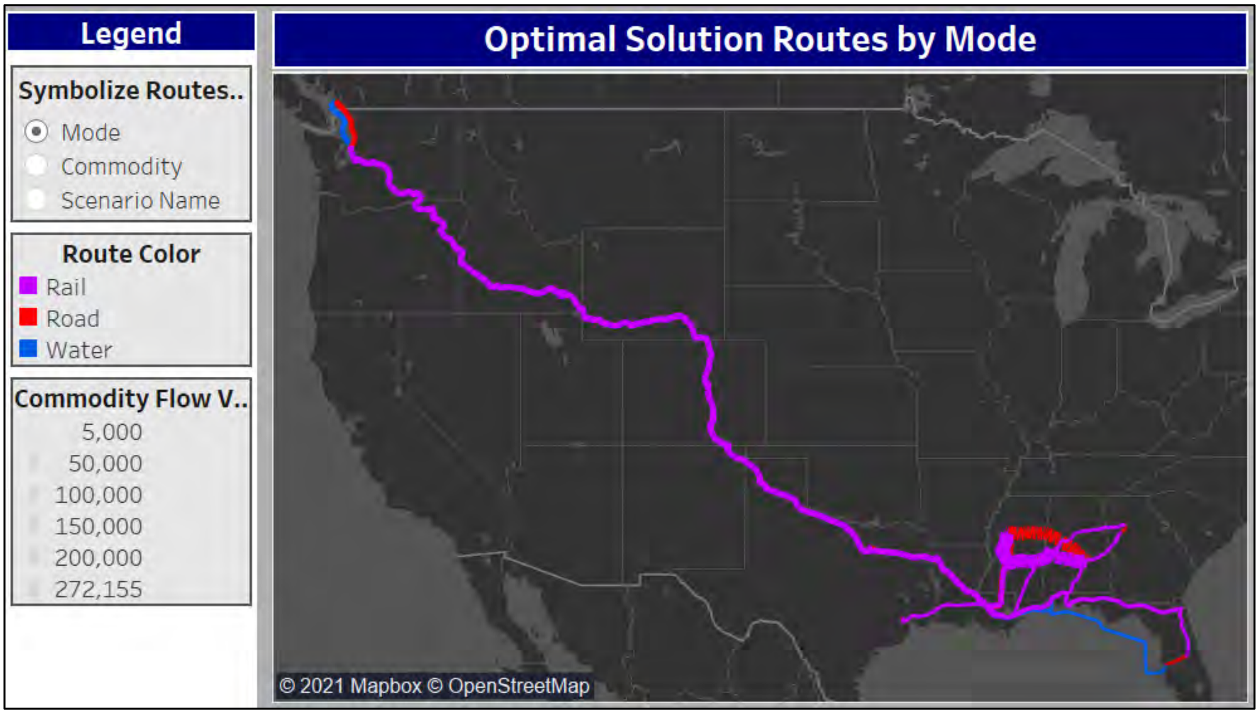



**Fig. 5.8. Optimal Solution Routes by Commodity for Scenario 8**

The optimal solution routes by transportation mode for FMLM Scenario 8 are depicted in Figure 5.9. All modes previously utilized in the baseline model (Ozkul et al. 2020) were used, including rail, road, and water. However, some changes to how FTOT optimizes for this scenario are slightly different than previous runs. This is consistent with the dynamic nature of FTOT as an optimization tool using active data parameters. Specifically, a small modification was made to accommodate various characteristics of the network used by FTOT.

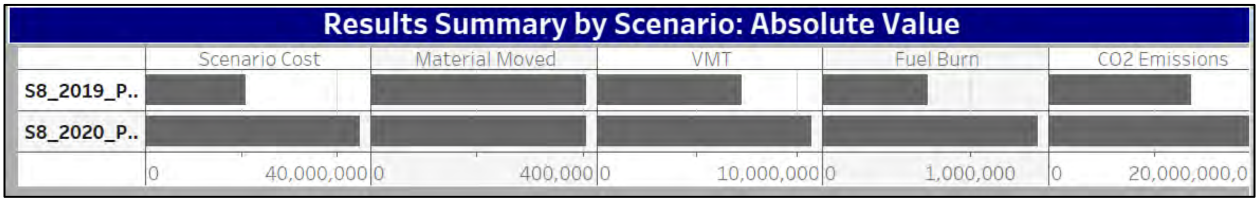
The destination for diesel and naphtha, VCV, is located at the US-Canada border near Vancouver and is located approximately 25 miles from the nearest link in the road network. This end user/destination resides close to a Canadian pipeline. However, FTOT networks are constrained by the tariff data and therefore only consider US pipelines. In addition, the facility is near a waterway link in the network, which is how FTOT previously routed product within the 2019 baseline models. For the FMLM analysis, an adjustment to the max artificial link distance for road in the scenario.xml file for FMLM Scenario 8 was required. This modification was to extend to 30 miles in proximity in order to connect to the logistics network. As a pipeline was not utilized for transporting the coproducts in the last mile of delivery, a multi-modal transportation format was computed. This includes both road transportation along the I-5 corridor through Seattle, as well as marine shipping through the Puget Sound enroute to VCV. Similarly, FMLM Scenario 8 utilizes new road paths within the state of Florida, connecting with Port Tampa Bay, with continued shipment through the Gulf of Mexico.




### *5.4.2. Summary of Conclusions from Optimization Metrics Comparison – Scenario 8*

Comparative metrics for the baseline versus FMLM Scenario 8 logistics optimization models are found in Tables 5.8 and 5.9. As is seen in Table 5.8, the overall fuel burn for transporting coproducts increases drastically in the FMLM model. This can partially be attributed to the increase in VMT. Increases in costs and emissions are realized within the FMLM Scenario 8 model, as well.

**Table 5.8. Summary of Key Metrics Comparing Baseline to FMLM – Scenario 8**




In a further analysis of changes amongst key metrics between the baseline and FMLM Scenario 8 optimization models, the largest percentage increase is in the area of total transportation dollar cost. The FMLM model costs 53.3% more than the baseline model. The reasoning for this is largely due to the increased intermodal expenses and transloading costs associated with FMLM, as well as the costs incurred in the locations utilized in the logistics network. $CO_2$ emissions and total VMT also increased by 33.5% and 32.4%, respectively.

**Table 6.1. Summary of Differences Across Costs, CO2 Emissions, and VMT from Baseline to FMLM – Scenario 8**

| | Total Transportation Dollar Cost (USD) | Total $CO_2$ Emissions (kg) | Total Vehicle Miles Travelled (VMT) |
|---|---|---|---|
| **Scenario 8 (2019)** | 20,916,133.99 | 13,436,911 | 7,258,376.38 |
| **Scenario 8 (2020)** | 44,820,232.48 | 20,215,255 | 10,743,405.10 |
| **% Component of FMLM** | 53.3% | 33.5% | 32.4% |

# 6 FINDINGS AND CONCLUSIONS

As highlighted in Section 5, the results of the FMLM logistics optimization runs were analysed per the goals of this study, which was to develop more precise metrics than early baseline scenarios, given specific supply chain components, increased maturity of SPARC, and further development of the FTOT optimization tool. This research accounted for the high impact of FMLM costs on the overall logistics optimization modelling. Increases in metrics measured are driven by transloading costs incurred through intermodal facilities, the increased use of roadways necessary for connecting notes within the network, and the routes being utilized, among other characteristics programmed into the FTOT algorithms. These logistics networks were selected per the optimality of their logistics costs being the least given each specific scenario, building upon prior SPARC efforts with stakeholders. Table 6.1 summarizes the results obtained for each of the scenarios, comparing baseline scenarios with FMLM models. In terms of total transportation dollar cost (USD), all models exceeded the 40% average threshold often observed in transportation engineering and logistics research when accounting for first mile-last mile modifications to logistics networks. Increases in both total $CO_2$ emissions and VMT were also observed.

**Table 6.1. Total Optimal $CO_2$ emissions, Transportation Dollar Cost and VMT for Scenarios 1 through 3A and 3B**

| Scenario (Baseline/FMLM) | Total Transportation Dollar Cost (USD) | Total $CO_2$ Emissions (kg) | Total Vehicle Miles Travelled (VMT) |
|---|---|---|---|
| **Scenario 1 (2019-Baseline)** | 17,424,374.84 | 12,024,394,051.52 | 6,758,595.83 |
| **Scenario 1 (2020-FMLM)** | 42,715,139.20 | 18,761,158,129.09 | 10,004,750.94 |
| **Scenario 3 (2019-Baseline)** | 14,361,139.08 | 10,049,647 | 5,324,116.25 |
| **Scenario 3 (2020-FMLM)** | 26,736,699.00 | 12,146,689 | 6,278,081.44 |
| **Scenario 5 (2019-Baseline)** | 18,582,210.75 | 13,093,702 | 7,069,906.69 |
| **Scenario 5 (2020-FMLM)** | 40,894,298.44 | 17,948,208 | 9,431,901.46 |
| **Scenario 8 (2019-Baseline)** | 20,916,133.99 | 13,436,911 | 7,258,376.38 |
| **Scenario 8 (2020-FMLM)** | 44,820,232.48 | 20,215,255 | 10,743,405.10 |

### 6.1 Future Research Direction & Recommendations

The purpose of this report was to provide SPARC and its stakeholders with a better understanding of potentially changing supply chain metrics, due to FMLM modifications to the four most likely baseline scenarios co-developed with stakeholders and assessed in Ozkul et al. (2020). The effects from the FMLM modifications depicted are not inclusive of all possible paths forward for logistics optimization relative to SPARC goals. However, the four scenarios are consistent with proper supply chain FMLM optimization techniques, which focus on ramifications for connections between logistics network nodes and transportation segments across the optimized models. While the analysis was thorough, in keeping with prior research, the team cautions SPARC against over relying on any singular assessment. The analysis performed demonstrates current planning with regards to SPARC logistics, but stakeholders, nodes, routes, and networks are subject to change. In essence, the supply network is capable of adaptation, but the supply chain team strongly recommends continual assessment of changing dynamics across stakeholders in the supply chain to anticipate any future changes. As the SPARC effort continues to advance, the availability of data inputs required for more elaborate and refined models should be prioritized. Factors that could impact these modes include results from LCA and TEA, as well as the success of the extension efforts, among others. These will be critical to moving the effort from theory to monetization of processes, coinciding with the goals of developing a successful bioeconomy for SPARC coproducts.

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# APPENDIX A

## Scenario (1)

### Table A-1. Raw Material Producers – Scenario 1

| facility_name | commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude | County | State |
|---|---|---|---|---|---|---|---|---|
| RMP: MOBILE | grease | 5,000,000 | liquid | 1980 Avenue A, Mobile | 30.649 | -88.066 | Mobile | AL |
| RMP:BATROUGE | grease | 5,000,000 | liquid | 1225 Neodho Avenue, Baton Rouge | 30.469 | -91.179 | East Baton Rouge Parish | LA |
| RMP:JACKSONVILLE | grease | 8,000,000 | liquid | 1640 Talleyrand Ave, Jacksonville | 30.344 | -81.629 | Duval | FL |
| RMP:KISSIMMEE | grease | 8,000,000 | liquid | 1745 S. John Young Pkwy, Kissimmee | 28.276 | -81.422 | Osceola | FL |
| RMP:ATLANTA | grease | 9,000,000 | liquid | 930 Marietta Blvd, Atlanta | 33.782 | -84.430 | Fulton | GA |
| HAND:CRGLL MONTGO | carinata_oil_seed_bulk | 300,000 ton | solid | 3250 Fitzpatrick Ave, Montgomery, AL 36108 | 32.355 | -86.352 | Montgomery | AL |

### Table A-2. Processors – Scenario 1

| facility_name | commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude |
|---|---|---|---|---|---|---|
| BREF:VALDOSTA | carinata_oil_crude | 35,000,000 | liquid | 1001 N Patterson St, Valdosta, GA 31601 | 30.841 | -83.283 |
| BREF:VALDOSTA | grease | 35,000,000 | liquid | | 30.841 | -83.284 |
| BREF:VALDOSTA | jet | 14,000,000 | liquid | | 30.841 | -83.284 |
| BREF:VALDOSTA | diesel | 39,000,000 | liquid | | 30.841 | -83.284 |
| BREF:VALDOSTA | naphtha | 11,000,000 | liquid | | 30.841 | -83.284 |
| PROC:EXPRSGRNMS | carinata_oil_seed_bulk | 300,000 ton | solid | 2015 River Rd., Greenwood, MS 38930 | 33.311 | -90.122 |
| PROC:EXPRSGRNMS | carinata_oil_crude | 35,000,000 | liquid | | 33.311 | -90.122 |

## Table A-3. End-users (Destinations) – Scenario 1

| facility_name | commodity | value | phase_of_matter | Address 1 | Latitude | Longitude |
|---|---|---|---|---|---|---|
| DEST:SAVGULFSTR | Jet | 2,000,000 | liquid | 500 Gulfstream Rd, Savannah, GA 31408 | 32.139 | -81.197 |
| DEST:MCO | Jet | 12,000,000 | liquid | 1 Jeff Fuqua Blvd, Orlando, FL 32827 | 28.431 | -81.308 |
| DEST:CHEVCA | Diesel | 39,000,000 | liquid | 841 Chevron Way, Richmond, CA 94801 | 37.931 | -122.391 |
| DEST:SWGAETH | Naphtha | 2,000,000 | liquid | 4433 Lewis B. Collind Rd, Pelham GA | 31.165 | -84.159 |
| DEST:TATELYLE | Naphtha | 2,000,000 | liquid | 198 Blair Bend Drive, Loudon, TN | 35.736 | -84.318 |
| DEST:ADM | Naphtha | 7,000,000 | liquid | 1350 Waconia Drive, Cedar Rapids, IA | 41.930 | -91.692 |

Scenario (3)

## Table A-4. Raw Material Producers – Scenario 3

| facility_name | commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude | County | State |
|---|---|---|---|---|---|---|---|---|
| RMP:GLHORNHOUSTON | grease | 9,000,000 | liquid | 250 Gellhorn Drive, Houston, TX 77013 | 29.787 | -95.261 | Harris | TX |
| RMP:PRTWLLHOUSTON | grease | 9,000,000 | liquid | 560 Portwall St, Houston, TX 77029 | 29.773 | -95.276 | Harris | TX |
| RMP:AUSTIN | grease | 8,000,000 | liquid | 7019 Burleson Rd., Austin, TX 78744 | 30.199 | -97.707 | Travis | TX |
| RMP:ELLTROUTLUFKIN | grease | 4,000,000 | liquid | 600 Ellen Trout, Lufkin, TX 75904 | 31.374 | -94.717 | Angelina | TX |
| RMP:LAFAYETTE | grease | 5,000,000 | liquid | 504 Industrial Parkway, Lafayette, LA 70508 | 30.181 | -91.996 | Lafayette | LA |
| HAND:CRGLLMONTGO | carinata_oil_seed_bulk | 300,000 ton | solid | 3250 Fitzpatrick Ave, Montgomery, AL 36108 | 32.355 | -86.352 | Montgomery | AL |

## Table A-5. Processors – Scenario 3

| facility_name | commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude |
|---|---|---|---|---|---|---|
| BREF:CHVRNMS | carinata_oil_crude | 35,000,000 | liquid | 250 Industrial Rd, Pascagoula, MS 39581 | 30.386 | -88.503 |
| BREF:CHVRNMS | grease | 35,000,000 | liquid | | 30.386 | -88.503 |
| BREF:CHVRNMS | jet | 14,000,000 | liquid | | 30.386 | -88.503 |
| BREF:CHVRNMS | diesel | 39,000,000 | liquid | | 30.386 | -88.503 |
| BREF:CHVRNMS | naphtha | 11,000,000 | liquid | | 30.386 | -88.503 |
| PROC:CRGLLMONTGO | carinata_oil_seed_bulk | 300,000 ton | solid | 3250 Fitzpatrick Ave, Montgomery, AL 36108 | 32.355 | -86.352 |
| PROC:CRGLLMONTGO | carinata_oil_crude | 35,000,000 | liquid | | 32.355 | -86.352 |

## Table A-6. End-users (Destinations) – Scenario 3

| facility_name | commodity | Value | phase_of_matter | Address 1 | Latitude | Longitude |
|---|---|---|---|---|---|---|
| DEST:LAX | Jet | 14,000,000 | liquid | 1 World Way, Los Angeles, CA 90045 | 33.945 | -118.398 |
| DEST:CHEVCA | Diesel | 39,000,000 | liquid | 841 Chevron Way, Richmond, CA 94801 | 37.931 | -122.391 |
| DEST:SWGAETH | Naphtha | 2,000,000 | liquid | 4433 Lewis B. Collind Rd, Pelham GA | 31.165 | -84.159 |
| DEST:TATELYLE | Naphtha | 2,000,000 | liquid | 198 Blair Bend Drive, Loudon, TN | 35.736 | -84.318 |
| DEST:ADM | Naphtha | 7,000,000 | liquid | 1350 Waconia Drive, Cedar Rapids, IA | 41.930 | -91.692 |

Scenario (5)

## Table A-7. Raw Material Producers – Scenario 5

| facility_name | commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude | County | State |
|---|---|---|---|---|---|---|---|---|
| RMP:MOBILE | grease | 5,000,000 | liquid | 1980 Avenue A, Mobile | 30.649 | -88.066 | Mobile | AL |
| RMP:BATROUGE | grease | 5,000,000 | liquid | 1225 Neodho Avenue, Baton Rouge | 30.469 | -91.179 | East Baton Rouge Parish | LA |
| RMP:JACKSONVILLE | grease | 8,000,000 | liquid | 1640 Talleyrand Ave, Jacksonville | 30.344 | -81.629 | Duval | FL |
| RMP:KISSIMMEE | grease | 8,000,000 | liquid | 1745 S. John Young Pkwy, Kissimmee | 28.276 | -81.422 | Osceola | FL |
| RMP:ATLANTA | grease | 9,000,000 | liquid | 930 Marietta Blvd, Atlanta | 33.782 | -84.430 | Fulton | GA |
| HAND:CRGLLMONTGO | carinata_oil_seed_bulk | 300,000 ton | solid | 3250 Fitzpatrick Ave, Montgomery, AL 36108 | 32.355 | -86.352 | Montgomery | AL |

## Table A-8. Processors – Scenario 5

| facility_name | commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude |
|---|---|---|---|---|---|---|
| BREF:SUNSHINETPA | carinata_oil_crude | 35,000,000 | liquid | Port Tampa Bay 1101 Channelside Drive Tampa, FL 33602 | 27.950 | 82.445 |
| BREF:SUNSHINETPA | Grease | 35,000,000 | liquid | | 27.950 | 82.445 |
| BREF:SUNSHINETPA | Jet | 14,000,000 | liquid | | 27.950 | 82.445 |
| BREF:SUNSHINETPA | Diesel | 39,000,000 | liquid | | 27.950 | 82.445 |
| BREF:SUNSHINETPA | Naphtha | 11,000,000 | liquid | | 27.950 | 82.445 |
| PROC:CRGLLMONTGO | carinata_oil_seed_bulk | 300,000 ton | solid | 3250 Fitzpatrick Ave, Montgomery, AL 36108 | 32.355 | -86.352 |
| PROC:CRGLLMONTGO | carinata_oil_crude | 35,000,000 | liquid | | 32.355 | -86.352 |

## Table A-9. End-users (Destinations) – Scenario 5

| facility_name | commodity | Value | phase_of_matter | Address 1 | Latitude | Longitude |
|---|---|---|---|---|---|---|
| DEST:TPA | Jet | 14,000,000 | liquid | 4100 George J Bean Pkwy, Tampa, FL 33607 | 27.973 | -82.537 |
| DEST:LAX | Jet | 14,000,000 | liquid | 1 World Way, Los Angeles, CA 90045 | 33.945 | -118.398 |
| DEST:DSM | Naphtha | 11,000,000 | liquid | 5800 Fleur Dr, Des Moines, IA 50321 | 41.532 | -93.645 |

Scenario (8)

## Table A-10. Raw Material Producers – Scenario 8

| facility_name | commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude | County | State |
|---|---|---|---|---|---|---|---|---|
| RMP:MOBILE | grease | 5,000,000 | liquid | 1980 Avenue A, Mobile | 30.649 | -88.066 | Mobile | AL |
| RMP:BATROUGE | grease | 5,000,000 | liquid | 1225 Neodho Avenue, Baton Rouge | 30.469 | -91.179 | East Baton Rouge Parish | LA |
| RMP:JACKSONVILLE | grease | 8,000,000 | liquid | 1640 Talleyrand Ave, Jacksonville | 30.344 | -81.629 | Duval | FL |
| RMP:KISSIMMEE | grease | 8,000,000 | liquid | 1745 S. John Young Pkwy, Kissimmee | 28.276 | -81.422 | Osceola | FL |
| RMP:ATLANTA | grease | 9,000,000 | liquid | 930 Marietta Blvd, Atlanta | 33.782 | -84.430 | Fulton | GA |
| HAND:CRGLLMONTGO | carinata_oil_seed_bulk | 300,000 ton | solid | 3250 Fitzpatrick Ave, Montgomery, AL 36108 | 32.355 | -86.352 | Montgomery | AL |

## Table A-11. Processors – Scenario 8

| facility_name | Commodity | Value (gal) | phase_of_matter | Address | Latitude | Longitude |
|---|---|---|---|---|---|---|
| BREF:REGGEISMARLA | carinata_oil_crude | 35,000,000 | liquid | REG Geismer, Geismar, LA 70734 | 30.242 | 30.242 |
| BREF:REGGEISMARLA | Grease | 35,000,000 | liquid | | 30.242 | 30.242 |
| BREF:REGGEISMARLA | Jet | 14,000,000 | liquid | | 30.242 | 30.242 |
| BREF:REGGEISMARLA | Diesel | 39,000,000 | liquid | | 30.242 | 30.242 |
| PROC:EXPRSGRNMS | Naphtha | 11,000,000 | solid | 2015 River Rd Greenwood, MS 38930 | 30.242 | 30.242 |
| PROC:EXPRSGRNMS | carinata_oil_seed_bulk | 300,000 ton | liquid | | 33.518 | 33.518 |

## Table A-12. End-users (Destinations) – Scenario 8

| facility_name | commodity | value | phase_of_matter | Address | Latitude | Longitude |
|---|---|---|---|---|---|---|
| DEST:IAH | Jet | 7,000,000 | liquid | "2800 N Terminal Rd, Houston, TX 77032 | 29.984 | -95.332 |
| DEST:DFW | Jet | 7,000,000 | liquid | 2400 Aviation Dr, DFW Airport, TX 75261 | 32.898 | -97.039 |
| DEST:VCV | Diesel | 39,000,000 | liquid | USA-Canada Border Crossing Location Closest to Vancouver | 49.250 | -123.119 |
| DEST:VCV | Naphtha | 11,000,000 | liquid | | 49.250 | -123.119 |