APPENDIX F:
FEEDSTOCK TRANSPORTATION AND LOGISTICS

RENEWABLE FUELS ROADMAP AND SUSTAINABLE BIOMASS FEEDSTOCK SUPPLY FOR NEW YORK

Final Report

Submitted to

PACE ENERGY AND CLIMATE CENTER

White Plains, NY

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NEW YORK STATE DEPARTMENT OF AGRICULTURE AND MARKETS

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ABSTRACT

This Appendix discusses transportation and distribution (T&D) implications of increased biofuel feedstock and fuel production in New York State. For each Scenario presented in the Roadmap, this analysis evaluates capacity, energy, and environmental impacts associated with moving feedstock and fuel throughout the State. In particular, this appendix uses geographic locations of feedstock supplies, biorefineries, and distribution networks to evaluate the energy and environmental impacts due to transporting feedstock and fuel for each Scenario (based on the results of the modeling work presented in Appendix L). This analysis reveals potential capacity constraints and economic issues that inform the discussion regarding infrastructure needs and opportunities to support a sustainable biofuels industry.

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OVERVIEW

The impacts of feedstock and fuel transportation and distribution (T&D) are important considerations when examining the potential for sustainable biofuels production in New York State. The existing capacity of transport modes (including train, barge and truck) will have a bearing on the development of the biofuels industry. Improvement and expansion of T&D networks may facilitate or counteract the sustainability of industry development, as alternative transportation modes can have quite different energy, environmental, and economic characteristics. This appendix addresses the opportunities for, and potential impacts of, biofuels T&D under the scenarios presented for this Roadmap project.

The authors evaluate capacity, energy, and environmental impacts associated with moving feedstock and fuel throughout the state. In particular, this Appendix identifies the geographic locations of feedstock supplies and distribution networks; evaluates the energy and environmental impacts due to transporting feedstock and fuel for each Scenario (based on the results of the modeling work presented earlier); raises issues related to capacity constraints and economics; and discusses needs and opportunities for expanded transportation infrastructure.

1. GEOGRAPHIC LOCATIONS OF FEEDSTOCK SUPPLIES AND FEEDSTOCK FLOWS

SCENARIO OVERVIEW

This Roadmap report discusses the production of different feedstocks to support an emerging, sustainable biofuel industry in New York. Feedstock supply varies by county and is different for each of the three Scenarios (1, 2, 3) and two price cases ("a" for the $3/gallon gasoline equivalent (gge) case, and "b" for the $4/gge case). To review the Scenario descriptions in the context of T&D:

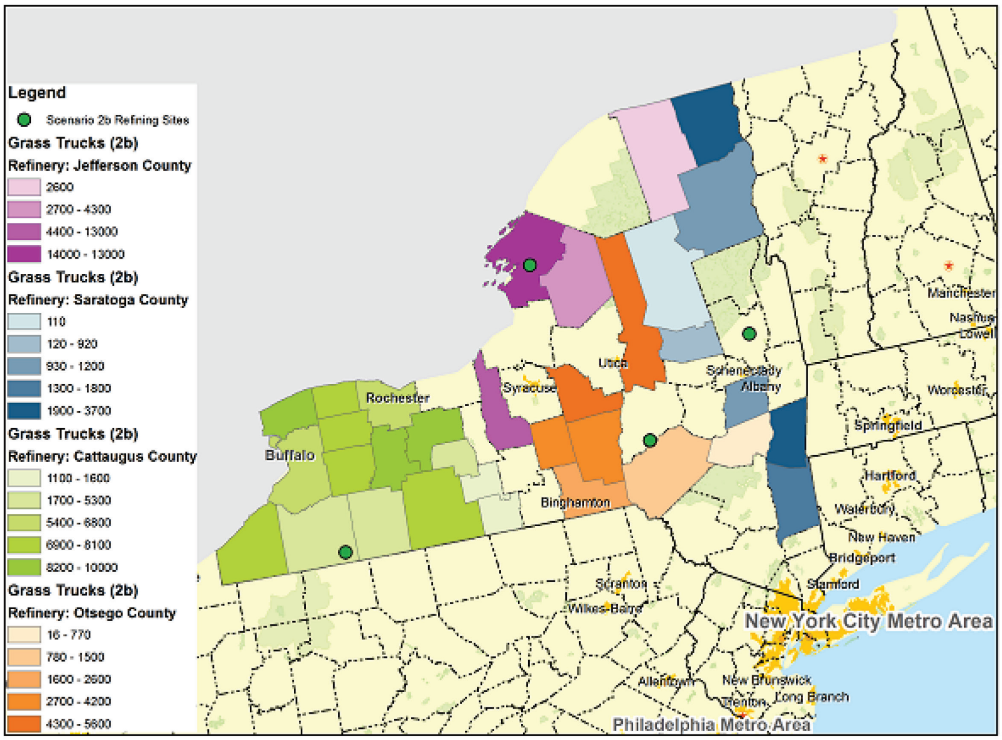
- **Scenario 1** depicts a biofuel industry scenario with smaller scale feedstock production compared to Scenarios 2 and 3 (Scenario 1a and 1b assume 7.7 and 15.3 million wet tons of feedstock, respectively, while Scenarios 2 and 3 assume over 23 million wet tons), with four biorefinery locations in the State. Scenario 1 assumes that cost and performance expectations for the first generation of lignocellulosic conversion technologies (biochemical and thermochemical systems) are met. Lower yields of ethanol per ton of feedstock are produced compared to Scenarios 2 and 3.
- **Scenario 2** depicts a biofuels industry where larger-scale biofuel production exists. Feedstock availability for biofuels in this scenario is greater than in Scenario 1. The Scenario 2 biofuels industry is centralized, with few (but high capacity) biorefinery locations in the State; thus, similar to Scenario 1, feedstock and fuel transportation distances are greater than would be seen in a distributed, localized biofuels industry. Scenario 2 assumes that biorefineries employ advanced lignocellulosic conversion technologies, yielding more ethanol per ton input than Scenario 1.
- **Scenario 3** depicts a distributed biofuels industry, with a greater number of lower capacity biorefinery locations in the State. These refineries, though distributed, in combination process similar volumes of feedstock to Scenario 2. Feedstock and fuel transportation distances are less than would be seen in a centralized biofuels industry. Scenario 3 assumes that biorefineries employ advanced lignocellulosic conversion technologies, as in Scenario 2.

GEOGRAPHIC LOCATIONS OF FEEDSTOCKS

Figures F-1 through Figure F-8 illustrate production quantities of each feedstock by county for Scenario 2b (in which high feedstock production is coupled with longer-distance feedstock transportation). The maps also identify the estimated number of truck-trips required to transport feedstock from origin county to biorefinery (destination), assuming a full truckload carrying 22 tons of wet feedstock.
Table F-1 aggregates these data for each Scenario.

Note that feedstock transport calculations assume that feedstock is wet (moisture content at origin) when transported from origin county to destination county. This implies that drying and storage takes place at the biorefinery location, though we do not consider storage logistics here. Proper drying of feedstock is required for storage to prevent fires, fermentation and spoilage; also, allowing rainwater to seep into feedstock can increase weight twofold. Furthermore, alternative feedstock storage strategies (i.e., round vs. rectangular bales; plastic covered vs. twine) have an effect on weight of feedstock and the amount of feedstock that can fit into a truck at one time (Austin, 2009). Feedstock transport calculations here employ assumptions used in economic modeling[1] conducted in Appendix L; we do not examine alternative truck or feedstock weight configurations due to changes in storage logistics.

Figure F-1. Scenario 2b Grass Production by County and Biorefinery (Truck = 22 Wet Tons).



[1] This Roadmap appendix was not designed to find the pathway that would have the least impact to transportation as it relates to biofuels production, but to quantify and describe the impacts of such development on transportation. What the authors of this Appendix did was to take the outputs from the biorefinery siting model (Appendix L) and construct the transportation emissions and energy use calculations based on those outputs. No preference was given for selecting one mode of transportation over another – truck vs. barge, vs. rail -- in creating the biorefinery siting model; instead, the economic model employed in siting the biorefineries was a cost minimization model that indentified only the private costs of feedstock production, transportation, and fuel production. This model does not include potential social costs from biofuels production. In the future, this appendix could form part of a baseline for developing a social costs model that values the environmental and health impacts from the transportation and distribution of biofuels.

Figure F-2. Scenario 2b Hardwood Production by County and Biorefinery (Truck = 22 Wet Tons).

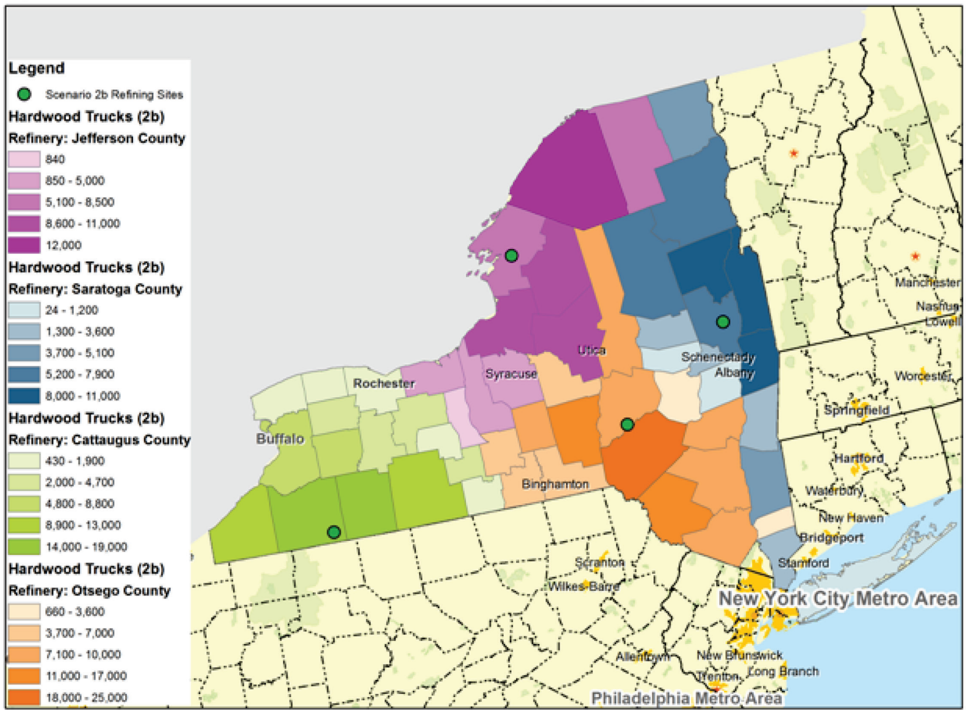


Figure F-3. Scenario 2b Softwood Production by County and Biorefinery (Truck = 22 Wet Tons).

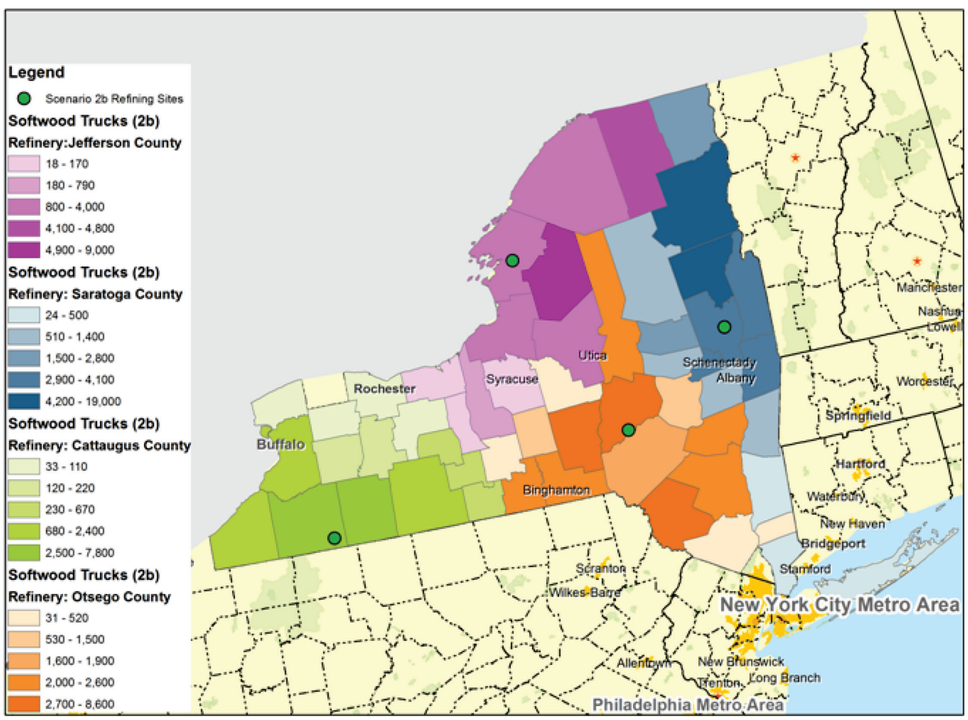


Figure F-4. Scenario 2b Corn Stover Production by County and Biorefinery (Truck = 22 Wet Tons).

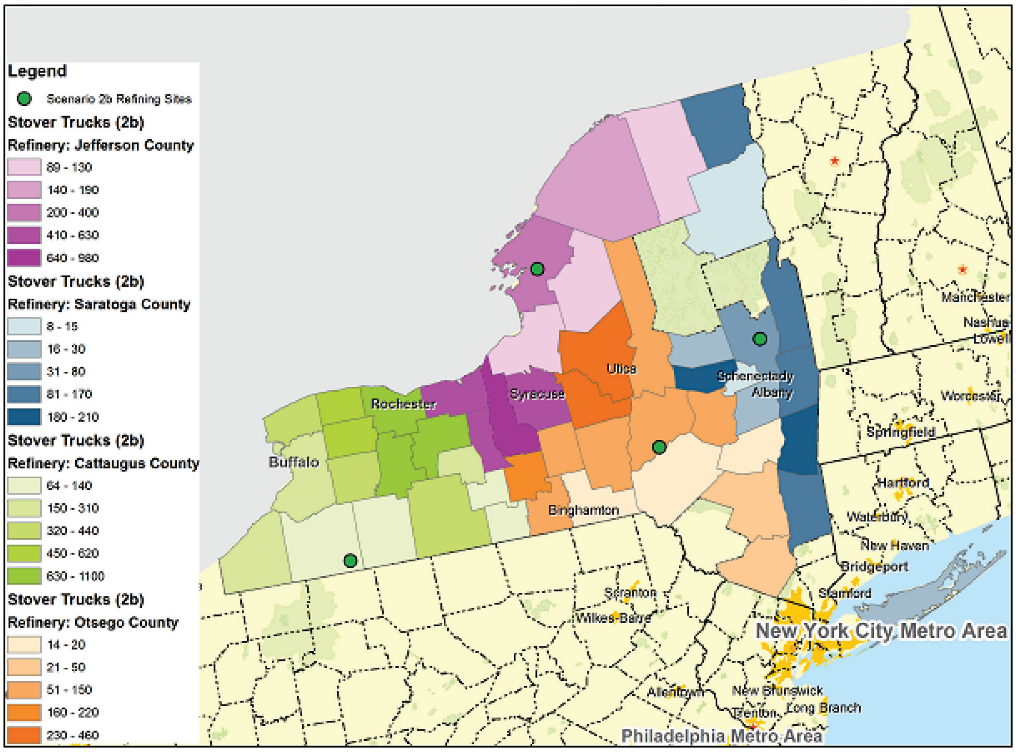


Figure F-5. Willow Production by County and Biorefinery (Truck = 22 Wet Tons).

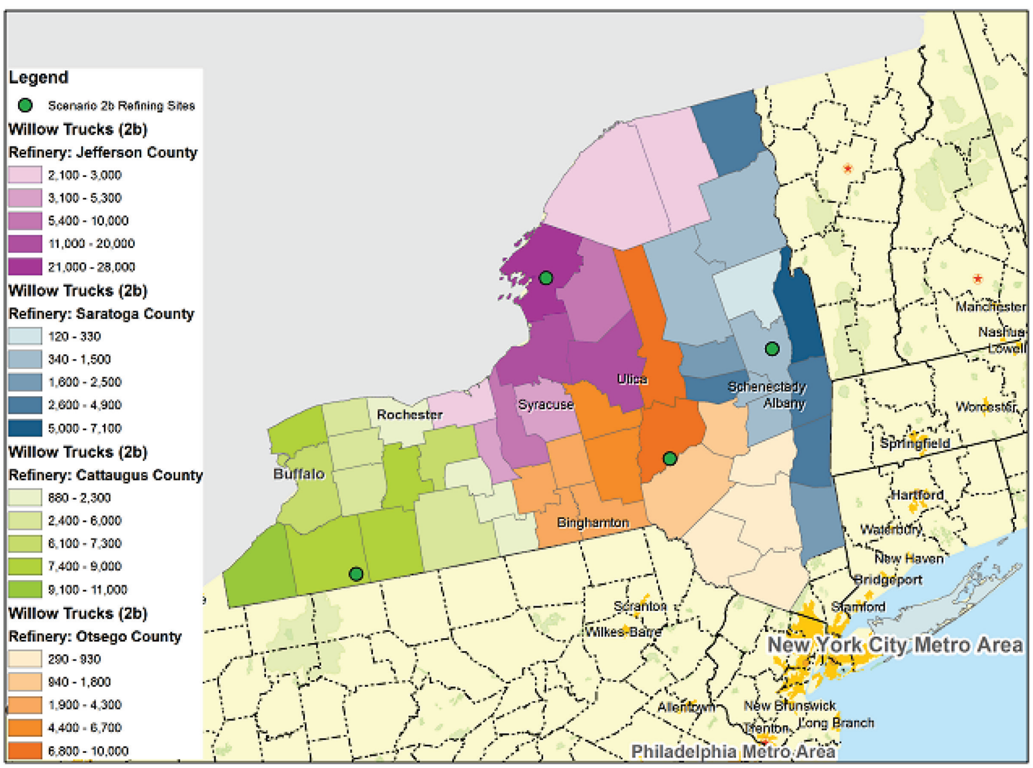


Figure F-6. Corn Grain Production by County and Destination Ethanol Plant (Truck = 22 Tons Corn Grain).

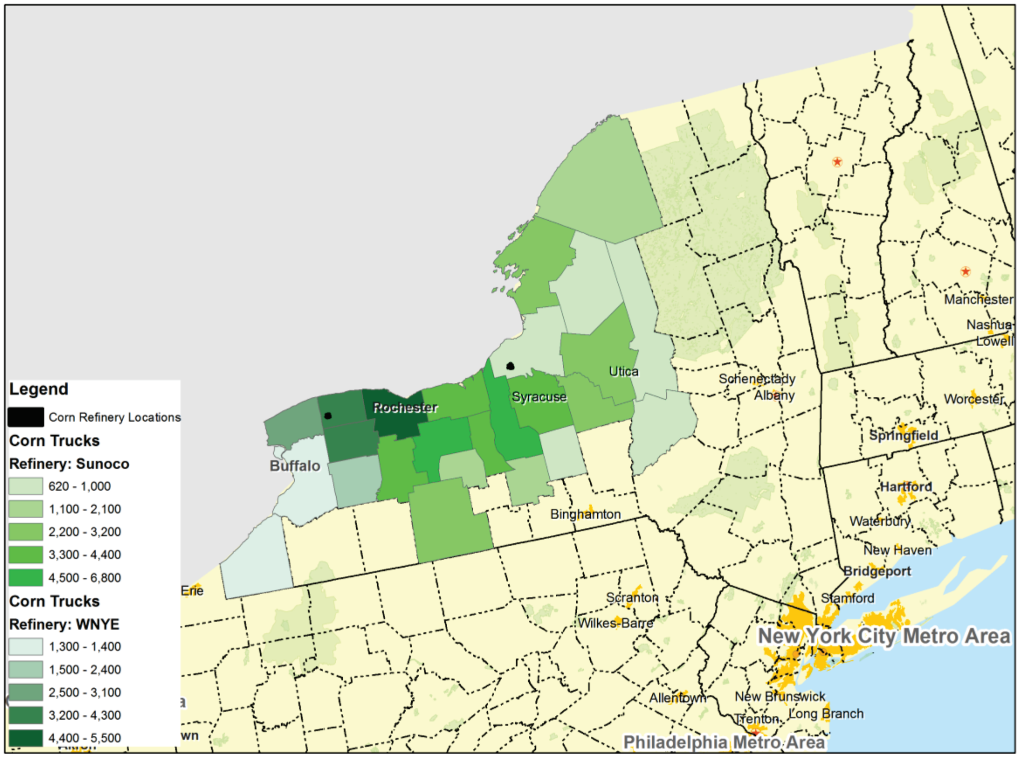


Figure F-7. Soybean Production by County (Truck = 22 Tons Soybeans).

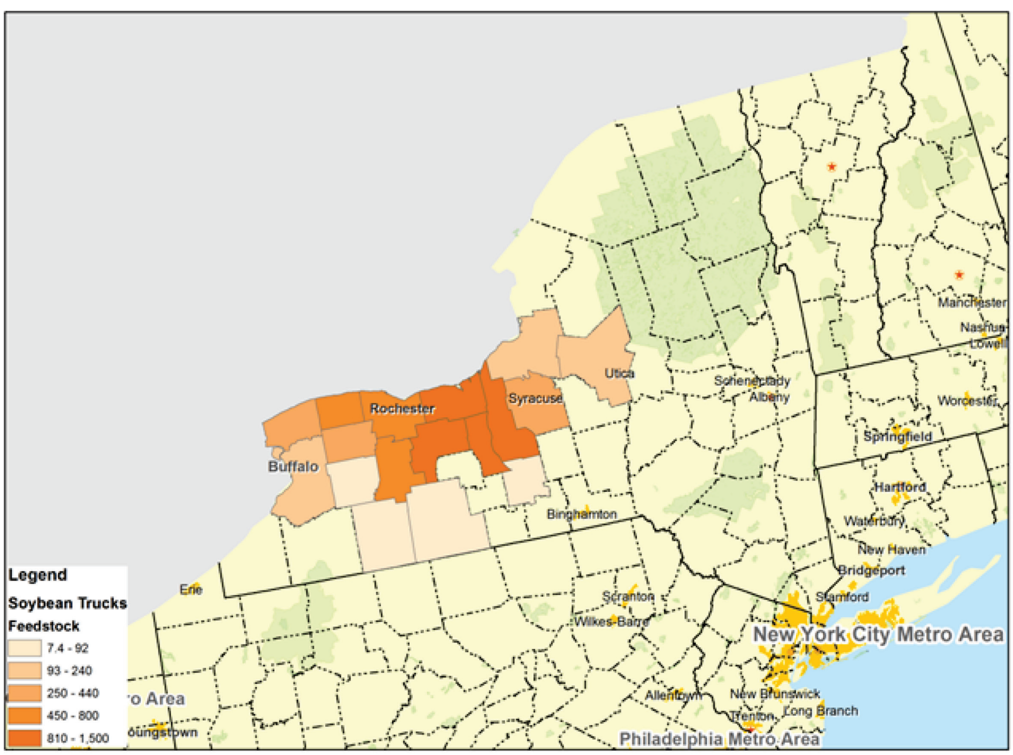


Figure F-8. Combined Total Lignocellulosic Ethanol Feedstock Production by County (Truck = 22 Wet Tons).

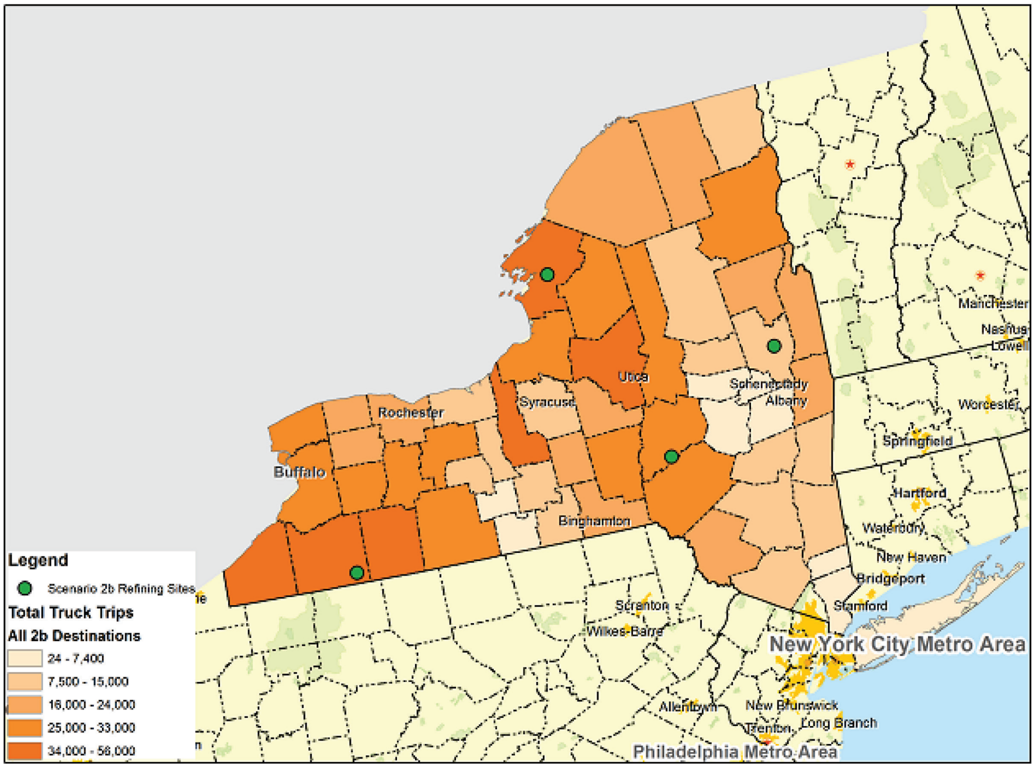


Table F-1. Quantity of Feedstock Production by Type and Scenario, Wet Tons.

	Corn Stover	Grass	Willow	Softwood Forest Residue	Hardwood Forest Residue	Total
Scenario 1a	32,540	0	2,760,960	1,517,240	3,383,400	**7,694,151**
Scenario 1b	287,290	2,616,900	3,743,800	2,494,180	6,250,420	**15,392,144**
Scenario 2a	287,290	5,201,030	6,035,620	3,216,180	8,486,620	**23,136,740**
Scenario 2b	287,290	5,272,000	6,035,620	3,216,180	8,486,620	**23,207,710**
Scenario 3a	287,290	5,270,690	6,035,620	3,216,180	8,486,620	**23,206,400**
Scenario 3b	287,290	5,272,000	6,035,620	3,216,180	8,486,620	**23,207,710**
Corn Grain	-	-	-	-	-	**1,680,520**
Soybeans	-	-	-	-	-	**194,645**

Feedstock and Fuel Transportation Flows, Origin County to Biorefinery

Flows of feedstock were calculated from origin county to biorefinery destination, considering tonnage of feedstock and distance traveled for each origin-destination pair. Table F-2 shows the average distance by feedstock type from origin county to biorefinery for each Scenario by mode. Lignocellulosic ethanol (LCE) feedstock transportation distances vary by Scenario. For instance, in Scenario 1a corn stover travels

24.3 miles by truck to biorefineries on average, in Scenario 2a, corn stover travels 79.3 miles by truck, and in Scenario 3a, corn stover travels only 24.4 miles by truck on average. The variation in transportation distance is largely attributable to the difference in number of biorefineries (centralized vs. decentralized) and the scale of feedstock production. In general, LCE feedstocks travel fewer than 100 miles by truck, and when traveling by barge, they travel between 150-180 miles. Corn grain travels over 120 miles on average from farm to biorefinery, while soybeans travel nearly 230 miles in the transit from farm to crusher (in Ontario, Canada) to the biorefinery; corn and soybeans/soy oil travel exclusively by truck.

Total feedstock flows by biorefinery for each Scenario are summarized in Table F-3. Feedstock flows for Scenario 2b and Scenario 3b are shown in Figure F-9 and Figure F-10, respectively. Scenario 2b and 3b are chosen for illustration as these Scenarios involve the greatest amount of feedstock production (and thus the greatest T&D impacts); further these Scenarios illustrate differences due to a centralized (2b) vs a decentralized (3b) biofuels industry. Figure F-9 shows ton-miles of total feedstock transport in Scenario 2b by origin county, color-coded to depict four biorefinery locations assumed in the Roadmap. Figure F-10 shows ton-miles of feedstock flows by origin county to the 22 biorefinery locations identified in Scenario 3b. A decentralized biofuels industry measurably decreases required ton-miles of feedstock transport. Although Scenario 2b and 3b generate equivalent quantities of feedstock and ethanol, the quantity of ton-miles in Scenario 3b is roughly half that in Scenario 2b. As discussed later in this appendix, ton-miles are directly associated with energy use, emissions, and economics of transport.

Table F-2. Average Distance in Miles, Feedstock to Biorefinery by Scenario and Mode.

Scenario	Mode	Feedstock						
		Corn Stover	Grass	Willow	Softwood	Hardwood	Corn Grain	Soybeans
Scenario 1a	Truck	24.3	n/a	46.5	38.0	37.2	122.7	227.4
	Barge	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Scenario 1b	Truck	79.4	59.6	59.4	57.4	57.7	122.7	227.4
	Barge	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Scenario 2a	Truck	79.3	69.7	60.9	57.5	61.4	122.7	227.4
	Barge	179.2	179.2	179.2	178.7	176.1	n/a	n/a
Scenario 2b	Truck	79.5	70.2	60.9	57.5	61.4	122.7	227.4
	Barge	179.2	179.2	179.2	178.7	176.1	n/a	n/a
Scenario 3a	Truck	24.4	26.3	22.7	39.3	30.1	122.7	227.4
	Barge	146.9	158.1	179.2	179.2	179.2	n/a	n/a
Scenario 3b	Truck	25.1	26.2	22.2	39.0	30.2	122.7	227.4
	Barge	179.2	156.3	179.2	179.2	179.2	n/a	n/a

Note: No trains were selected for transportation of feedstock in the simulation results.

Figure F-9. Feedstock Transportation, Scenario 2b Wet ton-miles by Origin County and Biorefinery.

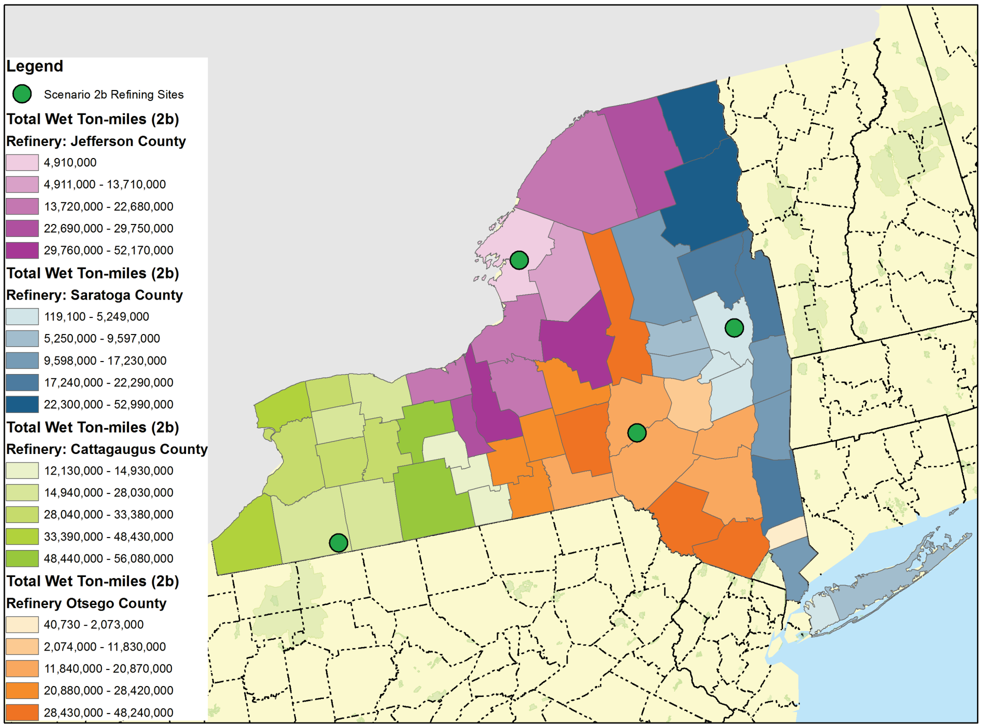
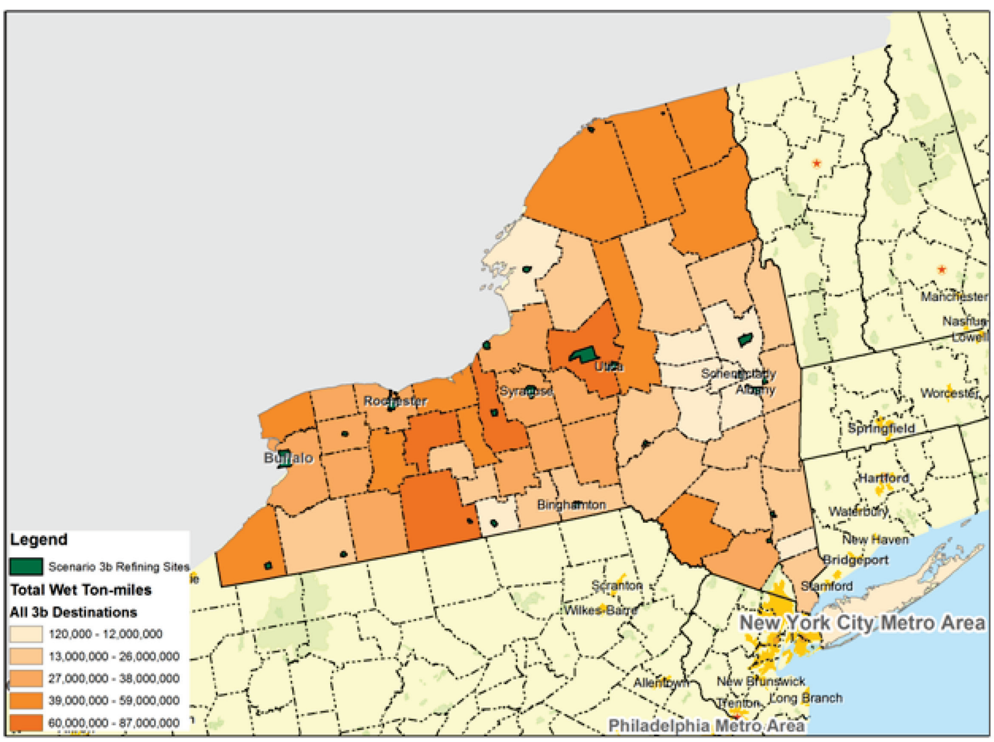


Figure F-10. Feedstock Transportation, Scenario 3b Wet ton-miles by Origin County.



Ethanol production, average distance from biorefinery to blending terminal, and ton-miles of fuel transport by Scenario and fuel type are shown in Table F-4. Fuel transportation occurs exclusively by truck and is less than 30 miles on average. Fuel transportation represents a fraction of feedstock transportation ton-miles in all Scenarios and fuel types.

Current Distribution Networks in New York State

New York has an expansive highway and rail system that may be employed to move feedstock throughout the State; additionally, the State waterway network includes an inland canal system, Lake Ontario, Lake Erie and Finger Lakes access, and Atlantic coastal waters.[2] This infrastructure is depicted in Figures F-12-F-14, which display the highway, waterway, and rail, networks for the State. Analysis conducted for the Roadmap indicates that trucks will be used extensively, if not exclusively, in all Scenarios based on a least cost production model. Given the short distances needed for feedstock and fuel transport (see above figures), this reliance on trucks is predictable. Further, Figure F-12 shows that the highway network in the State extends into all feedstock origin counties. In contrast, the State waterway and rail networks do not reach into several northeastern and southwestern counties in the State where potential feedstock production is pleZntiful, therefore in many cases truck transportation is the only currently existing option for feedstock transport. There may be opportunities for the State to take advantage of railway and waterway networks, however, as discussed in later sections of this Appendix.

The New York State Canal System, connecting the Hudson River with the Great Lakes, Finger Lakes, and Lake Champlain, is an impressive 524 miles long. Unfortunately, many sections of the canal system have vertical clearance issues or shallow depths. Efforts are underway to return the canal system to a control depth of 14 feet between Waterford and Oswego and 12 feet elsewhere (NYS Canal Corporation, 2009). Though impressive in length east to west, the Canal System does not reach extensively into many regions of the State, limiting the usefulness of the system for transport of feedstock from many counties to refining sites modeled in this Roadmap project. Water-based transport generally is less expensive than truck on a marginal cost basis (per ton-mile); however it tends to be less cost-effective over distances less than a few hundred miles as there are fixed transfer costs associated with water-based transport (e.g., cargo loading and unloading). These costs may increase the average costs of transport (per ton-mile) to be greater than truck for short distance hauls. Indeed, the least cost analysis conducted for this Roadmap selected marine transport for less than 2% of feedstock transport in all Scenarios, and marine was only used for distances over 100 miles.

[2] We did not consider ethanol transport via pipeline in this analysis; pipeline transport of ethanol is not practical with existing petroleum pipeline infrastructure as ethanol is somewhat corrosive and its quality can be compromised from pipeline water seepage. However, modifications to the infrastructure may be possible in the future to accommodate ethanol delivery.

Table F-3. Feedstock Transportation: Ton-miles by Feedstock, Scenario and Mode.

Scenario	Mode	Feedstock Type						Mode % of Transport
		Corn Stover	Grass	Willow	Softwood Forest Residue	Hardwood Forest Residue	Total	
Scenario 1a	Truck	792,137	0	128,487,736	57,653,257	125,753,001	**312,686,129**	100%
	Barge	0	0	0	0	0	**0**	0%
Scenario 1b	Truck	22,770,595	155,949,610	222,233,028	143,191,236	360,381,618	**904,526,088**	100%
	Barge	0	0	0	0	0	**0**	0%
Scenario 2a	Truck	22,789,888	362,468,154	367,557,375	179,727,869	520,878,947	**1,453,422,236**	98.8%
	Barge	118,546	1,547,763	491,907	693,669	14,136,069	**16,987,955**	1.2%
Scenario 2b	Truck	22,828,525	369,861,095	367,557,376	179,732,695	520,980,559	**1,460,960,249**	98.8%
	Barge	118,546	2,518,526	491,907	693,669	14,136,069	**17,958,718**	1.2%
Scenario 3a	Truck	6,998,372	138,488,553	134,409,029	122,920,370	255,311,102	**658,127,426**	98.8%
	Barge	97,145	2,174,932	491,907	599,505	1,994,659	**5,358,149**	1.2%
Scenario 3b	Truck	7,221,651	138,243,662	134,241,398	121,949,355	256,608,246	**658,264,312**	98.8%
	Barge	118,546	2,196,968	491,907	599,505	1,994,659	**5,401,586**	1.2%

Note: No trains were selected for transportation of feedstock in the simulation results.

Table F-4. Biofuel Fuel Transport by Scenario, Biorefinery to Blending Terminal.

Scenario	Million Gal Year	Thousand Tons Ethanol	Tons Per Truck	Average Miles, Biorefinery to Blending Terminal	Fuel Transport Ton-miles
Scenario 1a	354.2	1,169	29.7	28.1	**32,795,077**
Scenario 1b	769.9	2,540	29.7	28.1	**71,276,858**
Scenario 2a	1,295.0	4,274	29.7	27.0	**115,558,034**
Scenario 2b	1,300.1	4,290	29.7	27.0	**115,786,133**
Scenario 3a	1,300.0	4,290	29.7	24.5	**104,945,577**
Scenario 3b	1,300.1	4,290	29.7	24.5	**104,968,182**
Corn Ethanol	163.2	539	29.7	23.6	**12,732,456**
Soy Biodiesel	9.6	35	32.9	0.5	**17,520**

Figure F-11. Biorefinery Sites and Blending Facilities (Scenario 3b).

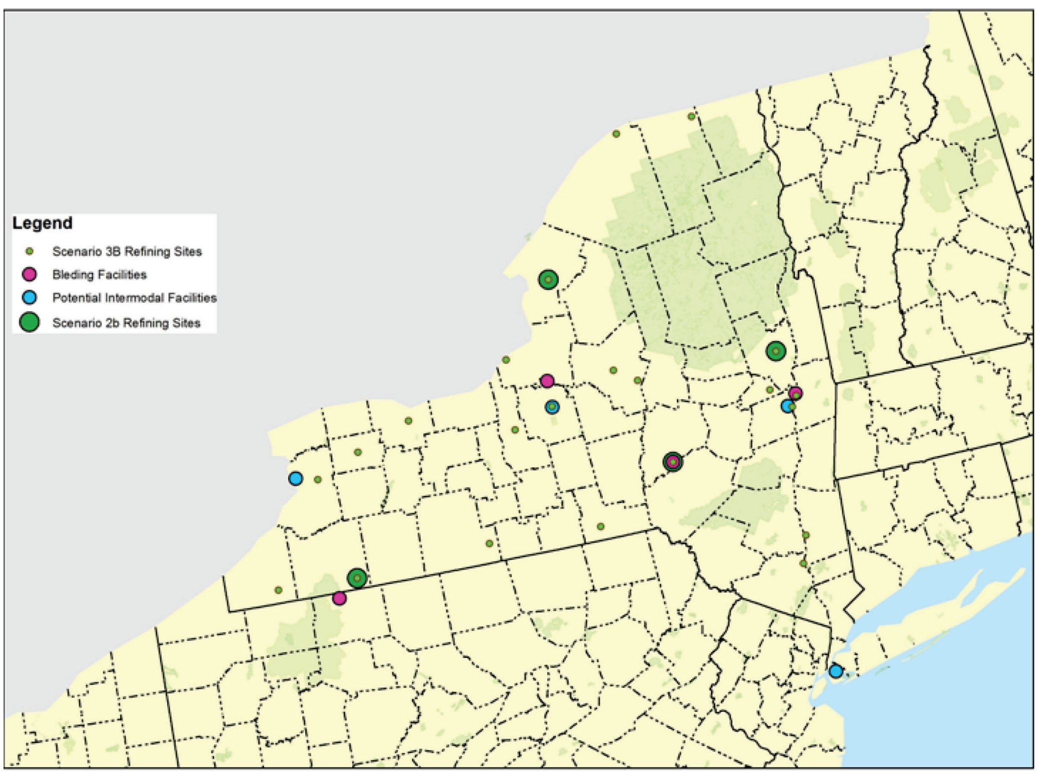


Figure F-12. Map of New York State Highway Networks.

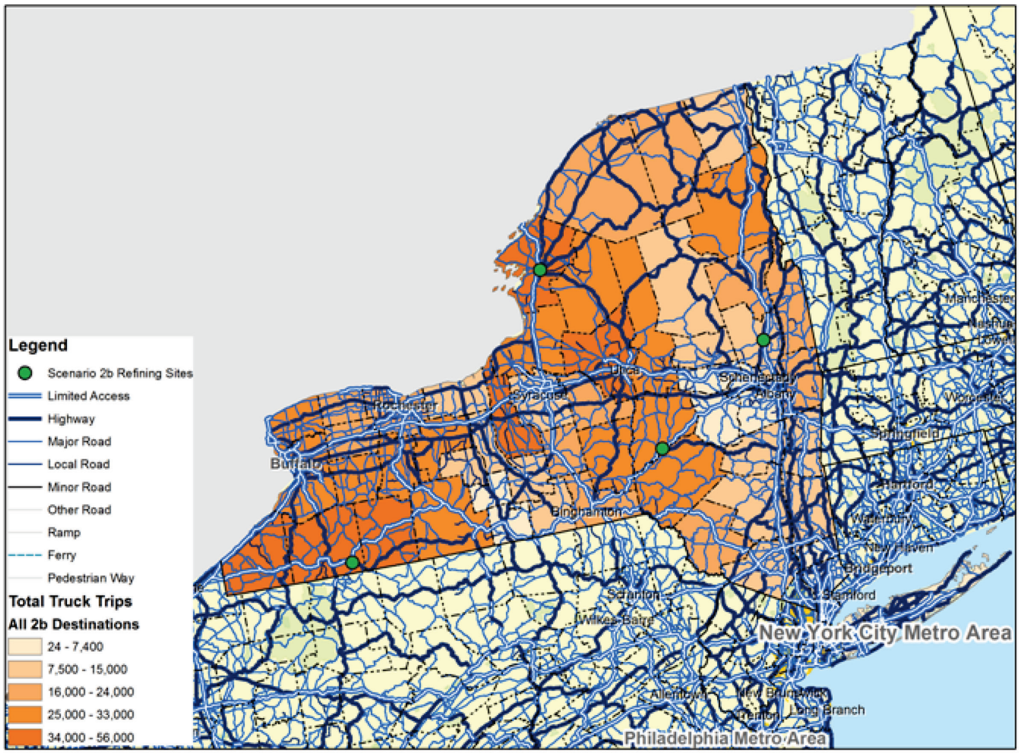


Figure F-13. Map of New York State Waterway Transportation Network.

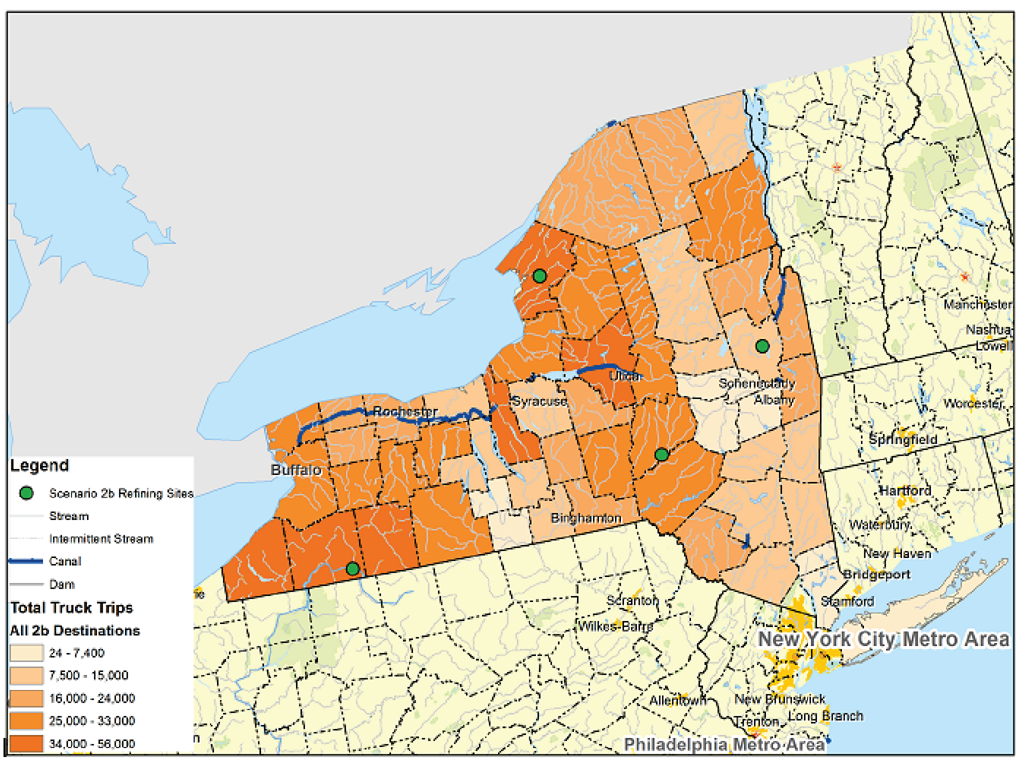
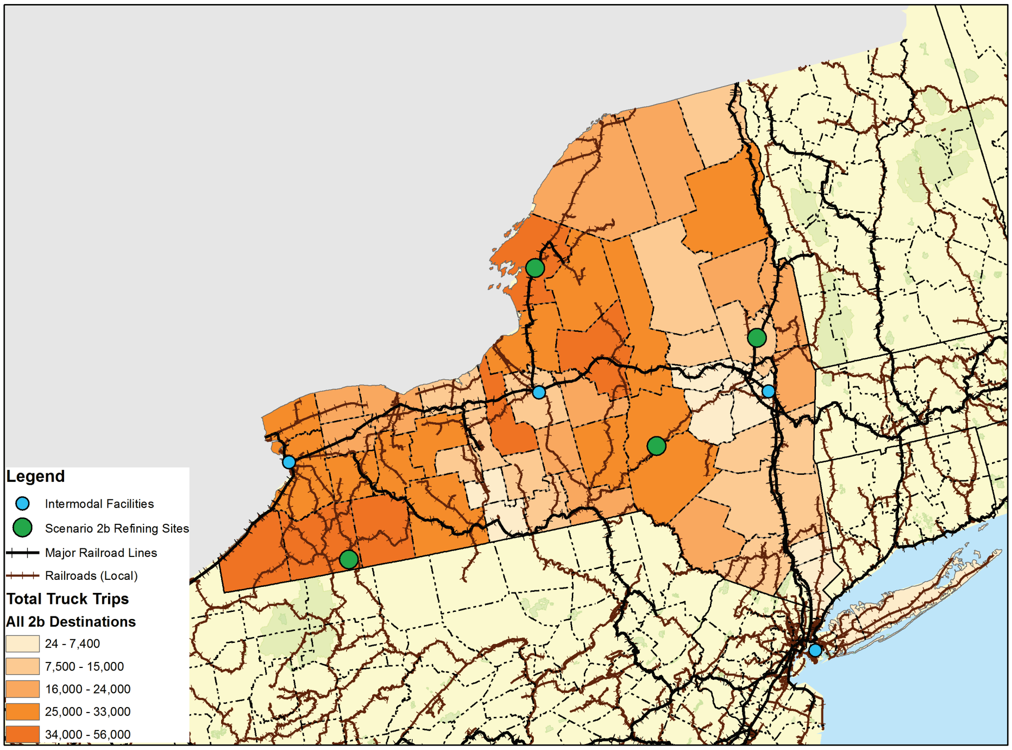


Figure F-14. Map of New York State Rail Network and Intermodal Facilities.



Most feedstock is produced in counties where rail infrastructure is present, raising the potential for rail transportation from these counties. However, access to these rail systems is uncertain and will depend on the number of rail transfer facilities and their proximity to feedstock collection points. Like marine transport, rail transport is generally less expensive than truck on a marginal cost basis (per ton-mile), but fixed transfer costs increase the average cost of transport to be greater than trucks for short distance hauls. The economic modeling conducted in Appendix L did not select rail transport of feedstocks in any Scenarios. Figure F-14 also depicts five intermodal facilities where freight containers are moved between transportation modes (i.e. rail, truck, barge). These are located in: Buffalo (two), Syracuse, Albany and Staten Island. However, these facilities handle containers rather than bulk transfer operations. As noted in the New York State Rail Plan (NYSDOT, 2009), the vision for the State rail system includes the development of three new intermodal facilities or inland ports, at least two of which would be sited in upstate New York. If developed near areas of major feedstock production, and if they include bulk transfer operations, these new intermodal facilities might allow for use of rail transport where it is currently infeasible or uneconomical. Though not examined in the Scenarios, there is potential that export markets for biofuel feedstocks or fuel might develop; in this case use of rail may make up a larger scale than in-State only biofuel markets.

2. ENERGY USE, EMISSIONS, ECONOMIC AND CAPACITY ANALYSIS

ENERGY USE AND EMISSIONS[3]

Data were collected on the economic, energy use, and emissions associated with truck, rail, and water transportation. The authors used data generated through the literature and through activity-based analyses to derive energy use and emissions factors shown in Table F-5. Assumptions used to calculate "downstream" (operational/tailpipe) emissions and energy use are shown in Table F-5; NY-GREET model[4] assumptions were used to calculate "upstream" (feedstock extraction, fuel processing and transportation, etc) emissions and energy use. From an energy use and emissions standpoint, trucks are the most energy- and emissions-intensive per ton-mile (Table F-6). However, their versatility in decentralized feedstock and fuel production systems most often makes them the economically optimal choice for feedstock movement to refining locations.

Using the values presented in the following tables, the authors calculated energy use and emissions associated with each of the Scenarios and cases. Note that these results represent a lower bound of T&D emissions, as we assume full truckloads only traveling from feedstock source-county to biorefinery. Energy use and emissions from partially empty trucks or empty returns are not included in the analysis. Note that Table F-7 shows energy and emissions associated with T&D in Scenario 2 and are approximately twice those in Scenario 3, even though nearly identical quantities of feedstock and ethanol are produced.

Figures F-9 and F-10 depict ton-miles of feedstock transportation by source-county. Emissions and energy use are a function of ton-miles of freight—increased ton-miles equates to increased GHG and criteria pollutant emissions. (Note that the ethanol production modeling results did not select rail as a feedstock transportation mode, and thus rail is not included in Table F-7. These figures roughly represent the counties that may generate the most feedstock-related transportation emissions in the State. Although this feedstock movement may transit through other counties, these results suggest that darker source-counties and biorefinery-counties may be exposed to the greatest share of T&D emissions. Counties through which or to which large quantities of feedstock are transported may therefore experience negative health impacts due to higher concentrations of criteria pollutants.

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[3] This section is not intended to find the transportation pathways that have "least impact" on the environment. Rather, its purpose is to quantify and describe the energy and environmental impacts of a biofuel T&D network as defined by the Roadmap modeling output.

[4] Based on the national GREET model developed at Argonne National Lab, but uses input assumptions relevant for New York State (such as electricity mix, fuel transportation distances, and agricultural assumptions).

Table F-5. Assumptions Employed in Three-Mode Emissions and Energy Use Model (Downstream).

Model Input	Value	Units	Source
All Modes			
Carbon Content of Diesel Fuel	0.86	gC/gFuel	Argonne National Lab 2009
Energy Density of Diesel Fuel	128,450	BTU/gal	Argonne National Lab 2009
Mass Density of Diesel Fuel	3,167	g/gal	Argonne National Lab 2009
Truck			
Fuel Economy	6.0	mi/gal	National Research Council 2008
Cargo Weight per Truckload	Feedstock: 22.0 Ethanol: 29.7 Biodiesel: 32.9	Tons/ Truckload	See Appendix L, Assumes 9,000 gallons of fuel per truckload
Engine Efficiency	0.42		National Research Council 2008
NOx	0.2	g/bhp-hr	40 CFR 86.007-11
PM_{10}	0.01	g/bhp-hr	40 CFR 86.007-11
Sox	15	ppm	40 CFR 80.520
Rail			
Number of Engines	2		
Horsepower per Engine	4,000	Hp	Casgar, DeBoer et al. 2003
Tons Capacity	3,320	tons	
NOx	1.3	g/bhp-hr	EPA 2008
PM_{10}	0.03	g/bhp-hr	EPA 2008
Sox	15	ppm	EPA 2008
Tug-and-Barge			
Horsepower per Engine	1,550	Hp	
Tons Capacity	1,830	tons	
Engine Efficiency	0.40		Estimated
Load Factor	0.65		MARAD 2005
Avg. Speed	9	mph	MARAD 2005
NOx	1.3	g/bhp-hr	EPA 2008
PM_{10}	0.03	g/bhp-hr	EPA 2008
Sox	15	ppm	EPA 2008

Table F-6. Calculated Energy Use and Emissions per Ton-Mile, Feedstock and Fuel Transport.

Component of T&D	Fuel Cycle Stage	Energy Use and Emissions per ton-mile				
		Energy (Btu)	**CO_2 (grams)**	**SO_2 (grams)**	**NOx (grams)**	**PM (grams)**
Feedstock Transport, Truck	Upstream	189	15	0.0201	0.0416	0.0084
	Downstream	973	76	0.0007	0.0426	0.0021
	Total Fuel Cycle	1162	91	0.0208	0.0842	0.0106
Feedstock Transport, Barge	Upstream	76	6	0.0080	0.0167	0.0034
	Downstream	390	30	0.0003	0.0797	0.0018
	Total Fuel Cycle	465	36	0.0083	0.0964	0.0052

Table F-7. Energy use and emissions results for each Scenario by transportation stage.

Scenario	Feedstock or Fuel Transport	Mode	Total Fuel Cycle Energy Use and Emissions, Feedstock + Fuel Transportation				
			Energy (MMBtu)	CO_2 (metric tons)	SO_2 (metric tons)	NOx (metric tons)	PM (metric tons)
Scenario 1a	Feedstock	Truck	363,221	28,369	6.50	26.33	3.31
		Barge	0	0	0	0	0
	Fuel	Truck	29,821	2,332	0.68	2.40	0.33
Scenario 1b	Feedstock	Truck	1,050,733	82,067	18.80	76.15	9.56
		Barge	0	0	0	0	0
	Fuel	Truck	70,071	5,477	1.47	5.44	0.73
Scenario 2a	Feedstock	Truck	1,688,316	131,865	30.20	122.37	15.36
		Barge	7,905	617	0.14	1.64	0.09
	Fuel	Truck	105,080	8,218	2.38	8.45	1.16
Scenario 2b	Feedstock	Truck	1,697,073	132,549	30.36	123.00	15.44
		Barge	8,357	653	0.15	1.73	0.09
	Fuel	Truck	105,288	8,234	2.38	8.47	1.16
Scenario 3a	Feedstock	Truck	764,490	59,710	13.68	55.41	6.96
		Barge	2,493	162	0.00	0.43	0.01
	Fuel	Truck	95,430	7,463	2.16	7.68	1.05
Scenario 3b	Feedstock	Truck	764,649	59,723	13.68	55.42	6.96
		Barge	2,514	196	0.04	0.52	0.03
	Fuel	Truck	95,450	7,465	2.16	7.68	1.05
Corn Grain	Feedstock	Truck	239,459	18,703	4.28	17.36	2.18
		Barge	0	0	0	0	0
	Fuel	Truck	11,578	905	0.26	0.93	0.13
Soy Biodiesel	Feedstock	Truck	40,363	3,153	0.72	2.93	0.37
		Barge	0	0	0	0	0
	Fuel	Truck	15	1	0.00	0.00	0.00

ECONOMICS

Table F-8 compares economics of truck, rail, and water modes based on the movement of containerized goods. These values represent average segment costs from the literature and do not account for the costs of feedstock or fuel transfer. As shown in the table, transportation by truck has a higher marginal cost per mile than rail or ship. As discussed earlier, the use of rail or ship will require transfers (i.e., from truck to rail, rail to truck) that have high fixed costs. For long distance travel, these fixed costs are divided over a great many miles, so the average costs of rail or ship transport is usually less than for truck transportation.

For shorter distances, these fixed costs lead to higher average costs compared with trucks. Some literature on goods movement has shown that trains and ships can effectively compete with trucks economically when shipping distances are greater than 500-750 miles.

Table F-8. Average freight rates for feedstock movement via truck, rail, and ship.

	Truck	Rail	Ship
Cost per TEU-mile[a]	$0.87	$0.55	$0.50
Cost per Ton-mile, Feedstock Transport[b]	$0.105	$0.066	$0.060
Cost per Ton-mile, Fuel Transport[c]	$0.077	$0.049	$0.045

[a]Source: Winebrake, et al., 2007; note that TEU is "twenty foot-equivalent unit" and is used to measure containerized freight transport; [b]Assumes 22 tons per truck; [c]Assumes 29.7 tons per truck.

CAPACITY ISSUES

Given the extensive use of trucking to move feedstock and fuel throughout the state, potential capacity issues that local roadways may face should be considered. A road-specific analysis of these capacity constraints is not possible given how modeled origin-destination pairs were reported. Necessary simplifications in modeling created feedstock production points at centroids of counties instead of actual locations of farms and forests; further, the precise locations of biorefineries are not determined in the Roadmap. Nevertheless, with the available data we are able to discuss potential changes in highway capacity in future years, as well as determine what the Scenarios imply about the numbers of trucks entering biorefinery areas.

Figure F-15 depicts current and estimated future highway congestion in the State. In 2002, congestion on the national highways was limited to the greater New York City region, Buffalo, and Rochester. However, by 2020 congestion is expected to expand across Western New York highways and north of New York City; by 2035 peak period congestion is expected to expand across the State. Future congestion is expected on highways near biorefinery locations and near feedstock origins. Therefore, it is important to examine the potential truck traffic generated by the biofuels industry in these areas.

Table F-9 shows the number of trucks required to deliver feedstock to each of the biorefinery locations annually. The values in the table represent a lower bound, as these results assume full truckloads (22 tons per truck) for all feedstock transportation. Results indicate that the number of trucks entering certain biorefinery locations[5] may exceed 300,000 per year in Scenario 2 (as a lower bound). Scenario 3 quantities of feedstock and fuel produced are near-equal to Scenario 2, yet the highest number of trucks to a single biorefinery location is about 85,000 annually.

[5] A biorefinery location may represent one biorefinery or a cluster of biorefineries. For scenarios 1 and 2 (centralized) these clusters may represent up to four biorefineries operating in a particular area. For scenario 3 (decentralized) a location would likely represent individual biorefineries.

Table F-9. Annual Number of Trucks Entering Biorefinery for Each Scenario.

Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b	Scenario 3a	Scenario 3b
90,487	186,697	309,110	311,054	52,274	52,274
83,989	178,906	276,778	278,313	51,371	51,371
80,000	139,162	192,599	192,346	52,274	52,274
95,259	194,879	273,182	273,182	85,429	85,429
0	0	0	0	41,207	41,207
0	0	0	0	81,187	81,187
0	0	0	0	48,563	48,563
0	0	0	0	43,437	43,437
0	0	0	0	49,399	49,372
0	0	0	0	41,894	41,894
0	0	0	0	38,498	38,498
0	0	0	0	47,617	47,617
0	0	0	0	37,634	37,707
0	0	0	0	40,870	40,870
0	0	0	0	46,657	46,657
0	0	0	0	30,598	30,619
0	0	0	0	38,946	38,946
0	0	0	0	45,889	45,889
0	0	0	0	45,933	45,933
0	0	0	0	42,185	42,509
0	0	0	0	46,616	46,608
0	0	0	0	46,356	46,032

Table F-10 shows the average number of daily trucks entering each biorefinery by Scenario. These calculations assume an even distribution of truck traffic at the biorefineries throughout the year (i.e., total truck traffic for the year divided by 365). In some locations, the number of trucks entering the biorefinery each day is quite high. For example, in Scenario 2, refineries will receive 500 to over 850[6] trucks per day. The anticipated increases in highway congestion and truck traffic at biorefinery destinations present considerations for regional planners when considering where to site LCE biorefineries. Further heavy truck traffic of the scale estimated here may potentially result in excessive damage to roadways near and en route to biorefineries, as well as potentially generating disturbances and concern in residential areas (depending on biorefinery site). Moreover, the addition of trucks in these regions raises important safety concerns that should be evaluated in further research. Counties and biorefinery sites receiving hundreds of truck-trips per day will experience increased emissions, which may result in negative health impacts in exposed populations. Together these issues suggest that feedstock movement via rail or barge may be more desirable.

Table F-10. Average Number of Daily Trucks Entering Biorefinery for Each Scenario.

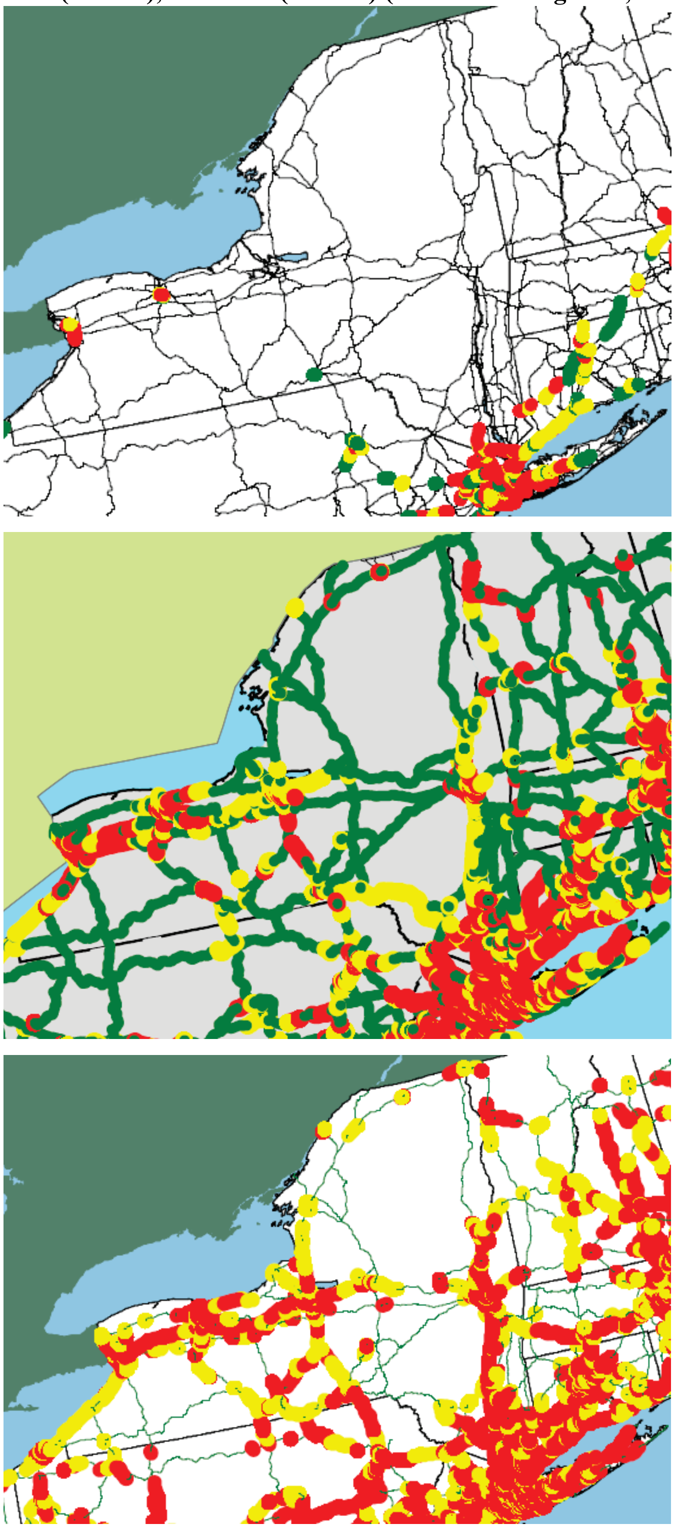
Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b	Scenario 3a	Scenario 3b

[6] See Table F-10; note that the numbers vary by biorefinery.

248	511	847	852	143	143
230	490	758	763	141	141
219	381	528	527	143	143
261	534	748	748	234	234
0	0	0	0	113	113
0	0	0	0	222	222
0	0	0	0	133	133
0	0	0	0	119	119
0	0	0	0	135	135
0	0	0	0	115	115
0	0	0	0	105	105
0	0	0	0	130	130
0	0	0	0	103	103
0	0	0	0	112	112
0	0	0	0	128	128
0	0	0	0	84	84
0	0	0	0	107	107
0	0	0	0	126	126
0	0	0	0	126	126
0	0	0	0	116	116
0	0	0	0	128	128
0	0	0	0	127	126

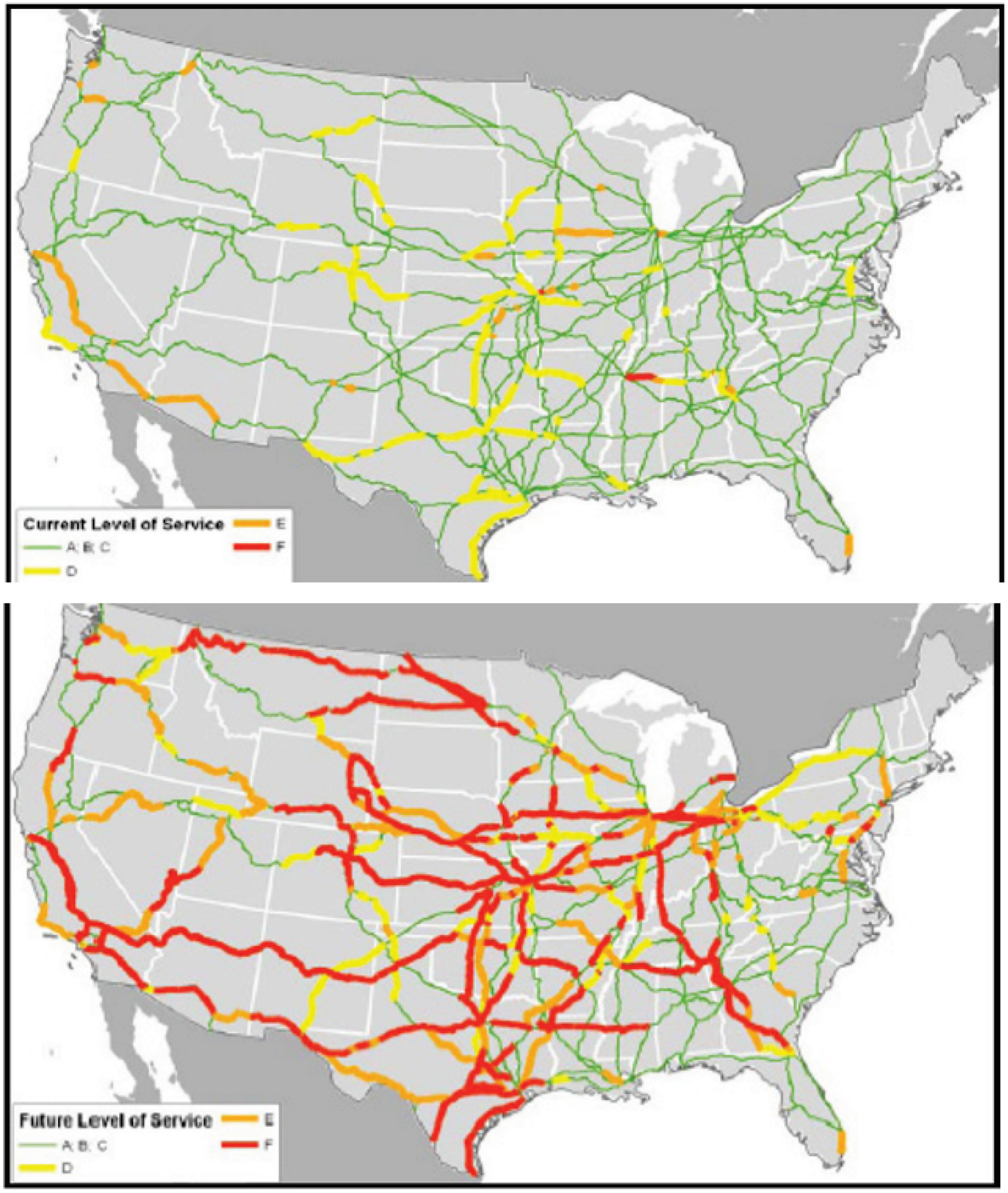
As shown in Figure F-16, railroads in the State are currently operating under capacity and in 2035 are anticipated to be under- or near-capacity. Therefore, in the future, rail may present a more optimal biofuel feedstock transportation option. Capacity constraints and congestion may present opportunities for the development of decentralized rail hubs that would collect and aggregate feedstock by truck and then transport larger shipments to the biorefineries via rail. This will of course have important implications as to where the biorefineries ultimately are sited, as access to rail services may be important.

Figure F-15. Peak Period Congestion on the National Highway System in New York State, 2002 (top), 2020 (middle), and 2035 (bottom) (Green=Uncongested, Yellow= Congested, Red=Highly Congested).



Source: U.S. DOT FHWA 2007a; 2007b; 2009.

Figure F-16. Present (Top) and 2035 (Bottom) Train Capacity Conditions Nationally. Green = Under Capacity; Yellow = Near Capacity; Orange = At Capacity; Red = Over Capacity.



Source: NYSDOT (2009).

3. USE OF ALTERNATIVE MODES OF TRANSPORT

Truck transport provides essentially 100% of the feedstock and fuel movement throughout the State for all the Scenarios. Part of these results reflects the economy of trucking in the Scenarios that were evaluated. As mentioned earlier, rail and marine transport do not tend to be cost-effective until transport distances reach several hundred miles. Even in Scenario 2b (the Scenario in which feedstock transportation distances are the longest), only 12 origin-destination pairs (representing less than 2% of total feedstock) are more than 100 miles apart—and none are more than 200 miles apart. This indicates that a large-scale shift towards rail or marine transport is unlikely unless economics of transport change in favor of rail and marine.

Nevertheless, a lower bound for the T&D emissions and energy use is useful to illustrate potential energy and emissions savings due to modal shifts. Table F-11 shows the energy and emissions associated per ton-mile of feedstock movement, by mode. The table also shows the percent reduction in energy and emissions, comparing marine and rail to trucks. Table F-12 demonstrates by Scenario the energy use and emissions that would be associated with a complete movement of feedstock by rail and by ship, and compares this to truck.

Table F-11. Comparison of Total Fuel Cycle Energy and Emissions per Ton-mile by Mode.

Mode	Total Fuel Cycle Energy Use and Emissions per Ton-mile by Mode				
	Energy (Btu)	**CO_2 (grams)**	**SO_2 (grams)**	**NOx (grams)**	**PM (grams)**
Truck	1162	91	0.021	0.084	0.011
Barge	465	36	0.008	0.096	0.005
Barge % Reduction from Truck	-60%	-60%	-60%	14%	-51%
Rail	585	46	0.011	0.109	0.006
Rail % Reduction from Truck	-50%	-50%	-50%	29%	-41%

Table F-12. Comparative Analysis of Trucking T&D with Rail and Marine, Assuming all Truck Ton-miles Shifted to Alternative Mode.

Scenario	Mode	Total Annual Fuel Cycle Energy Use and Emissions, Feedstock Transportation				
		Energy (MMBtu)	CO_2 (metric tons)	SO_2 (metric tons)	NOx (metric tons)	PM (metric tons)
Scenario 1a	Truck	363,221	28,369	6.50	26.33	3.31
	Barge	145,503	11,364	2.60	30.13	1.63
	Rail	183,008	14,294	3.27	33.98	1.96
Scenario 1b	Truck	1,050,733	82,067	18.80	76.15	9.56
	Barge	420,913	32,875	7.53	87.15	4.72
	Rail	529,410	41,349	9.4709	98.2880	5.6783
Scenario 2a	Truck	1,688,316	131,865	30.20	122.37	15.36
	Barge	676,322	52,824	12.10	140.04	7.59
	Rail	850,656	66,440	15.22	157.93	9.13
Scenario 2b	Truck	1,697,073	132,549	30.36	123.00	15.44
	Barge	679,830	53,098	12.16	140.77	7.63
	Rail	855,068	66,785	15.30	158.75	9.17
Scenario 3a	Truck	764,490	59,710	13.68	55.41	6.96
	Barge	306,247	23,919	5.48	63.41	3.44
	Rail	385,187	30,085	6.89	71.51	4.13
Scenario 3b	Truck	764,649	59,723	13.68	55.42	6.96
	Barge	306,311	23,924	5.48	63.42	3.44
	Rail	385,268	30,091	6.89	71.52	4.13
Corn Grain	Truck	239,459	18,703	4.28	17.36	2.18
	Barge	95,925	7,492	1.72	19.86	1.08
	Rail	120,651	9,423	2.16	22.40	1.29
Soy Biodiesel	Truck	40,363	3,153	0.72	2.93	0.37
	Barge	16,169	1,263	0.29	3.35	0.18
	Rail	20,337	1,588	0.3638	3.7756	0.2181

4. FUTURE RESEARCH NEEDS

There are a number of future research needs associated with the transportation and distribution of ethanol feedstock and fuel that emerge from this appendix. In particular, we recommend additional research in the following areas:

- *Evaluate the impacts of increased truck traffic on local traffic patterns, air quality, and health*. The Appendix demonstrates that in some cases, truck traffic in local communities that are home to biorefineries can be significant. More research is needed to evaluate the air quality and health impacts of these new trucking patterns on the communities and their populations. Such work would involve a more thorough assessment of geospatial emissions inventories, air modeling, and health risk assessments.
- *Evaluate the potential for rail and water transport if centralized collection points develop for feedstock or if export market become significant*. The Appendix showed that there was little opportunity for rail or water to participate in the movement of feedstock or fuel under the Scenarios evaluated. However, if export markets develop or if centralized collection facilities are created, the role of rail and/or water in moving feedstock or fuel could expand. New research is needed to fully evaluate this expansion potential.
- *Conduct more detailed route analysis.* The modeling approach found in the Roadmap used county centroids as origin nodes for feedstock transport. In actuality, we would expect feedstock to be collected at various points within a county and transported to either final destination or to a central holding facility. A transportation analysis at this level of detail could be useful to identify and mitigate more specific traffic, air quality, or health impacts associated with feedstock movements in the State.
- *Analyze the role of various policies on feedstock and fuel movements*. Using the results of the Roadmap as a baseline, more research could be conducted to analyze the role of various policy mechanisms on feedstock transportation and distribution choices. For example, it would be useful to analyze the role of financial incentives in influencing mode-selection (rail, marine or truck) for ethanol feedstock and fuel transportation and distribution.
- *Value the environmental and health costs of a biofuels transportation and distribution network*. Montezing the emissions modeled in this chapter and summing them with the private cost of a T&D network would provide insight to the true costs from a social welfare economic perspective.

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