DEVELOPMENT OF A STRATEGIC PLAN FOR REDUCING EMISSIONS ASSOCIATED WITH FREIGHT MOVEMENT IN CONNECTICUT

Prepared for:

Connecticut Department of Energy and Environmental Protection

Prepared by:

de la Torre Klausmeier Consulting, Inc.

Cambridge Systematics

Eastern Research Group

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Executive Summary

Air quality in Connecticut often fails to meet the health based standard established by the U.S. Environmental Protection Agency (EPA) for ground-level ozone. Ozone is produced when by-products of combustion mix in the atmosphere in the presence of sunlight. Exposure to ozone is known to cause negative health effects, including significant decreases in lung function, inflammation of airways, and increased symptoms such as coughing, wheezing and pain when breathing deeply. Unfortunately, these health effects disproportionately impact individuals with pre-existing conditions, such as asthma, children and the elderly. For over forty years the Connecticut Department of Environmental Protection (DEEP) has examined many of the sectors that contribute to the ozone problem, but has never before closely examined the freight movement sector. Exhaust emissions from heavy duty diesel engines, the primary source of freight movement in Connecticut, contain pollutants that are known to contribute to the ozone problem. While federal emission standards have resulted in cleaner new vehicles, older vehicles still emit higher levels of harmful emissions such as oxides of nitrogen (NOx), and other precursors of ozone, particulate matter (PM), greenhouse gases (GHG), and other toxic pollutant emissions. Reducing air pollution from the mobile source sector is an integral part of the state's clean air efforts and an important part of a balanced strategy that includes reductions in stationary, area source and mobile emissions. These reductions will be more important in safeguarding public health when EPA issues a new, more stringent ozone standard in 2013.

EPA and the State of California are the only entities authorized to establish emission standards for heavy duty diesel engines. The potential opportunities for states to reduce freight movement related air pollution are often limited to projects outside the arena of traditional environmental regulatory programs, such as requiring technology based solutions to mitigate air pollution. Identifying these opportunities requires an in depth understanding of freight movement and additional drivers that could lead to new economic opportunities, support long-term energy goals and produce favorable environmental outcomes. Since freight movement is an area of highly specialized knowledge, in order to better understand the impact of freight movement on Connecticut's economy and environment and to identify potential mitigation options, DEEP looked to consultants with expertise in these fields and commissioned this independent study to analyze freight movement, develop a recommended strategy for reducing emissions from freight movement in the state and identify opportunities to foster economic growth through expansion of marine and rail shipments. This report identifies short-, medium-, and long-term strategies that may be implemented to mitigate the air quality impacts associated with state-specific freight movement logistics, while also supporting Connecticut's long-term energy policy goals and furthering local economic development opportunities.

Freight movement is critical to Connecticut's economy; it is responsible for 3.5% of the state's jobs. Heavy duty diesel trucks transport 92% of the freight moved into or through Connecticut. The top commodities transported in Connecticut include food, secondary moves (movement of freight from primary to secondary outlets), chemicals, and non-metallic minerals. The types of commodities moved are not expected to change significantly by 2040. Vehicle Miles Traveled associated with freight movement is projected to increase 88% by 2040 and heavy duty trucks account for over 95% of the pollutants caused by freight movement activities. Although cleaner trucks will result from more stringent national emission and fuel economy standards, the need to reduce emissions and congestion will persist into the future. Resultantly, any strategy intended to effectively mitigate freight emissions in Connecticut must focus on all trucks because no single commodity class dominates freight movement.

Trucks are and will continue to be the primary mode of freight movement in Connecticut so any strategy to mitigate freight emissions must first focus on trucks. Connecticut's geographical area is small, and trucks are the most economical way to transport goods over short distances (less than 400 miles). Key conclusions include:

- ***The most promising short-term strategy is to enhance current anti-idling restrictions[1].*** There is an increasing reliance on trucks used for freight movement and the number of trucks operating in Connecticut will increase by 33% by 2020 and double by 2040. While running emissions will decrease by 90% by 2020, emissions from idling will remain at uncontrolled levels. As a result, modeling predicts that extended idling, idling for greater than 30 minutes, will double emissions of NOx from trucks by 2020. Consequently, the most promising control measure in the short term (i.e., within five years) is to strengthen Connecticut's prohibition on idling. This could be accomplished by extending infraction authority for idling to public safety agencies and peace officers, along with an outreach program to raise awareness as well as evaluation of the feasibility of providing incentives for idle reduction technologies such as auxiliary power units.
- ***The most promising medium-term strategy is to establish a heavy-duty vehicle inspection and maintenance program.*** Although EPA's emission standards will result in cleaner vehicles, instituting a heavy-duty diesel truck inspection and maintenance (I/M) program would ensure that these trucks are properly maintained. Such a program would not only further enhance the air quality benefits realized from EPA's stringent standards, but would also provide an economic benefit to owners, since well-maintained vehicles use less fuel and incur lower overall maintenance costs. I/M programs for rail/port vehicles and equipment would provide similar air quality and economic benefits and should be considered as part of a comprehensive program to reduce emissions associated with freight movement.
- ***The most promising long-term strategy is to pursue regional coordination to change freight movement modes from reliance on trucks to more efficient modes, such as rail and marine***. The study found carbon dioxide emissions per ton of freight transported are lower for rail and marine, so shifting to one of those modes would help support clean energy initiatives and help reduce GHG emissions in Connecticut. In addition, shifting freight to rail or marine should help alleviate the recurring costs linked with congestion and road maintenance. Coordination efforts among federal and regional entities, as well as stakeholders, are now taking place to achieve the objective of transforming the movement of freight to the most efficient and lowest emitting mode.

[1] Other promising short term strategies include accelerating vehicle retirement and encouraging the use of voluntary fuel saving programs, like EPA's SmartWay® program.

1.0 Introduction

The Connecticut Department of Energy and Environmental Protection (DEEP) commissioned this study to analyze and develop a strategy to reduce emissions from freight movement in the state. de la Torre Klausmeier Consulting (dKC) produced this study with technical support from Eastern Research Group (ERG) and Cambridge Systematics.

Freight movement is critical to Connecticut's economy, being responsible for 3.5% of the state's jobs[2]. The movement of freight consumes large amounts of fossil fuels, so addressing energy security and global warming concerns must consider ways to optimize this activity. Emissions from freight movement represent a significant air pollution concern, so these activities must also be addressed in plans to attain the 2008 8-hour National Ambient Air Quality Standards (NAAQS) for ozone.

This report summarizes the results of this study and addresses the following issues:

1. **How is freight moved in Connecticut?** An analysis of the origin and destination of freight and the types of commodities transported determined that most freight is moved by truck, and that over half the trucks are just passing through the state.
2. **What emissions are associated with freight movement activities now and in the future?** Emissions levels from 2009 to 2040 were projected. Emissions from trucks and other freight modes will benefit in the short term from the U.S. Environmental Protection Agency's (EPA's) new emission standards. However, in the long term, truck emissions will increase unless additional controls are implemented and/or freight is shifted to rail or other modes.
3. **What are the most promising strategies to reduce the energy and environmental impacts of freight movement?** Short-, medium-, and long-term strategies to reduce emissions and energy consumption from freight movement activities were evaluated. In the short-term, strengthening Connecticut's prohibition on idling by extending enforcement authority on idling to all peace officers and public safety officials along with developing outreach programs which outline the drawbacks of engine idling should significantly reduce emissions from trucks. Because new trucks emit a fraction of the oxides of nitrogen (NOx) and particulate matter (PM) that are emitted from 2006 and older models, for a medium term strategy, DEEP could encourage the replacement of older vehicles with new vehicles and formulate new initiatives to ensure that these vehicles are properly maintained. In the long term, due to the advantages of lower carbon dioxide (CO_2) emissions, Connecticut could explore avenues to improve rail and marine infrastructure so that more freight, especially through freight, can be transferred from truck to rail or marine transport. Rail transport should be thoroughly considered as it is the most efficient means to transport freight. Maximizing the use of marine resources should also continue to be evaluated.

Findings are presented in the next section. These findings discuss the origin/destination and types of commodities moved in Connecticut, and provide emissions associated with freight movement. Section 3 presents an analysis of best practices to reduce emissions and energy consumption from freight movement. Conclusions and recommendations to address the environmental impacts of freight movement are presented in Section 4.

[2] Connecticut Department of Economic and Community Development, *Connecticut Economic Digest*, September 2012, http://www.ct.gov/ecd/lib/ecd/ct_digest/2012/cedsep12.pdf.

2.0 Findings

In this project, freight movement and related emissions in Connecticut were characterized. This information will help Connecticut focus on the most promising strategies to reduce emissions from freight movement. To characterize freight movement, the study utilized data that provides the estimated freight volumes by mode – truck, rail, or marine. Estimated freight volumes were provided for three years: 2009, 2020, and 2040. Using information on freight volumes by mode and emission factors, emissions were estimated for 2009, 2020, and 2040, and then options for reducing these freight movement emissions were identified and evaluated.

2.1 Characteristics of Freight Movement in Connecticut

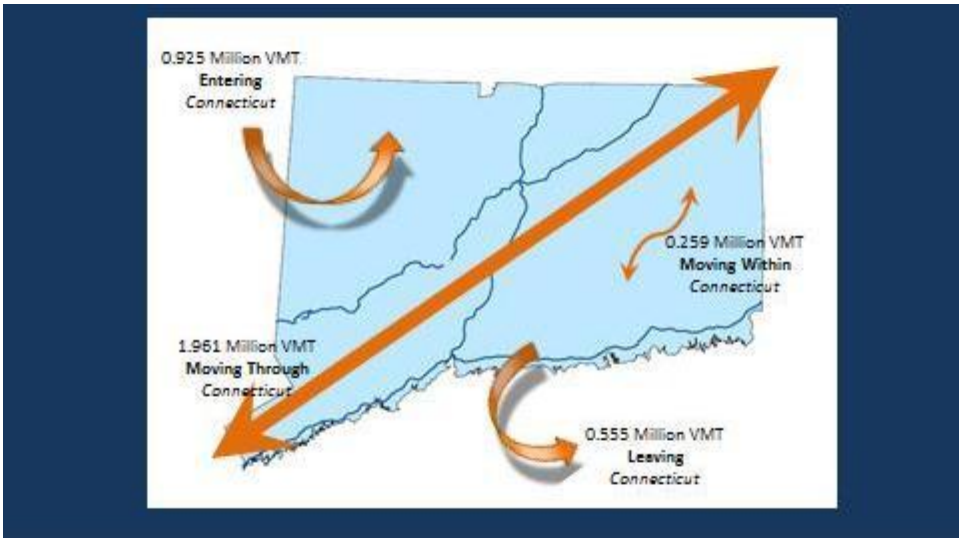
How Freight is Moved in Connecticut

To characterize freight movement in Connecticut, dKC analyzed Transearch data[3], which is commonly used to provide the estimated value and tonnage of goods moving between geographic origins and destinations by commodity and mode. In 2009, trucks carried 92% of the freight in Connecticut. Accordingly, trucks are responsible for almost all the emissions associated with freight movement. Marine transport accounts for 6% of the freight movement and rail accounts for the remaining 2%. A majority of the truck freight is handled by tractor trailers.

As shown on Figure 1, over half (53%) of the 3.7 million vehicle miles traveled (VMT) associated with freight movement activity is the result of freight shipped through Connecticut, generally along its interstate corridors. Inbound and outbound freight comprise 25% and 15% of the freight activity, respectively. Only 6% of the freight in Connecticut is associated with local freight movement activities. Connecticut likely has a much larger share of through freight than most other states due to its location between major population and shipping centers. VMT from truck traffic has a major impact on road conditions and contributes greatly to congestion on I-95 and I-84.

[3] Transearch data was used under a proprietary license. To obtain this data, interested parties can contact IHS-Global Insight at http://www.ihs.com/products/global-insight/industry-analysis/commerce-transport/database.aspx.

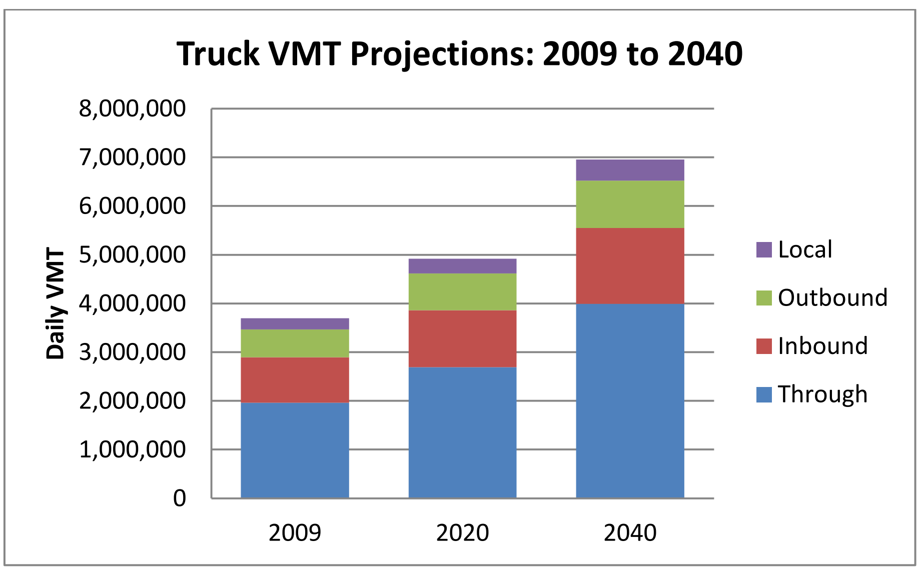
Figure 1 – Movement of Truck Freight in Connecticut



Source: dKC Analysis of Transearch, DEEP prepared graphic

Total freight related VMT is expected to increase by 88% from 2009 to 2040. As shown in Figure 2, the largest projected growth is in the through freight category, which is expected to increase by 103%. The increased truck VMT will add to already serious problems with congestion and road maintenance in Connecticut. Since trucks are responsible for the overwhelming share of freight movement in Connecticut, there must be a focus on trucks to effectively mitigate freight emissions.

Figure 2 – Past and Future VMT in Connecticut

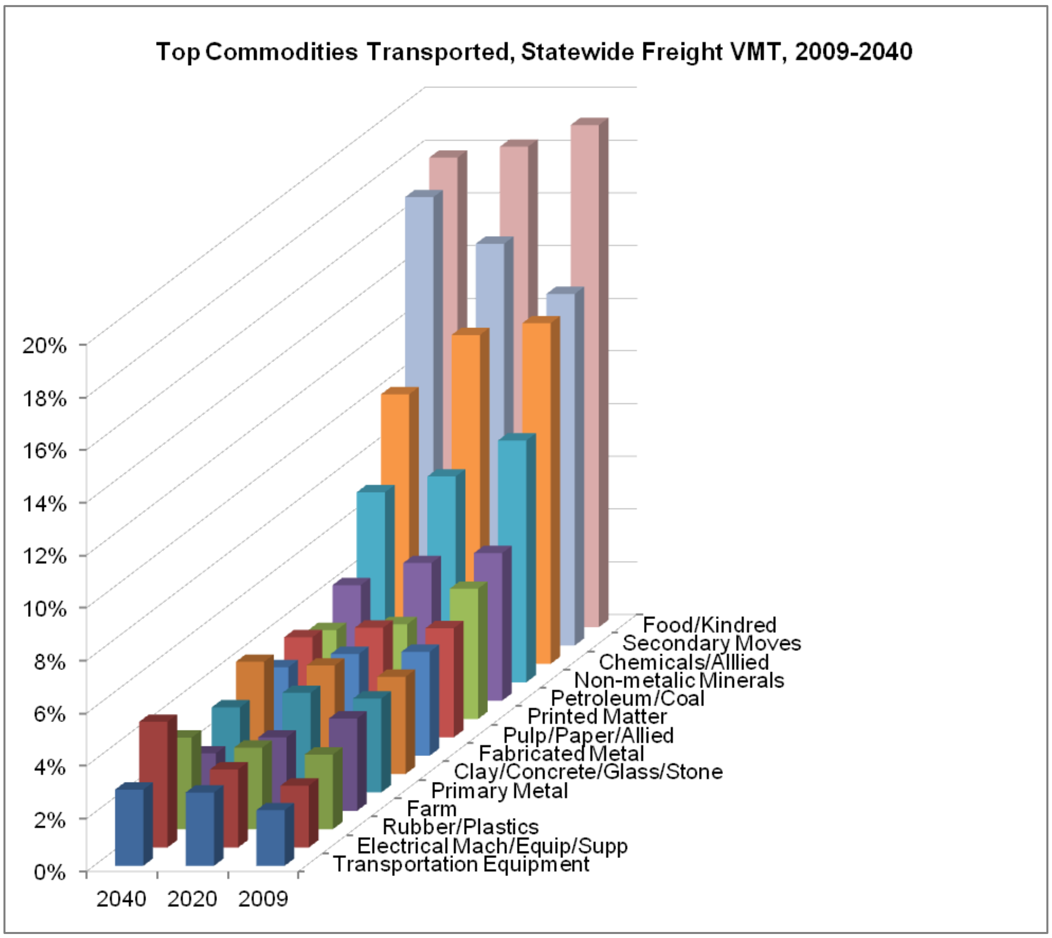


Source: dKC Analysis of Transearch

Commodities Transported in Connecticut

Figure 3 shows the percentage of different types of commodities projected to be transported in Connecticut from 2009 to 2040. Of all commodities transported in Connecticut in 2009, food products comprise the largest share of VMT with 19% of the statewide total. Secondary moves and chemicals/allied materials each represent 13% of statewide VMT. Most freight movement in the secondary moves category is comprised of traffic associated with distribution centers and warehousing. Also included in secondary moves are the drayage portions of rail and air freight moves.[4] Non-metallic minerals, such as sand and gravel, petroleum/coal and printed matter account for 5 to 9% of Connecticut's total freight. The values for petroleum/coal do not include product moved by pipeline. Data from Federal Highway Administration's 2007 Freight Analysis Framework indicate that products transported by pipeline represent 3-4% of total tonnage. 27 commodities cover the remaining 35% of total freight-related VMT, including 12 with less than 1% share. The types of commodities expected to be moved within Connecticut in the future are not expected to change significantly from the types of commodities currently being transported in the state.

Figure 3 – Commodities Transported by Truck in Connecticut



Source: dKC Analysis of Transearch

[4] Drayage is the transport of goods over a short distance, usually to shift from one mode (e.g. marine) to another mode (e.g., truck).

Trends are fairly consistent by county with a few exceptions. Movement of non-metallic minerals is dominant in both Hartford and New London counties, with 39% and 36%, respectively. Much of the activity in this category is related to construction activity (buildings, roads, etc.) since it includes sand and gravel, so the higher percentages in those counties could reflect higher than average construction activity.

Within the broad freight movement categories are multiple sub-categories. For example, the food/kindred category includes movement of meat, poultry, butter, cheese, canned products, pet food, and alcohol beverages. Since no single commodity class dominates, control measures should apply to all trucks. More details on freight movement trends in Connecticut are set forth in Appendix A.

Empty Backhauls

Empty backhauls in Connecticut are a concern. An empty backhaul is a truck returning to its base empty after dropping off a shipment. According to information collected in stakeholder interviews (Appendix C), carriers utilize a range of strategies to fill their backhauls when making deliveries within, to, or from the State of Connecticut. A major "export" for Connecticut is waste. Waste haulers report many carriers will make deliveries to retail outlets, warehouses and distribution facilities, and other customers in Connecticut, and then collect a load of outbound waste or recyclables bound for the neighboring states of New York, Massachusetts, Rhode Island, and New Jersey. Despite efforts to reduce backhauls, data from Transearch indicates that both inbound and outbound trucks in Connecticut have a backhaul ratio of about 70%. This means that for every ten trucks that make a delivery in the state, about seven have an empty backhaul (i.e., no cargo). Several stakeholders reported higher overall costs for making deliveries in Connecticut, the result of the challenges in securing a backhaul. By 2040, the backhaul ratio associated with inbound cargo is projected to increase to nearly 80 percent.

Impact of Increased Freight Movement on Congestion in Connecticut

Projections indicate that freight movement will create more traffic congestion in the future, unless something is done to mitigate increases in truck VMT. Truck volumes in the Northeast Corridor are expected to double by 2040. More freight is expected to come through the Port of New York. In addition, Connecticut is seeking economic development opportunities to expand the freight handled in its ports. These factors will add to already congested traffic conditions. The fact that congestion in urban Connecticut areas caused an estimated 33 million hours of truck delays and cost 2.4 billion dollars[5] in 2011 must be taken into account in considering any future options.

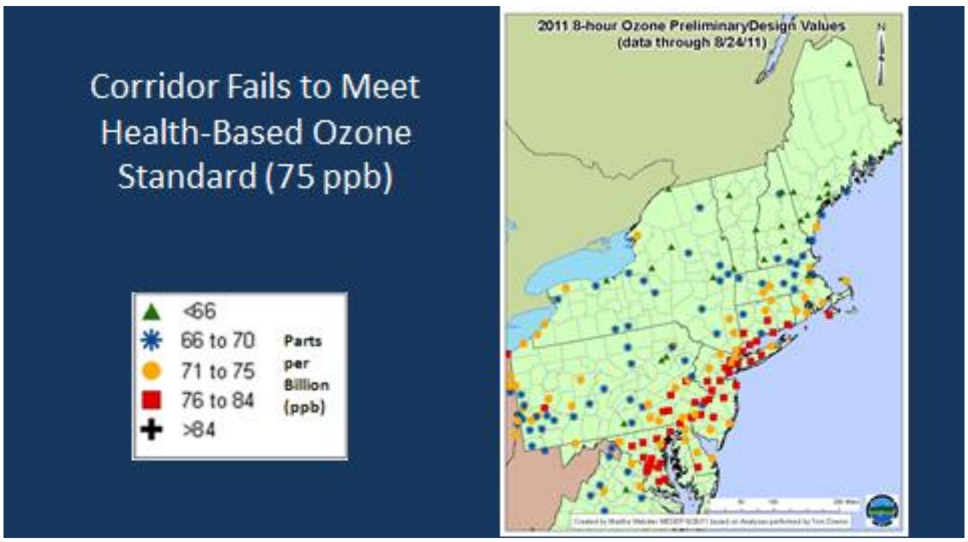
Clearly, more freight must be carried by rail or marine modes. The rail system in the Northeast Corridor currently has many constraints, making it difficult to switch from truck to rail. In addition, the condition of the rail system in the Northeast is worsening, which reduces its capability to handle more freight. Without infrastructure improvements, diversion to rail does not appear to be an option. However, expanding marine shipping may offer some relief. The I-95 Corridor Coalition's M-95 project aims to develop a waterside system for freight transport to help mitigate future truck congestion.

[5] 2011 Mobility Report, Texas Transportation Institute, (http://mobility.tamu.edu/ums/).

2.2 Current and Future Emission Estimates

Emissions from the movement of freight are a significant air quality concern. The pollutants of greatest concern are NOx, PM and CO_2. NOx emissions from diesel powered trucks are a precursor to ozone formation in Connecticut. Ozone is a health concern because it causes airway irritation, reduces lung capacity, aggravates asthma, and can lead to permanent lung damage. As mentioned in Section 2.1, over half of the freight moved in Connecticut is just passing through, usually on Connecticut's interstate highways. Figure 4 shows ozone levels recorded in 2011 in the Northeast. The highest levels are along the I-95 corridor, with most exceedences of the 75 parts per billion (ppb) 8-hour ozone NAAQS occurring around that highway. Reducing truck pollution is a critical component of Connecticut's plans to meet the 75 ppb ozone NAAQS and any future revisions to such standard.

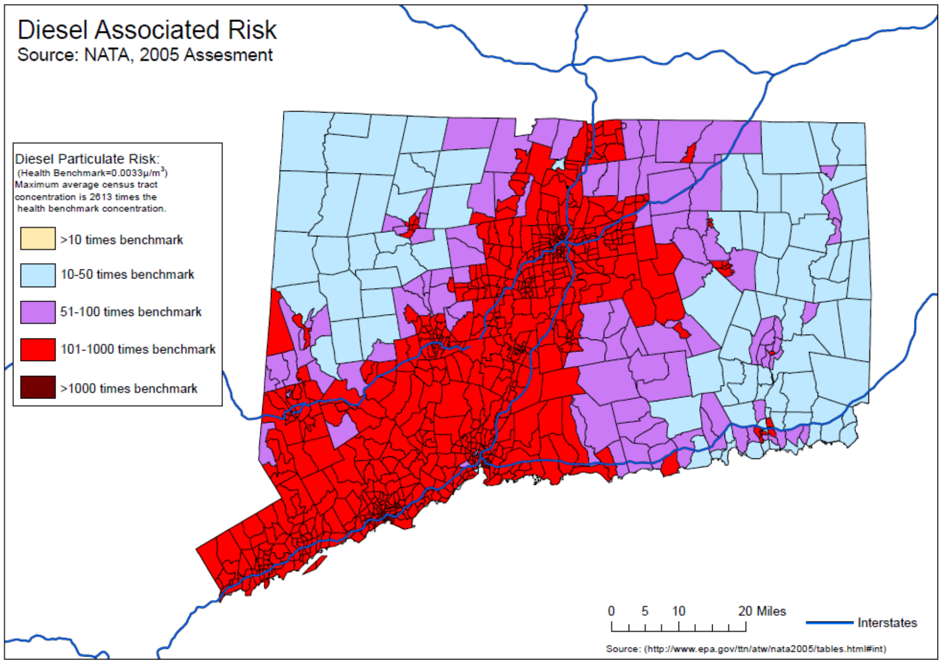
Figure 4 – Air Quality in CT and Throughout the I-95 Corridor



Source of data and graphic: Maine DEP

PM emissions from diesel-powered vehicles have been implicated in incidents of irregular heartbeats, heart attacks, and premature death in individuals with heart and lung disease. In addition, the International Agency for Cancer Research classified diesel exhaust as a human carcinogen. Figure 5 shows that the health risk from exposure to diesel exhaust in Connecticut exceeds EPA's health benchmark. Fortunately, extremely stringent PM standards for diesels will greatly reduce future particulate emission levels. CO_2 emissions in diesel exhaust from freight movement contribute to global warming as CO_2 is one of the primary greenhouse gases (GHGs) that contribute to global climate change.

Figure 5 – Health Risk Associated with Diesel Particulate Matter (PM)



Source: EPA/2005 National Air Toxics Assessment

Impact of EPA Initiatives on Emissions from Freight Movement

EPA has enacted stringent emission and fuel standards for all mobile sources including heavy-duty trucks, locomotives, and marine vessels. These actions will significantly reduce the emissions associated with freight movement. For example, NOx emissions during the 2007 to 2020 period are estimated to drop by 52% due to EPA emission and fuel standards. Table 1 summarizes the EPA initiatives by freight movement mode. All modes will benefit from stringent emission and fuel standards.

Table 1 – EPA Initiatives by Mode (Source: DEEP)

Truck	Rail	Marine
• Regulation: - 2006: Low sulfur diesel fuel (<15 ppm) - 2007: Heavy-duty highway engines and vehicles - 2010: NO_x and Non-Methane Hydrocarbons - 2011: Program to Reduce GHG Emissions and Improve Fuel Efficiency of Medium- and Heavy-Duty Vehicles • Voluntary: - 2003: SmartWay program	• Regulation: - 2008 Locomotive and Marine Emission Standards - 2008 Locomotive Idle Emissions Standards (new and rebuilt) • Voluntary: - Low emission switch engines (Gen-set, battery) - Electric cranes - EPA best practices tool	• International Maritime Organization North American Emission Control Area - Reduces emissions by fuel switching (2012-2016) • EPA Marine Diesel Engine Standards - Varies with size - Phased in 2012 to 2017

Total Emissions Estimated for Different Freight Movement Modes

Emissions associated with freight movement were estimated for 2009, 2020, and 2040. The following activity and emission factors were used to estimate emissions:

- Several sources of data were analyzed to estimate truck VMT and rail/marine freight activity. Appendix B describes these data and how VMT and activity factors were derived from them.
- EPA's latest mobile source emissions model, MOVES[6], was run for 2009, 2020, and 2040 to generate on-road emission factors.
- EPA's recommended procedures were used to generate emission factors for rail and marine freight activity.

Table 2 summarizes emissions associated with freight movement. In 2009, on-road trucks accounted for 95% of the NOx emissions, 93% of the PM emissions, and 97% of the CO_2 emissions from freight movement. Within the truck category, long-haul tractor trailers accounted for most emissions. Long-haul tractor trailers account for 80% of the NOx emissions, 76% of the PM emissions, and 71% of the CO_2 emissions from freight trucks. This is significant, since long-haul tractor trailers spend a lot of time idling due to safety requirements for drivers to rest. EPA projects that long-haul tractor trailers idle five to eight hours per day. Connecticut's freight movement includes a disproportionate number of long-haul tractor trailers because over half of the freight traffic is passing through the State. This situation has major implications on emissions, as discussed below.

Table 2 – Projected Emissions by Freight Movement Mode (Source: ERG)

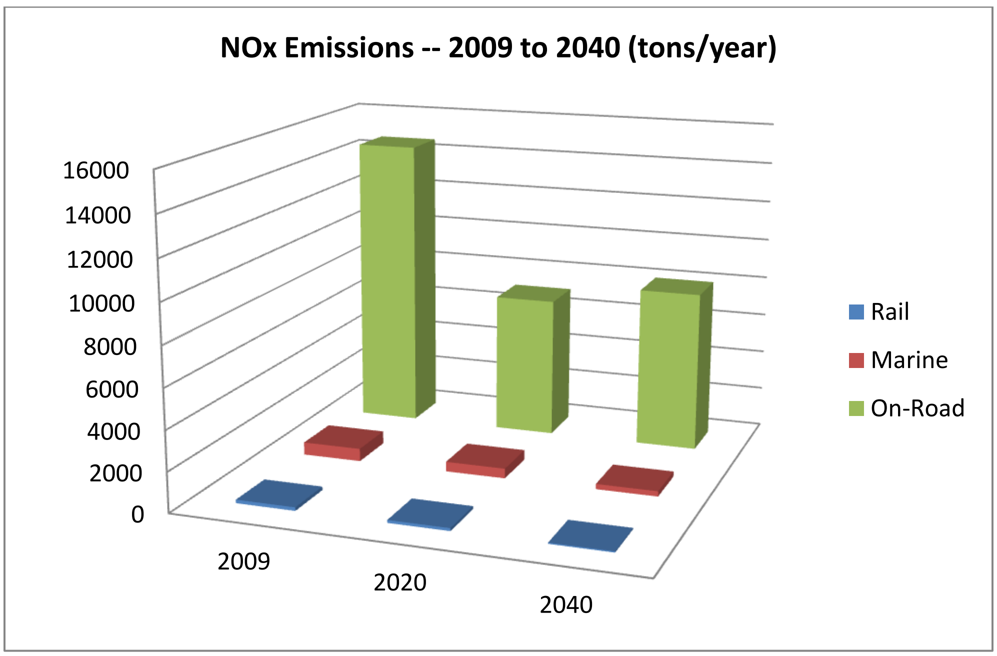
Pollutants by Freight Type – 2009-2040 (tons/year)			
2009			
Type	**NOx**	**PM**	**CO_2**
On-Road	**14,636**	**539**	**1,729,025**
Rail	**173**	**4**	**8,605**
Marine	**638**	**38**	**50,175**
Total	**15,447**	**581**	**1,787,805**
2020			
On-Road	**7,069**	**113**	**2,292,949**
Rail	**141**	**3**	**9,682**
Marine	**492**	**12**	**55,938**
Total	**7,701**	**129**	**2,358,568**
2040			
On-Road	**8,058**	**53**	**2,808,804**
Rail	**56**	**1**	**12,425**
Marine	**263**	**11**	**59,520**
Total	**8,376**	**65**	**2,880,749**

Figure 6 shows NOx emissions by freight movement mode for 2009, 2020, and 2040. NOx emissions from trucks will drop significantly from 2009 to 2020 due EPA's stringent NOx standards for new trucks.

[6] MOVES, which is EPA's Motor Vehicle Emissions Simulator, estimates emissions from cars, trucks and motorcycles, covers a broad range of pollutants and allows multiple scale analysis.

However, NOx emissions from trucks are projected to increase between 2020 and 2040, due to two factors: 1) truck usage is expected to double, and 2) EPA emission standards do not address extended idle operation. For the 2010 model year, the NOx standard dropped from 2 grams/hp-hr[7] to 0.2 grams/hp-hr. Engine manufacturers were able to meet pre-2010 standards without catalytic NOx controls. However, to meet the 2010 and later NOx standards, manufacturers had to add on catalytic NOx controls. These controls greatly reduce NOx during on-road driving conditions, but have little impact on NOx emissions during extended idle operation, because at idle, exhaust temperatures are too low for catalytic NOx controls to be effective. Adding to the problem is the fact that manufacturers recalibrated engines to make them more efficient to improve fuel economy. However, these changes increased engine-out (pre catalyst) NOx emissions. These factors have a major impact on NOx emissions from long-haul tractor trailers, because, as mentioned above, they spend five to eight hours per day idling. In fact, in 2020, 47% of the NOx emissions are projected to be from extended idling[8] in long-haul tractor trailers. By 2040, over 60% of the NOx is from extended idling. If emissions during extended idling were eliminated, NOx emissions would continue to drop from 2009 to 2040, contributing to Connecticut's attaining and maintaining the NAAQS for ozone.

Figure 6 – NOx Emissions by Freight Movement Mode



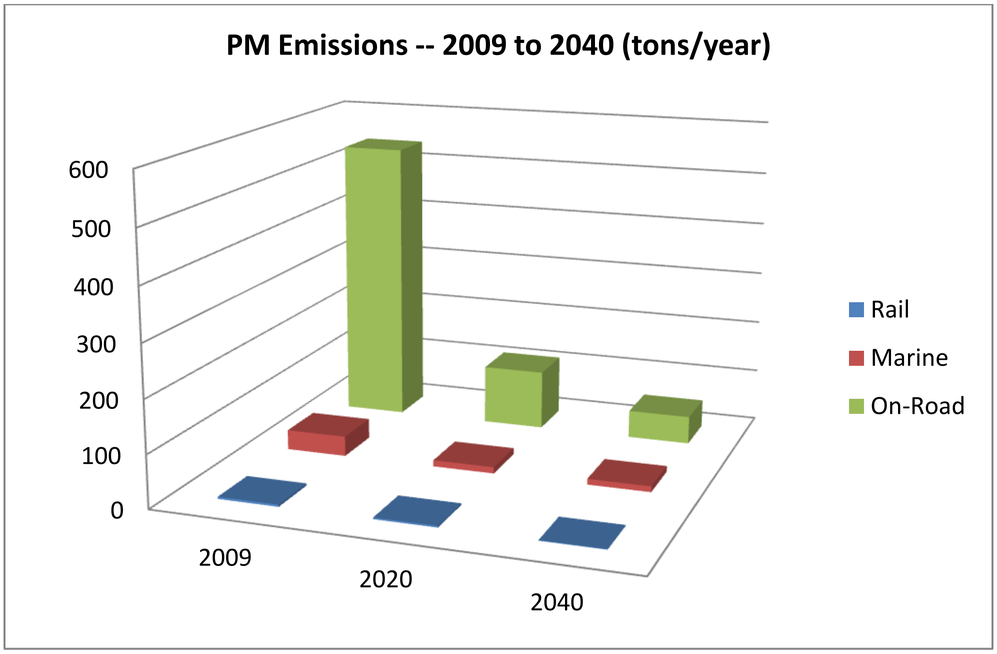
Source: ERG

Figure 7 shows PM emissions by freight movement mode for 2009, 2020, and 2040. PM emissions from trucks are projected to drop significantly from 2009 to 2040, primarily due to EPA's stringent PM emission standards for diesel-powered on- and off-road vehicles. For 2007 and later model years, the PM standard dropped from 0.1 grams/hp-hr to 0.01 grams/hp-hr. Manufacturers meet these standards by optimizing combustion and installing particulate traps. PM emissions also are impacted by extended idling, but not as much as NOx emissions[9]. In 2020, extended idling in long-haul tractor trailers is

[7] Emission standards for engines used in heavy-duty vehicles are expressed in terms of mass (grams) per unit of work (hp-hr).
[8] Extended Idling is considered to be longer than 30 minutes.

projected to cause 7% of annual PM emissions. In 2040, this activity increases to 13% of annual PM emissions. Thus, reducing or eliminating extended idling will reduce PM emissions from trucks.

Figure 7 – PM Emissions by Freight Movement Mode



Source: ERG

Figure 8 shows CO_2 emissions by freight movement mode for 2009, 2020, and 2040. CO_2 emissions from on-road trucks are projected to increase significantly from 2009 to 2040, because VMT is projected to greatly increase. Although truck fuel economy in terms of miles per gallon is expected to improve by about 10%, these improvements are dwarfed by increases in truck VMT, which is expected to double between now and 2040. Reducing or eliminating extended idling will reduce fuel consumption by about 5%, and accordingly, CO_2 emissions will drop by 5%, however, this reduction is not enough of a drop to keep overall CO_2 emissions from increasing. Shipping by rail and/or marine produces much less CO_2 emissions than truck shipments. Therefore, although reducing extended idling will reduce fuel consumption, efforts to meet statewide GHG reduction targets[10] will also need to consider actions to reduce VMT, such as increasing the freight moved by rail or marine.

[9] Unlike the case for trucks equipped with NOx catalysts, manufacturers attempt to minimize engine-out PM emissions to avoid overloading particulate traps.

[10] http://www.cga.ct.gov/current/pub/chap446c.htm#Sec22a-200a.htm.

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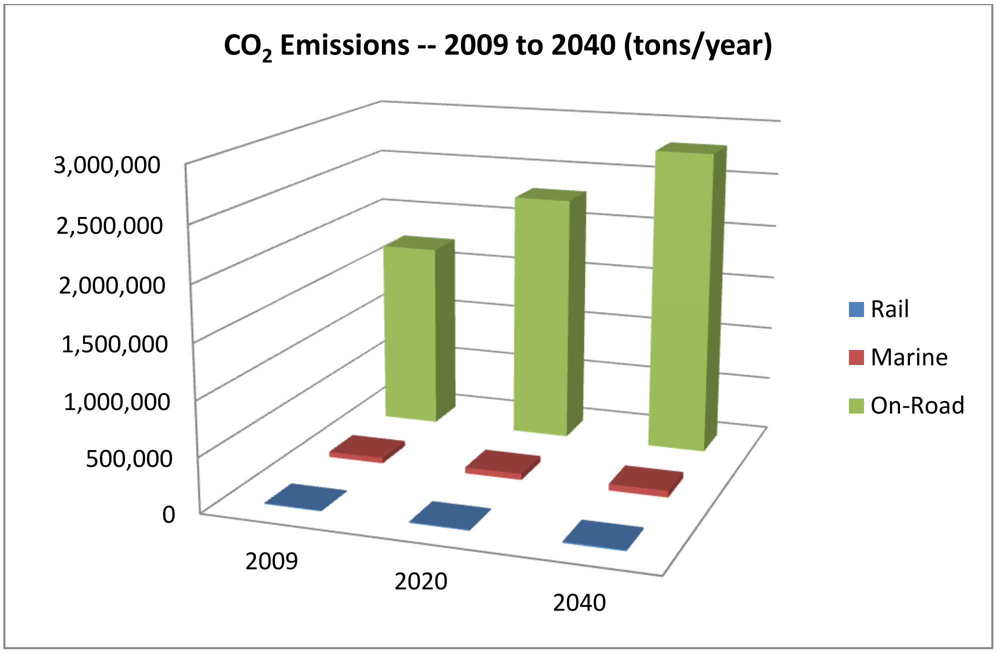
Figure 8 – CO_2 Emissions by Freight Movement Mode



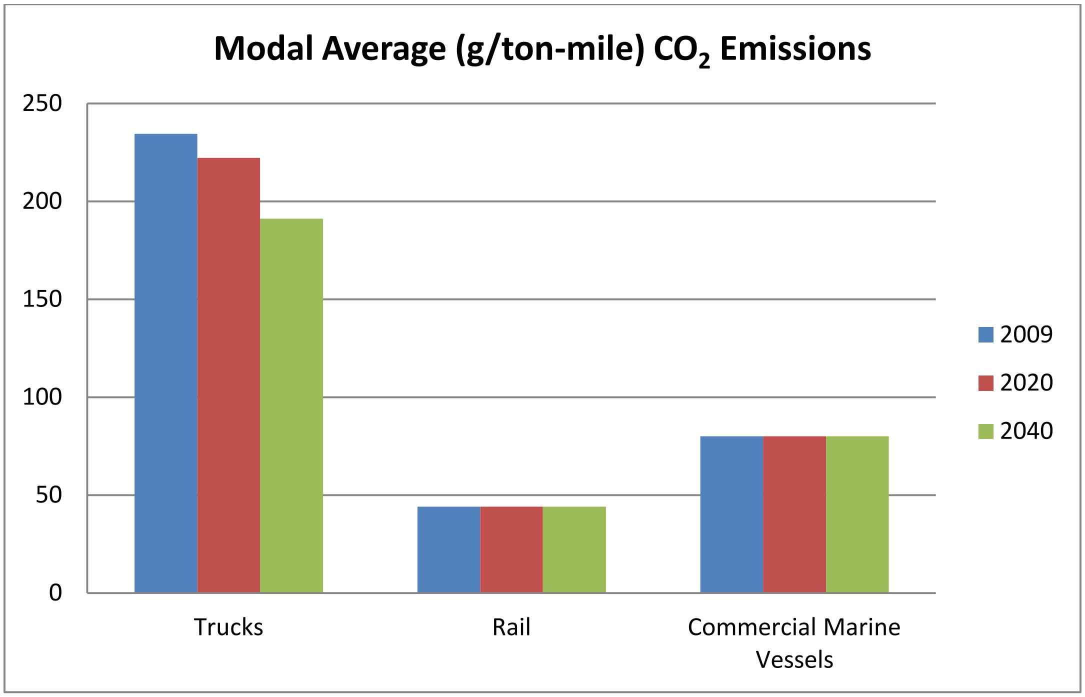
Source: ERG

Emissions per Ton-Mile by Freight Movement Mode

Estimates of CO_2, PM, and NOx emissions per ton-mile by freight movement mode are shown in Figures 9, 10, and 11, respectively. For all three modes, PM and NOx emissions per ton-mile drop significantly from 2009 to 2040, due to EPA's extremely stringent emission standards. These anticipated emission reductions highlight the importance of strategies to incentivize early retirement and replacement of older equipment and vehicles with new state of the art equipment and vehicles.

With regard to CO_2 emissions, now and in the future, the most efficient freight mode per ton-mile is rail. CO_2 emissions associated with rail-transported freight are 20% of the emissions expected for transporting the same tonnage of freight by truck. This illustrates the potential air quality benefits that could be realized by shifting freight from trucks to rail. CO_2 emissions associated with marine-transported freight are 30% of the emissions expected for transporting the same tonnage of freight by truck, so there are also air quality benefits from shifting freight from trucks to marine. While truck CO_2 emissions/ton-mile decrease in the future, trucks continue to have the highest emissions per ton-mile of CO_2 of the three modes. Eliminating extended truck idling will not change the ranking. The only way to reduce CO_2 emissions from freight movement is to shift from truck to rail or marine transport. Fuel consumption is directly proportional to CO_2 emissions so diverting truck freight to marine or rail will reduce the amount of fuel that's consumed by freight movement activities.

Figure 9 – CO2 Emissions per Ton Mile

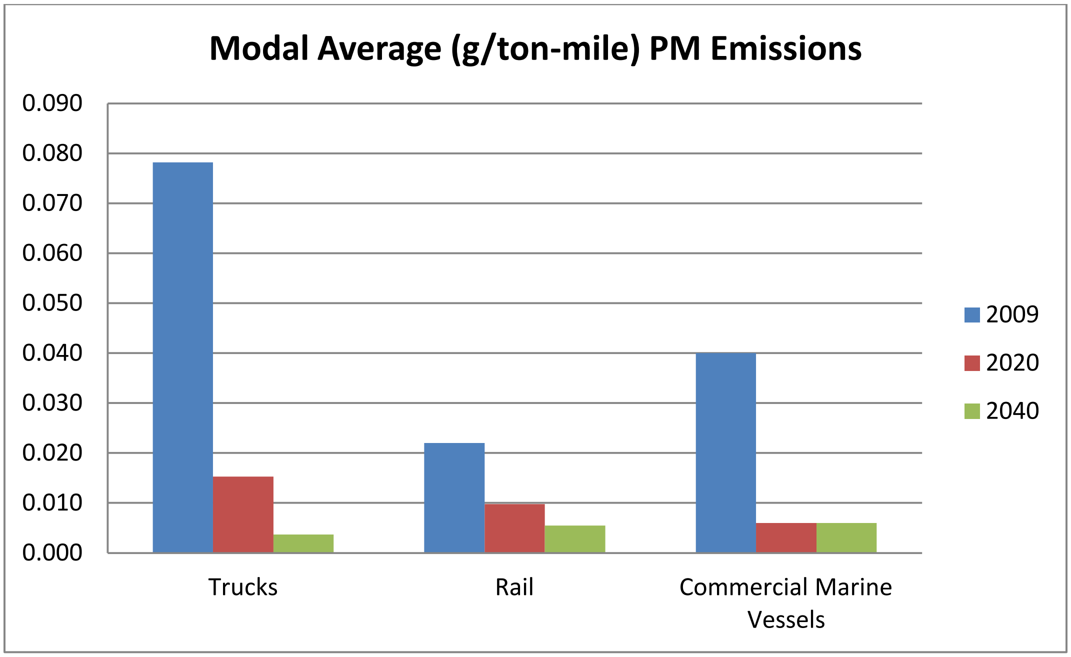


Source: ERG

In terms of PM emissions, trucks currently emit significantly more per ton-mile than other modes. However, due to EPA's extremely stringent emission standards for new trucks, by 2020, PM emission rates for trucks per ton-mile are about the same as PM emission rates for rail. Rates for truck and rail in 2020 are slightly higher than rates for commercial marine vessels, but by 2040, trucks have the lowest rate per ton mile.

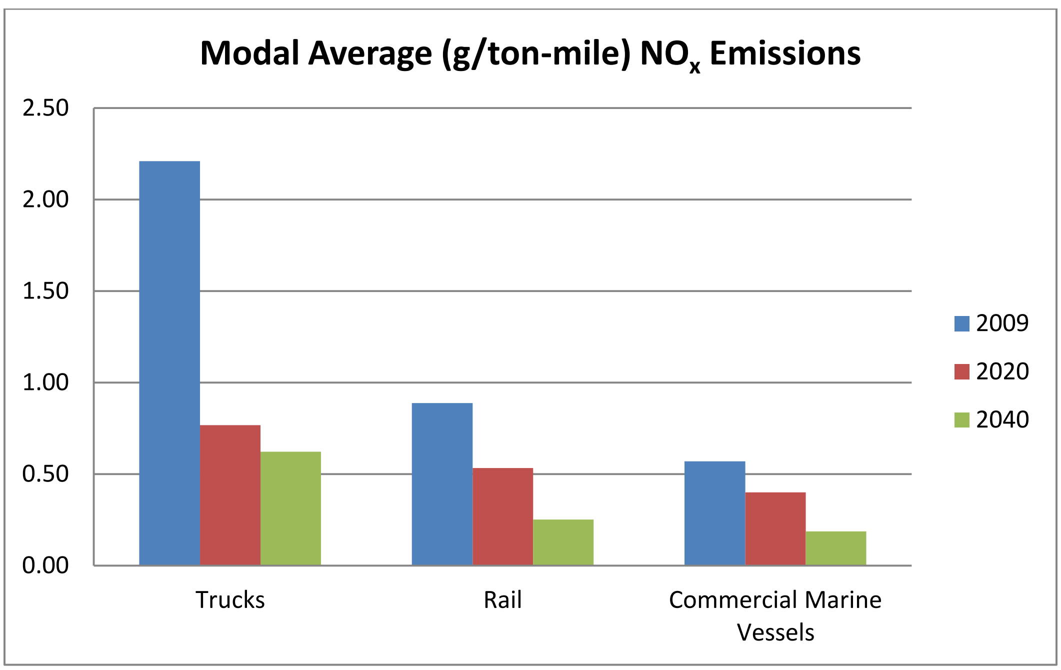
Currently, NOx emissions per ton-mile are significantly greater for trucks than for rail and marine, but in the future, truck emissions are closer to rail and marine levels. If extended idling by long-haul trucks were eliminated, these trucks would have about the same NOx emissions per ton-mile as rail by 2020. Marine has slightly lower NOx emissions per ton-mile than rail. Even if extended idling were eliminated, marine remains the lowest NOx emitting mode, making it important to look for opportunities to shift freight movement to marine. Projected emissions reductions will occur when older truck, rail, and marine engines are replaced with new engines that comply with the newer, more stringent EPA standards. The earlier the replacement occurs, the sooner the air quality benefits are achieved. These reductions also depend on the vehicles being properly maintained.

Figure 10 – PM Emissions per Ton Mile



Source: ERG

Figure 11 – NOx Emissions per Ton Mile



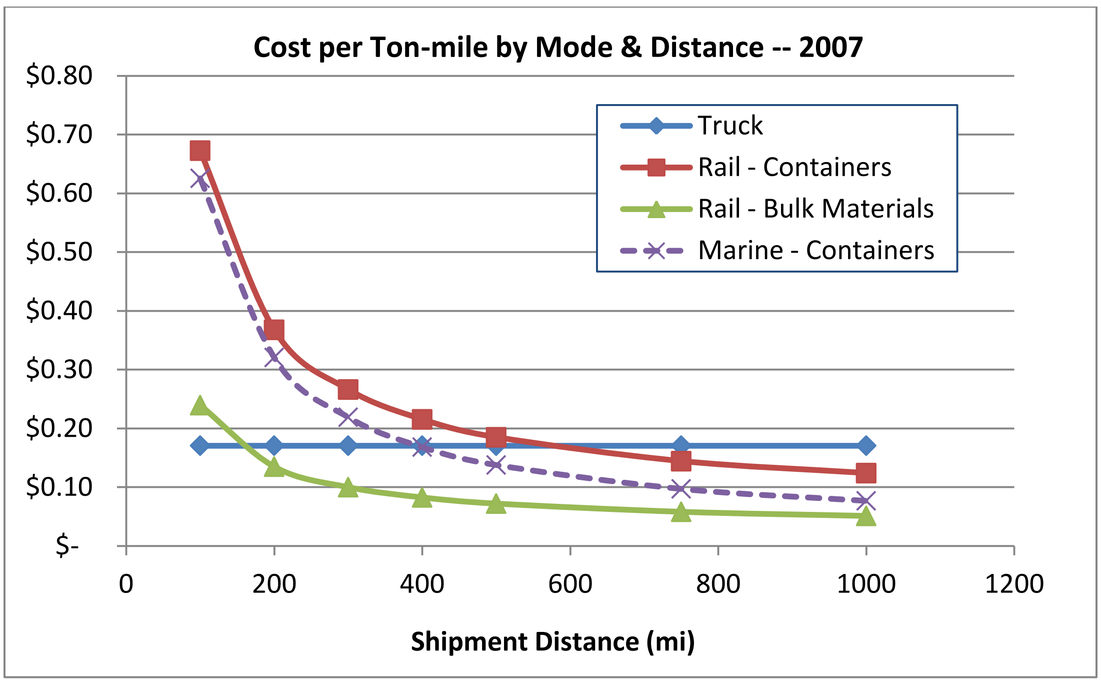
Source: ERG

Cost per Ton-Mile by Freight Movement Mode

Cost effectiveness is a prerequisite to changing freight modes from truck to marine or rail transport. To analyze this issue, costs per ton-mile of cargo shipped were calculated for truck, marine and rail transport. Truck costs are commonly expressed to shippers as a constant cost per mile with no fixed term. Rail and marine costs have both a fixed cost and a variable cost component based on distance travelled. The fixed cost is for drayage at both ends of the trip. The variable cost is for the movement of the freight. As a result, rail and marine costs drop as the shipping distance is increased while truck costs are constant.

Figure 12 presents estimates of costs per ton-mile by mode and distance shipped. These are the estimated charges to shippers; they do not include societal costs, such as the cost for traffic congestion from truck shipment. Costs per ton-mile shown on Figure 12 are based on data collected in 2007. Costs for rail shipments were broken down into two categories: bulk materials and container shipments. Bulk materials refer to commodities like coal, while containers refer to finished and semi-finished goods shipped in cargo containers.

Figure 12 – Cost per Ton-mile by Mode & Distance

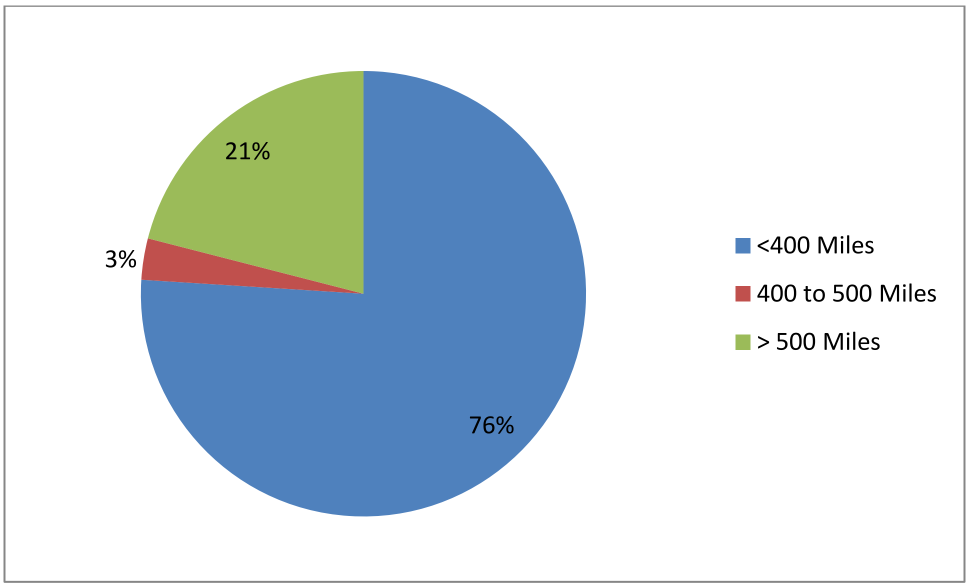


Source: Cambridge Systematics

As shown on Figure 12, for short distances freight movement by truck cost less than freight movement by rail or marine. The shipping distance where trucks become more expensive than rail or marine varies between 150 miles and 500 miles. Shipment of bulk materials by rail is cheaper than trucks for distances greater than 150 miles. Marine shipments of containers is cheaper than trucks for distances greater than 400 miles, while rail shipments of containers is cheaper than trucks for distances greater than 500 miles.

Based on Transearch data, less than 15% of the freight moved in Connecticut falls into the category of bulk materials, the rest comprises finished or partially finished goods. Figure 13 shows the distribution of shipping distances for finished goods. The breakpoints of 400 miles for marine and 500 miles for rail are of greatest interest. Trips greater than 400 miles account for 24% of the freight moved by truck[11]. Trips greater than 500 miles account for 21% of the freight moved by truck. This leads to the following conclusions: 1) trucks will be the most economical way to transport over 75% of the freight, so control measures must focus on reducing truck emissions through minimizing extended idling and early retirement of high emitting vehicles, and 2) shipping costs and CO_2 emissions, could be reduced by using rail and/or marine modes instead of trucks for long distance shipments. As mentioned earlier, CO_2 emissions and fuel consumption associated with rail and marine transported freight are 20% to 30% of the emissions and fuel consumption expected for transporting the same tonnage of freight by truck. Therefore, shifting long-distance shipments to rail or marine could reduce CO_2 emissions. Shifting long-distance shipments to marine will slightly lower NOx emissions. However, for truck shipments to be shifted to rail or marine, regional and national organizations must coordinate improvements to rail and marine infra-structure.

Figure 13 – Distribution of Finished Goods Shipped by Distance



Source: dKC analysis of Transearch

The costs per ton-mile shown on Figure 12 are based on data collected in 2007. Since 2007, highways have become much more congested. This congestion raises costs for truck shipments, while costs for the other modes, all else being equal, remain the same. Consequently, the distance where rail and marine become less expensive likely is lower now than it was in 2007, and will continue to drop in the future as highways become even more congested. Despite congestion, however, trucks will continue to be the most economical mode for a majority of shipments in Connecticut.

[11] According to Transearch, in 2009 24% of the freight shipments were for distances greater than 400 miles, 21 % were for distances greater than 500 miles.

3.0 Analysis of Best Practices to Reduce Environmental Impact of Freight Movement

Based on the analysis presented in the previous section, a strategy to reduce the environmental impact of freight movement should focus on trucks as they move 92% of the freight in Connecticut. In addition, a strategy may have the following characteristics:

- Be cost-effective.
- Eliminate emissions associated with extended idling.
- Accelerate the emissions reductions from trucks by ensuring that the full benefit from EPA emission standards are achieved through retirement and replacement of older vehicles and proper maintenance.
- Improve efficiency by moving freight to rail and marine, if regional planning can address necessary infrastructure improvements. Since truck fuel economy is predicted to only increase by 10%, future CO_2 emissions can only be reduced by switching mode. Mode switching has the additional benefit of reducing traffic congestion.
- Improve efficiency by reducing empty backhauls.
- Incorporate value added freight activities and electronic systems to manage traffic and enforce weight compliance. This includes expanding the State's participation in the Commercial Vehicle Information Systems and Networks (CVISN) program. CVISN is a cooperative effort among State and Federal agencies that allows compliant carriers to bypass truck inspection facilities.

The project team analyzed numerous options to reduce emissions from freight movement. This section presents the environmental and economic impact of the most promising options.

3.1 Strategy Overview

There are two basic ways to reduce emissions from freight movement:

- Technology strategies – Strategies that reduce emissions per ton-mile. These strategies address the extended idling, proper maintenance and early retirement/replacement of the vehicle fleet.
- VMT reduction strategies – Strategies that reduce VMT by improving the efficiency of freight transport. These strategies include diverting freight from trucks to more efficient modes such as rail and marine transport.

Given the current role of trucks in freight movement, technology strategies for trucks have the greatest immediate potential for air pollutant reductions. These strategies eliminate extended idle emissions, and ensure that full benefits are realized from EPA emission standards. In the long term, however, Connecticut must look to VMT reduction strategies for reducing emissions by transferring more freight to rail and marine transport, due to logistical constraints to mitigate congestion and decrease fuel use. This transfer will require the support and coordination of regional and national partners to be successful. Table 3 shows possible strategies organized by the origin and destination of the freight. Table 4 shows technology and VMT reduction strategies for the top commodity types transported to, from, and within Connecticut.

Technology Strategies

Technology strategies can reduce emissions from all vehicles used to carry freight in Connecticut. The most promising technology strategies for trucks, which account for most freight-related emissions, are listed below:

- Extended idle reduction: Eliminate emissions associated with extended idling.
- Inspection and Maintenance (I/M): Ensure that vehicles that emit pollutant above acceptable standards are required to get repaired to minimize emissions from existing vehicles.
- Accelerated retirement of older model year heavy-duty vehicles: Accelerate the turnover of older, high emission models with new, low-emission models.
- Encourage participation in SmartWay: SmartWay is a public/private collaboration between the EPA and the freight transportation industry that helps freight shippers, carriers, and logistics companies reduce emissions, improve fuel-efficiency and save money. SmartWay devices reduce drag yielding reductions in NOx and CO_2 emissions. This report focused on the most applicable options for Connecticut's fleet. A comprehensive review of SmartWay options can be found at *www.epa.gov/smartway/.*

Replacement with Natural Gas Vehicles

Replacement of conventionally fueled vehicles with natural-gas fueled vehicles is another possibility, if concerns over methane leaks are addressed. The project team evaluated the costs associated with replacing conventionally fueled vehicles with alternatively fueled vehicles, including natural gas-fueled vehicles. At current compressed natural gas (CNG) and diesel prices, natural gas has the potential to considerably reduce fuel costs for fleet owners. Due to significant upfront investment in vehicle and refueling facility infrastructure, fleets that accumulate greater than average amount of mileage are the best candidates for natural gas. Operating on natural gas has the potential to significantly reduce CO_2 emissions. While natural gas replacement has the potential to save operators fuel costs, diesel and gasoline vehicles must meet the same emission standards, so there is no benefit with respect to the tailpipe emissions.

Table 3 – Strategies by Movement Origin/Destination (Source: dKC, ERG and Cambridge Systematics)

Origin/Destination	VMT Reduction Strategies*	Technology Strategies**
Through traffic	• Rail and marine infrastructure improvements • Truck tolls or VMT fees • Reduced empty backhaul	• Extended idle reduction • I/M • SmartWay • Accelerated retirement of older vehicles
Long distance inbound/outbound traffic	• Reduced empty backhaul • Rail and marine infrastructure improvements • Rail and marine oriented land use and freight transfer facilities (bulk goods)	• Extended idle reduction • I/M • SmartWay • Accelerated retirement of older vehicles
Short-distance and in-state traffic	• Reduced empty backhaul • Increased weight limits on tanker trucks	• Extended idle reduction • I/M • Accelerated retirement of older vehicles

Table 4 – Strategies by Commodity Type (Source: dKC, ERG and Cambridge Systematics)

Commodity Type	VMT Reduction Strategies*	Technology Strategies**
Non-metallic minerals (sand, gravel, etc.)	• Facilities to transfer to rail and marine • Rail-oriented land use • Reduced empty backhaul	• Extended idle reduction • I/M • SmartWay • Accelerated retirement of older vehicles
Secondary moves (drayage, distribution, etc.)	• Reduced empty backhaul	• Extended idle reduction • I/M • Accelerated retirement of older vehicles
Food, chemicals, and other commodities:	• Truck tolls or VMT fees • Rail and marine infrastructure improvements • Reduced empty backhaul	• Extended idle reduction • I/M • SmartWay • Accelerated retirement of older vehicles
Petroleum	• Increased tanker truck weight limits	• I/M • Accelerated retirement of older vehicles
Municipal solid waste	• Facilities to transfer to rail	• Extended idle reduction • I/M • Accelerated retirement of older vehicles

*All types of freight benefit from value added freight activities and electronic systems to manage traffic and enforce weight compliance. ** EPA standards apply to movement of all commodities.

Technology strategies are described below. Details on technology strategies can be found in Appendix D.

Extended Idle Reduction

Reducing or eliminating extended idle events offers the greatest potential emission reductions. Extended idling increases NOx and PM emissions as well as fuel consumption (and CO_2 emissions). Extended idle reduction strategies target long-haul trucks that typically park during the daytime or at night so that drivers can rest. Extended idling is defined as idling for more than 30 minutes. Long-haul tractor-trailers idle an average of eight hours per day. According to EPA MOVES model, NOx emissions from extended idling activities will account for 44% of truck NOx emissions in 2020, with this percentage increasing to over 60% by 2040. When idling, these trucks consume, on average, a gallon of diesel fuel per hour. This increases overall fuel consumption and CO_2 emissions by 5%. Reducing extended idling for long-haul trucks has immediate air quality benefits, however, extending enforcement authority of Connecticut's anti-idling regulation for all motor vehicles to local and state police officers allows for even greater benefits. Therefore, a promising two-pronged option is to develop a marketing campaign to increase anti-idling awareness and concurrently, extend infraction authority to peace officers and public safety agencies so the ability to enforce against idling is extended to a greater number of law enforcement officials.

The most effective way to eliminate extended idling through technical improvements in long-haul trucks is to place equipment on the truck to power the auxiliary systems, thereby allowing the engine, the primary emissions source, to be shut down. This equipment includes:

- Auxiliary power units (APUs)
- Direct fired heaters (DFH)

- Battery A/C systems.

APUs have the greatest emission benefits since they will eliminate all instances of extended idling. DFHs will eliminate idling in the winter to heat the cab. Consequently, they do not have significant benefits during the summer ozone period when NOx reductions are paramount. On the other hand, battery A/C systems help eliminate extended idling in the summer. APUs cost the most ($9,000) followed by battery A/C systems ($4,300) and DFHs ($900). APUs weigh about 400 pounds as compared to battery A/C systems (200 pounds) and direct fired heaters (less than 100 pounds). It's possible that trucks can be equipped with both battery A/C systems and DFHs, as a lighter and lower cost alternative to APUs. Truck-stop electrification was also evaluated as a means to reduce extended idling. However, truck stops in Connecticut have limited parking spaces available, so truck stop electrification, although cost effective (<$2,000/ton of NOx), will not be able to eliminate a significant portion of extended idling activities. Cost effectiveness estimates are strongly dependent on the extent of usage of truck stop electrification technology.

Inspection and Maintenance (I/M)

Engines used in heavy-duty trucks built since 2010 emit less than 5% of the NOx and PM emitted from a 2006 or earlier model engine. Model year 2010 and later models are equipped with catalytic NOx controls and diesel particulate filters that greatly reduce emissions. However, these devices must be maintained to keep emissions low. Often this requires properly maintaining a reagent tank. If the tank is not maintained and periodically refilled, emissions will increase dramatically.

Model year 2013 and later model heavy-duty trucks will be equipped with on-board diagnostic (OBD) systems that identify trucks needing maintenance, including reagent tank service. Remotely monitoring OBD systems (termed remote OBD) by equipping trucks with wireless transponders will help ensure continued low emission operation. Preliminary studies in other states have found that remote OBD I/M is emerging as a promising tool for reducing emissions of NOx, hydrocarbons (HC), and PM. HC and PM compounds are linked with toxic air pollutants. With remote OBD, trucks are equipped with transponders that are plugged into the vehicle's OBD port. These transponders transmit OBD status to receivers along the highway, e.g., at weigh stations. Remote OBD negates the inconvenience of having to stop and undergo testing for each truck, thereby also providing an economic benefit to the trucking firm and minimizing program implementation costs. Remote OBD inspections can be tied into other electronic initiatives that are being implemented to reduce inconvenience and lost revenue from enforcing truck regulations. Because it takes time for OBD-equipped trucks to be phased into the fleet, this strategy will not be effective until 2020, however early retirement and replacement will accelerate the air quality benefit. Coordination with other Northeastern states is crucial to enhancing the effectiveness of this strategy.

Older model trucks should continue to be subjected to snap acceleration tests to identify vehicles with excessive exhaust smoke opacity. Identifying and requiring the repair of vehicles with excessive opacity has the corollary benefit of reducing emissions of volatile organic compounds and PM. Currently, Connecticut Department of Motor Vehicles (DMV) conducts road side snap acceleration tests.

Accelerated Truck Retirement

Early retirement of older model trucks with new trucks has the potential to significantly reduce emissions. Although it is not cost effective to retire most truck fleets as a whole, the older vehicles in the fleet should be considered candidates for retirement. For example, replacing 2006 and older model year diesel trucks is estimated to lower PM and NOx emissions from the affected vehicles by over 90%. Fuel savings through efficiency improvements can result in the investment cost being paid back to the owner/operator in less than ten years. An incentive program would decrease the payback period and most likely make this option more attractive to the industry. The state should continue to support federal funding programs that can be used for such incentives. The current drayage fleet is much older than the average truck fleet, so vehicles in the drayage fleet should be targeted for retirement first.

SmartWay

Outfitting in-use trucks with SmartWay-certified products reduces fuel consumption and NOx emissions. SmartWay products recommended for this project include the following:

- Aerodynamic treatments for tractor trailers (front, side, rear trailer fairings); front fairings for single-unit trucks
- Low rolling resistance (LRR) tires and aluminum wheels for all but light commercial trucks

VMT Reduction Strategies

Truck VMT is projected to greatly increase in Connecticut, with the largest increase being for trucks that are just passing through. Air quality, energy and economic benefits can be achieved if rail and marine infrastructure is improved through coordination with regional and national organizations. Enhancing this infrastructure will improve the cost-effectiveness of rail and marine transport thereby encouraging shippers to shift truck freight to these modes. Further details on VMT reduction strategies are set forth in Appendices E - I.

Shift from Truck to Rail

Through truck traffic currently accounts for over half the truck traffic associated with freight use in Connecticut. Improving rail infrastructure would encourage using rail to transport goods through the state in lieu of using trucks. Increased rail utilization for freight movement would reduce truck VMT and CO_2 emissions along with GHG emissions. A single intermodal freight train can carry the same load as 500 trucks, minimizing tonnage moving over state highways and helping to reduce wear on the state's road system. Before a significant amount of freight can be diverted from truck to rail, existing rail lines must be improved, and a new rail bridge must be built across the Hudson River. Other options to help reduce inbound and outbound truck VMT are rail-oriented land use and the building of freight transfer facilities that encourage shifting transport from truck to rail. Regional and national coordination are needed to achieve improvements to the rail system and will need to be partially funded by the federal government. The regional freight rail situation is currently being studied in the Northeast Rail Operations Study (NEROps) being conducted by the I-95 Corridor Coalition. Connecticut's 2012 State Rail Plan should be used as a framework for planning any enhancements to the rail systems.

Shift from Truck to Marine

Another strategy to reduce through truck traffic is to shift from truck to marine transport. Connecticut's Deep Water Port Strategy Study[12], a market analysis conducted to determine the best uses of the ports at Bridgeport, New Haven and New London should be strongly considered as freight movement options are explored. Connecticut is also supporting the I-95 Corridor Coalition's M-95 project, which aims to develop a waterside system for freight transport. The M-95 project was selected as a Marine Highway

[12] Connecticut Deep Water Port Strategy Study, Moffatt and Nichol, September, 2012, http://www.ct.gov/ecd/lib/ecd/ct_opm_bd_port_final_report.pdf.

Corridor under the U.S. Department of Transportation's America's Marine Highway Program, a new initiative to move more cargo on the water rather than on crowded highways.

Enact Highway Tolls

Through truck traffic also could be reduced by enacting truck tolls or VMT fees to discourage transport on Connecticut's roads. This strategy would reduce NOx and PM emissions in Connecticut by reducing truck VMT in Connecticut. It may also lower GHG emissions. Harmonizing toll policies in Massachusetts and Connecticut would result in truck operators selecting the most efficient route, instead of going out of the way to go through Connecticut so as to avoid tolls in other states. This could lower overall truck VMT and reduce GHG emissions.

Reduce Empty Backhauls

Truck VMT also could be reduced by limiting empty backhauls. It is estimated that there are seven empty backhauls for every ten deliveries in Connecticut, so this is an area where large VMT reductions can be achieved. However, due to the complexity of the issue, it is difficult to formulate an effective strategy to reduce empty backhauls. Imbalances in flows, logistical challenges, and incompatibility issues all hinder efforts to fill empty trucks. For example, tankers, which account for about 5% of freight movement, cannot usually carry backhauls. Also, Connecticut is not a major manufacturer or natural resource producer, so more goods are imported than exported. Most goods are shipped into rather than out of the state, with waste being the primary export. A long-term strategy is needed in the empty backhaul area. Appendix F contains details on the issue of reducing empty backhauls.

Other Measures to Reduce VMT

Connecticut should continue to develop electronic systems to screen commercial vehicles. As part of the Commercial Vehicle Information Systems and Networks (CVISN) program, Connecticut has deployed electronic screening technology at its Union and Greenwich inspection facilities to target enforcement resources at non-compliant carriers and carriers with histories of non-compliance. CVISN is a cooperative effort among State and Federal agencies to organize information and communication systems related to commercial vehicle operations, and allow them to operate in an integrated manner. Compliant carriers that opt to enroll in the State's program are allowed to bypass the inspection facility, which reduces the number of commercial vehicles idling while in queue to be weighed and/or be inspected.

In an effort to increase efficiency, a new practice of 'value-added' freight movement has evolved. Value-added freight practices include bypassing distribution centers and shipping directly to retail stores and customers. Encouraging value-added freight practices will streamline freight movement and reduce emissions. Other measures include increasing weight limits on tanker trucks to cut down on the amount of VMT associated with fuel transport and optimizing waste management operations to reduce emissions associated with waste movement.

Strategies for Rail and Ports

Cost-effective strategies have been identified for reducing emissions associated with rail and marine transport. However the overall impact on the emission inventory will be small because their contribution to the total inventory is small. For this reason, this study focused more on strategies for trucks than rail and marine. The report also evaluated rail and marine strategies that have been successfully demonstrated in other areas.

Promising rail strategies include accelerated retirement and replacement of equipment, focusing on the following:

- New locomotives with low exhaust emissions and idle reduction technology
- Low emission switch engines (Gen-set, battery)

Promising strategies for marine include:

- Replacement of old equipment with new, low-emission equipment
- Idle reduction
- Gate Management Systems – Coordination of systems that speed the flow of trucks to reduce idling and emissions by automatically recognizing and giving clearance to drivers with cargo, as well as allowing night and weekend gate hours
- Maintenance programs to reduce fuel leakage and evaporation while ensuring appropriate maintenance is conducted
- Clean freight handling equipment (e.g., cranes and forklifts)
- Harbor speed reduction

The use of shore power at ports, also known as cold ironing, does not appear to be cost effective, due to the large capital investments required for ports and vessels.

Strategies Being Considered in Germany and Japan to Improve Freight Movement

As part of the effort to assess best practices globally, this report also evaluated strategies being considered in Germany and Japan to improve freight movement and reduce emissions. Germany and Japan have recognized and acted upon the need to improve infrastructure, particularly rail systems. One strategy being considered in these countries is segregating passenger and freight traffic on rail and highway networks. Germany has earmarked $66 billion Euros ($85 billion dollars) over the 2001 to 2015 time period to construct or upgrade federal railways, truck roads, and waterways. Systems to provide timely and comprehensive information on road conditions and traffic to reduce congestion are being developed there, as well as in the United States. In addition, systems to remotely enforce size and weight limits have been proposed in Germany, Japan, and the United States. Germany and the United States are developing strategies to vary toll rates according to the route driven and time of day, which may be applicable as Connecticut contemplates charging tolls on major highways or implementing VMT fees.

3.2 Environmental Impact

Technology Strategies

Table 5 summarizes the environmental impact of technology strategies. Emission reductions are expressed in tons per year (TPY). Strategies that have significant seasonal variations are noted. If emission reductions cannot be quantified, the environmental impact is expressed qualitatively.

The emission reductions estimated for extended idle reduction, accelerated retirement of older model vehicles, and SmartWay are only for applications that have a payback of less than 10 years. The greatest reductions are projected to result from reducing the time trucks spend idling in Connecticut, through use of APUs, DFHs and/or battery A/C systems. APUs and battery A/C systems are projected to reduce NOx emissions from freight movement by about 25% during the summer ozone period. DFHs do not have a summer NOx benefit, but they do reduce CO2 in the winter. An I/M program also has the potential to significantly reduce emissions. Based on a draft analysis[13] dKC did for states in the Ozone Transport Commission (OTC), I/M is projected to reduce NOx by 300 to 650 TPY in 2020, which translates to a 5% to 10% reduction in NOx emissions from freight movement. By 2040, estimated reductions from I/M increase to 670 to 1,400 TPY. The estimated emission reductions were generated by adjusting MOVES emission rates for the effects of an I/M program for heavy-duty vehicles. Other promising strategies include accelerated retirement of aged fleets (such as drayage fleets) and use of SmartWay aerodynamic features.

Table 5 – Environmental Impact of Technology Strategies (2020) (Source: dKC and ERG)

Strategy	Emission Reductions: TPY: Tons per year	Comments
Extended idle reduction APUs DFH Battery A/C	APUs: 1,800 TPY NOx, 2.3 TPY PM, 49,700 TPY CO_2 DFH (winter): 717 TPY NOx, 1.6 TPY PM, 24,200 TPY CO_2 Battery A/C (summer): 750 TPY NOx, 1.0 TPY PM, 23,700 TPY CO_2	Emission reductions are based on MOVES. Emission reductions assume use of idle reduction devices in vehicles where payback for the specific device (APU, etc.) is less than 10 years.
Inspection and Maintenance (I/M)	300-650 TPY NOx, 240 TPY VOC, 33 TPY PM	Assumes OBD inspection on 2013+ plus snap acceleration test on pre-2013 models.
Accelerated retirement of older model year heavy-duty vehicles	Retiring pre-2007 vehicles reduces per vehicle NOx and PM by 90%.	Accelerated retirement must be evaluated on a case-by-case basis.
SmartWay retrofit	300 TPY NOx, 0 TPY PM, 66,700 TPY CO_2.	Assumes use in vehicles where payback from fuel savings for installing measure is less than 10 years.
Port and rail strategies: Accelerated Equipment Turnover Gate Management Systems CNG and LNG infrastructure Inspection and Maintenance (I/M) Shore Power	Total inventory in 2020 is 630 TPY NOx, Estimated reductions for replacing aged drayage trucks with new trucks: 250TPY NOx, 13 TPY PM, 9,000 TPY CO_2. Cold Ironing: <180 TPY NOx (Estimated emissions for auxiliary activities at ports.)	I/M is conceptual; it has not been used in marine or rail applications.
Replacement of conventionally fueled vehicles with natural gas fueled vehicles	Primarily reduces CO_2 emissions. Natural gas combustion produces about 25% less CO_2 per mile, but could increase total GHG emissions if predicted leaks of methane are not mitigated.	Significant NOx or PM reductions are not expected as compared to 2007+ diesels.

[13] The Case for Assigning Mobile Source Emissions Benefits In State Implementation Plans Based on Heavy-Duty Vehicle Inspection & Maintenance (I/M) Programs, White Paper – OTC Draft, May 29, 2012.

VMT Reduction Strategies

Table 6 summarizes the environmental impact of VMT reduction strategies. Due to logistical challenges, quantifying the benefits of VMT strategies is far more uncertain than for technology strategies. If extended idle emissions are eliminated, shifting from truck to rail will primarily impact CO_2 emissions. Shifting to marine will have NOx and CO_2 benefits. If rail and marine infrastructure is not improved to handle more freight, traffic congestion will get worse and improvements in energy efficiency for trucks will be more than offset by increased truck VMT.

Table 6 – Environmental Impact of VMT Reduction Strategies (Source: dKC and Cambridge Systematics)

Strategy	Emission Reductions (Tons per Day)	Comments
Improve rail transport through state	Strategy will primarily affect CO_2 emissions.	21% of freight shipments were for distances greater than 500 miles, so there's moderate potential for diversion.
Build Intra-modal facilities to shift more in-bound and out-bound freight to rail	1-5% reduction in inbound and outbound truck VMT is possible. Strategy will primarily affect CO_2 emissions.	Reductions are highly uncertain because the actual quantity of freight that's shifted is unknown.
Shift from truck to marine	Strategy will reduce NOx and CO_2 emissions.	21% of freight shipments were for distances greater than 500 miles, so there's moderate potential for diversion.
Enact highway tolls	Strategy may reduce NOx, PM and CO_2 emissions.	Actual impact of tolls is unknown.
Reduce empty backhauls	Strategy will reduce NOx, PM and CO_2 emissions.	Currently, there are 7 empty backhauls for every 10 deliveries, so large reductions are possible. However, there are significant logistical challenges to increase empty backhauls.
Increase tanker truck weight limits	10% reduction in tanker truck VMT possible. (0.6% reduction in truck VMT.) This will reduce NOx, PM and CO2.	Feasibility and impact have not been determined.
Value added freight	Not available, strategy has not been defined.	Likely to reduce truck VMT by streamlining freight movement.

3.3 Cost Effectiveness

Technology Strategies

Table 7 summarizes the economic impact of technology strategies. The cost per ton is less than zero if the strategy pays back the investment. With many strategies, reductions in fuel costs pay back the additional investment cost to owners in less than 10 years[14]. For example, the fuel savings from eliminating extended idle by installing APUs, DFHs or Battery A/C systems pay back hardware costs in less than 10 years. I/M could have a low cost per ton of NOx ($1,700 to $3,500), if remote OBD inspection technology is used[15]. Cold ironing (use of shore power for marine vessels) does not appear to be cost effective with estimated costs per ton of NOx between $15,000 and $30,000.

[14] The analysis assumes a discount rate of 4.8% which was the average rate for small business borrowing in 2011.

[15] The cost per ton for I/M is based on the cost for CVISN which comprises a start-up cost of $275 and an annual cost of $125. CVISN is similar in concept to an I/M program with transponders to transmit OBD system status.

The economic impact of switching to natural gas depends on the amount of fuel used by the vehicle and how the vehicle is fueled. The increased cost for a new natural gas vehicle over a new gasoline- or diesel-fueled vehicle can be up to $80,000 per vehicle, so the vehicle must be -driven between 70,000 to 120,000 miles per year to pay back the additional capital cost in fuel savings. In addition, a natural gas refueling facility costs a minimum of one million dollars[16], which may limit refueling options to large private and/or municipal fleets.

Table 7 – Cost Effectiveness of Technology Strategies (Source: dKC and ERG)

Strategy	Strategy/Technology Cost	Cost per Ton of Reduced Emissions
Extended idle reduction APUs DFH Battery A/C	 $9,000/vehicle $880/vehicle $4,300/vehicle	These devices generally pay back investment in less than 10 years. Long-haul trucks idle an average of 1800 hrs per year and consume about 1 gal/hr. while idling. In addition, maintenance costs are reduced.
Inspection and Maintenance (I/M)	$275 transponder cost/vehicle $125 annual cost/vehicle	$1,700-$3,500 per ton of NOx for remote OBD inspections.
Accelerated retirement of older model year heavy-duty vehicles	Cost for new replacement vehicle.	Less than 10 yr. payback for fleets that are more than 15 years old.
SmartWay retrofit	$10,000 to $24,000 per vehicle	2 to 8 year payback, depending on vehicle age.
Port and rail strategies: Accelerated Equipment Turnover Gate Management Systems CNG and LNG infrastructure Inspection and Maintenance Cold Ironing	Same capital cost per vehicle as strategies for on-road trucks. Cold Ironing: $1.5 to $3 million for landside infra-structure $500,000 to $750,000 per vessel	Less than 10 yr. payback for accelerated turnover of drayage fleets and/or switch to natural gas. Cold Ironing: $15,000 to $30,000 per ton NOx.
Replacement of conventionally fueled vehicles with natural gas fueled vehicles	Cost per vehicle: $9,000 (medium duty trucks) to $80,000 (long-haul tractor trailers). Fuel cost savings: $/equivalent gal is $1.8 to 2.4.	Has a <10 year payback for on-road trucks >15 years old.

[16] Business Case for Compressed Natural Gas in Municipal Fleets, Caley Johnson, NREL/TP-7A2-47919 June 2010.

VMT Reduction Strategies

Similar to the environmental benefits for these strategies, there is considerable uncertainty regarding costs for VMT reduction strategies. Preliminary estimates were prepared on the costs for improvements to the rail system to allow more in-bound, out-bound, and through freight to be shifted to rail. The estimated costs for rail improvements are discussed in Appendix E and are summarized below:

- Track and bridge improvements within Connecticut: $500 million
- Hudson River Crossing: $1-2 billion
- Intermodal terminal: $200 million

Due to the need for regional and national coordination, costs must be shared with industry, other states, and the federal government. A strategy to shift to marine has not been defined so costs cannot be estimated for this strategy. Costs to shift to marine are likely to be much less than for rail improvements.

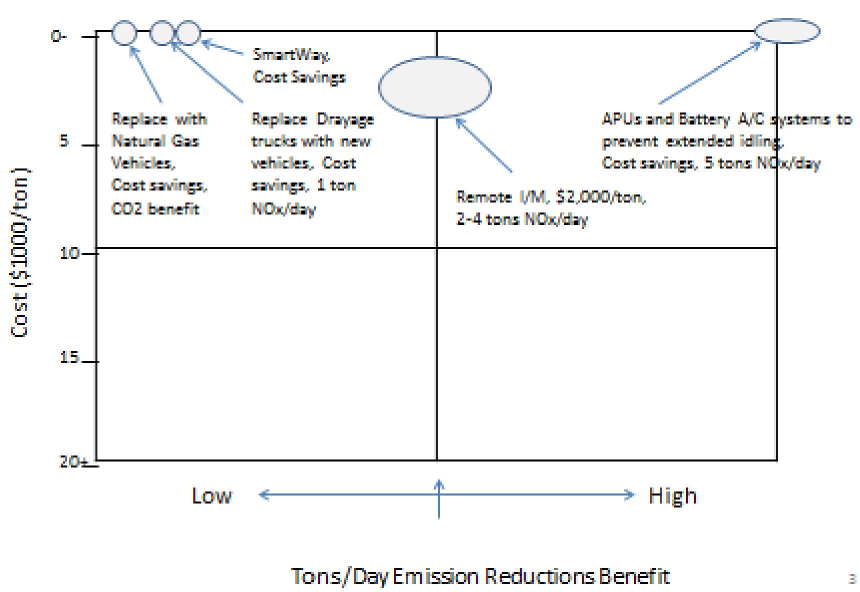
4.0 Conclusions and Recommendations to Address Environmental Impacts of Freight Movement

Conclusions

Following are the key conclusions of this study:

- Current and future EPA initiatives will greatly reduce emissions from all modes of freight movement. New trucks emit less than 5% of the PM and NOx emissions that are emitted from 2006 and older models. However, limited maintenance and extended idling events significantly increase emissions from trucks.
- Trucks are and will continue to be the primary mode of freight movement. Therefore, any strategy to mitigate freight emissions in Connecticut must focus on trucks. Connecticut's geographical area is small, and trucks are the most economical way to transport goods over short distances (less than 400 miles).
- Strategies that reduce emissions per ton-mile, which are termed technology strategies, offer the greatest benefits in the short- and medium-term time frame. Figure 14 summarizes the costs and benefits of technology strategies. The most promising strategies are those with low cost per ton and large emission reductions, i.e., the upper right-hand quarter. Using these criteria, extended idle reduction and remote I/M stand out as clear winners. SmartWay technologies and retirement of old trucks, such as drayage vehicles, result in moderate emission reductions for a low net cost.

Figure 14 – Summary of the Cost and Emission Reductions for Technology Strategies



- Rail and marine infra-structure must be improved through a coordinated regional and national effort to mitigate future increases in truck VMT and related CO_2 emissions. Otherwise, truck related road congestion and air pollution will increase.

Recommendations

Table 8 provides the summary of the most promising strategies to reduce emissions from freight movement. Strategies are broken down into short-term, those that can be implemented immediately, medium-term, those that can be implemented in 5-10 years, and long-term, those that will require 10 or more years to implement.

Table 8 – Summary of Most Promising Strategies

Name	Description	Rationale	TPY Reduction	Costs
Short Term (1-5 years)				
Enhance Idling Ban	Extend infraction authority for idling to public safety agencies and peace officers, post signs and conduct a marketing campaign to raise awareness.	Long-Haul Trucks generate a lot of emissions because they often idle for hours. Curbing all idling enhances the benefits.	1,800 TPY NOx, 2.3 TPY PM, 49,700 TPY CO_2 Reductions are based on APUs.	Cost savings
Accelerated Vehicle Retirement	Encourage replacement old, high emitting vehicles with new, cleaner vehicles.	NOx and PM Emission per vehicle can be reduced by 90%.	250TPY NOx, 13 TPY PM, 9,000 TPY CO_2 for drayage vehicles	Cost savings
SmartWay	Encourage outfitting SmartWay certified devices on trucks.	Reduces fuel consumption, and accordingly, CO_2 and NOx emissions.	300 TPY NOx, 66,700 TPY CO_2	Cost savings
Medium Term (5-10 years)				
Inspection and Maintenance (I/M)	Require inspections of trucks and other vehicles. High emitters must be repaired.	Keeps vehicles operating at low emission levels. Minimizes fuel consumption.	360-700 TPY NOx, 240 TPY VOC, 33 TPY PM	~$2,000 per ton NOx
Long Term (10+ years)				
Switching from Trucks to Rail or Marine	Coordinate with other states and federal government to develop rail and marine infrastructure.	Freight will continue to increase, but a switch to more efficient modes will provide clean energy and decrease congestion.	Switch to rail: CO2 benefits Switch to marine: CO2 and NOx benefits	To be determined. Too high for CT to do it alone.

Since EPA's emission models predict that extended idling (idling for more than 30 minutes), will double emissions of NOx from trucks by 2020, the most promising control measure in the short term is to strengthen Connecticut's prohibition on idling. This could be accomplished by extending infraction authority for idling to public safety agencies and peace officers, conducting an outreach program to raise awareness, and evaluating the feasibility of providing incentives for idle reduction technologies such as APUs.

Because a new truck emits a fraction of the NOx and PM that are emitted from 2006 and older models, DEEP could work with stakeholders to encourage replacement of older vehicles with new vehicles. In addition, DEEP and CTDOT could encourage truck owners to install SmartWay upgrades.

EPA's emission standards will result in cleaner vehicles and a heavy-duty diesel truck I/M program would ensure that these trucks are maintained, safeguarding air quality benefits and protecting expensive emission control systems. Additionally, the owners will realize an economic benefit as well maintained vehicles use less fuel and incur lower overall maintenance costs. DEEP could coordinate regionally to enhance the effectiveness of existing heavy duty diesel truck I/M programs to ensure that appropriate maintenance is conducted in a timely manner. In addition to trucks, I/M programs should also be considered to ensure that rail and port vehicles and equipment are as equally well-maintained to ensure low emissions.

In the long term, Connecticut could explore all practical possibilities to shift more freight to marine or rail. Connecticut could coordinate with other Northeastern states in the I-95 Coalition to support the M-95 project as well as improvements to the Northeast freight rail system. Recommendations from Connecticut's DEEP Water Port Strategy Study, a market analysis conducted to determine the best uses of the ports at Bridgeport, New Haven and New London should be strongly considered as freight movement options are explored.

APPENDICES

Contents

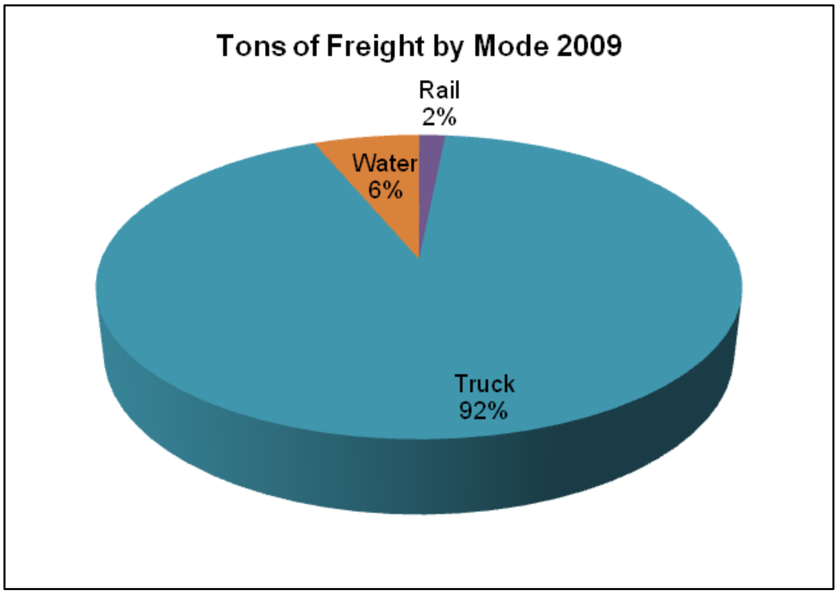
APPENDIX A: SUMMARY OF TRUCK FREIGHT MOVEMENT IN CONNECTICUT

de la Torre Klausmeier Consulting, Inc.

Cambridge Systematics

This appendix characterizes the types of freight moved in Connecticut. On-road trucks move over 90% of the freight in Connecticut and accordingly are responsible for almost all the emissions associated with freight movement.

Figure 1



Vehicle miles traveled (VMT) estimates shown in this summary are based on an analysis by Cambridge Systematics (CS) of Transearch and other datasets. Transearch is a commonly used database that provides estimated value and tonnage of goods moving between geographic origins and destinations in NAFTA markets by commodity and mode. CS estimated that in 2009 freight traffic was responsible for 3.7 million VMT per day in Connecticut[1]. Using Transearch freight projections, CS projected VMT in 2020 and 2040.

This appendix first provides an overview of the VMT for freight transported in the State. Then, freight transport is broken down into four general types: inbound, outbound, local, and through. This summary highlights the following:

- VMT associated with transporting specific commodities
- Differences between state-level and county-level trends
- Predicted changes in movement to 2040

A glossary of terms, in addition to a reference table of the Standard Transportation Commodity Codes (STCC) with example goods provided for each category, are provided in appendices A.1 and A.2.

[1] Total daily highway VMT in CT (all modes and all trip purposes) is 87 million miles. Heavy-duty diesel trucks, account for most of the 3.7 million VMT associated with freight movement. These vehicles have much higher NOx and PM emissions than passenger vehicles. As a result, freight movement accounts for a significant share of statewide NOx and PM emissions. According to the 2008 National Emissions Inventory, 44% of NOx and 57% of PM comes from on-road freight movement.

TOTAL FREIGHT

Of the 3.7 million VMT per day attributed to freight movement in Connecticut in 2009, 53% consists of through freight. Inbound and outbound freight comprise 25% and 15%, respectively. With 6% of statewide VMT in 2009, local transport makes up the smallest share. Figure 2 displays freight VMT by origin/destination.

The majority of freight movement in Connecticut occurs in Fairfield and New Haven counties. These counties account for 28% and 26% of the state VMT total, respectively. Hartford County comprises a 15% share of all freight and New London County accounts for 11% of the total. Aside from Tolland County with a 9% share, the remaining counties (Litchfield, Middlesex, and Windham) each cover less than 5%. Figure 3 presents the county shares. No major changes are expected among the division of freight among the counties from 2009 to 2040.

Figure 2

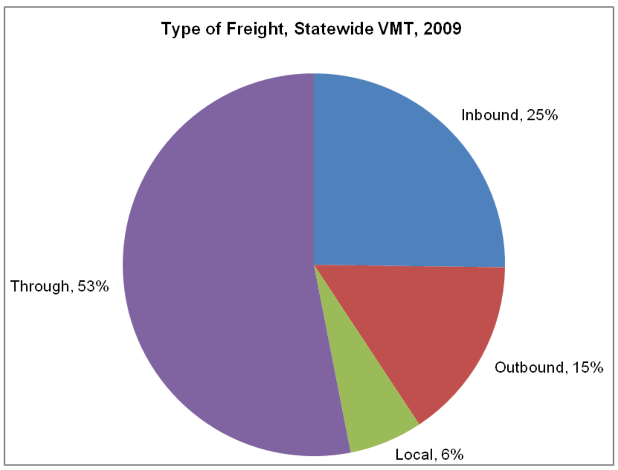


Figure 3

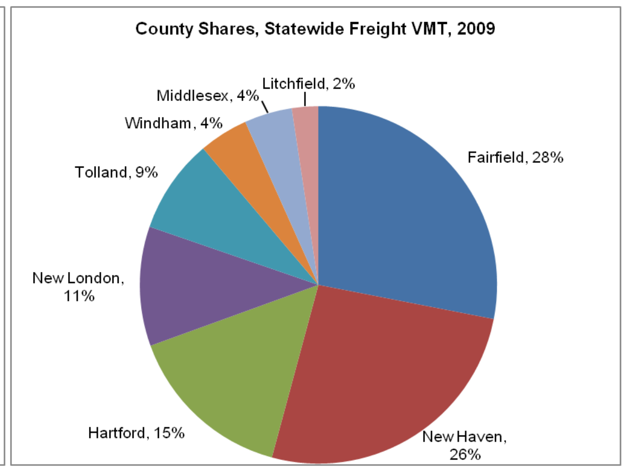
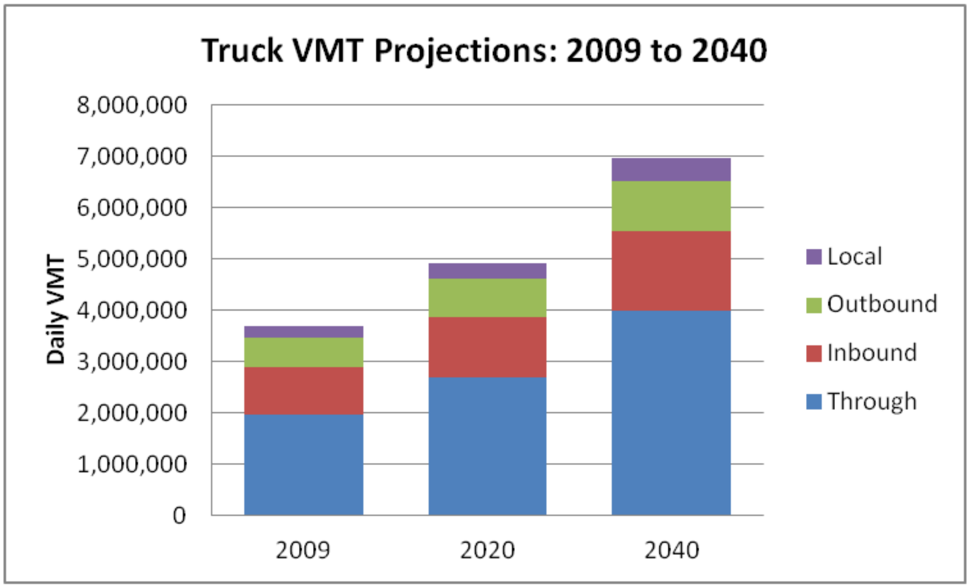


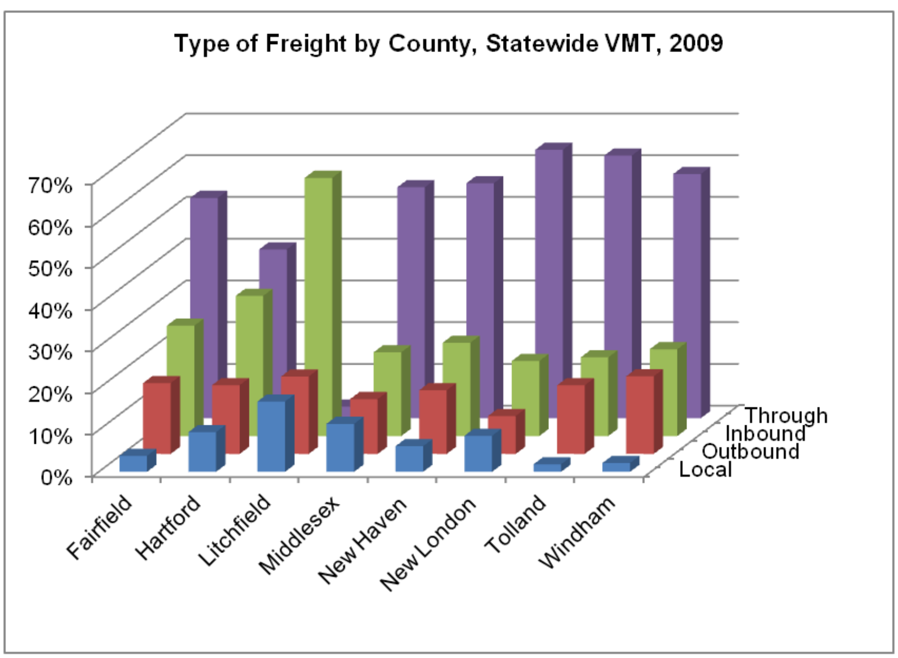
Figure 4 presents projections of freight by origin/destination, i.e., local, outbound, inbound, and through freight. Total freight VMT is estimated to grow by 88% from 2009 to 2040. Through freight shows the largest increase; it's expected to increase by 103% from 2009 to 2040.

Figure 4



As represented in Figure 5 below, the distribution of freight movement varies by county. In New London and Tolland counties, 64% and 63% of the county VMT total, respectively, is through freight. Conversely, 40% of the freight movement in Hartford County is through transport, 13% less than the average statewide percentage. Counterbalancing this reduction, inbound freight accounts for 34% in Hartford County, 8% more than seen on a state level. With the smallest VMT share, Litchfield County has an anomalous balance in freight with 62% inbound and 3% through freight.

Figure 5



Of all commodities transported in Connecticut in 2009, food products comprise the largest share of VMT with 19% of the statewide total. Secondary moves and chemicals/allied materials each have 13% of statewide VMT. Secondary moves represent traffic for which the actual commodity is not known. Most freight movement in the secondary moves category represents traffic associated with distribution centers and warehousing. Also included in secondary moves are the drayage portions of rail and air freight moves. Non-metallic minerals (such as sand and gravel), petroleum/coal and printed matter account for 5 to 9% of Connecticut's total freight. The values for petroleum/coal do not include product moved by pipeline. Although not included in this graph, FHWA's 2007 Freight Analysis Framework (FAF) dataset indicates products transported by pipeline represent 3-4% of total tonnage. 27 commodities cover the remaining 35% of total freight-related VMT, including 12 with less than 1% share.

Figure 6 presents a breakdown of all commodities in Connecticut (commodities with less than 1% each comprise the remaining 2% of the statewide VMT, cumulatively). Looking to 2040, food products maintain the largest VMT share with 18% in 2020 and 2040. A slight trade-off occurs as secondary moves grows 4% to 17% of the VMT share in 2040 and chemicals/allied materials falls 3% to 10%. Forecasts for transport of commodities are based primarily on the expected growth in employment in a particular industry. When a commodity is losing relative share against other commodities, the expected employment growth of the related industry lags behind the growth trend of other industries. Specifically, in the case of chemicals, employment in the aligned industries is expected to decline by nearly 3% on an average annual basis. Any other industry that has a positive rate of growth or even a lesser rate of decline will likely gain share against chemicals. Figure 7 presents trends predicted through 2040.

Figure 6

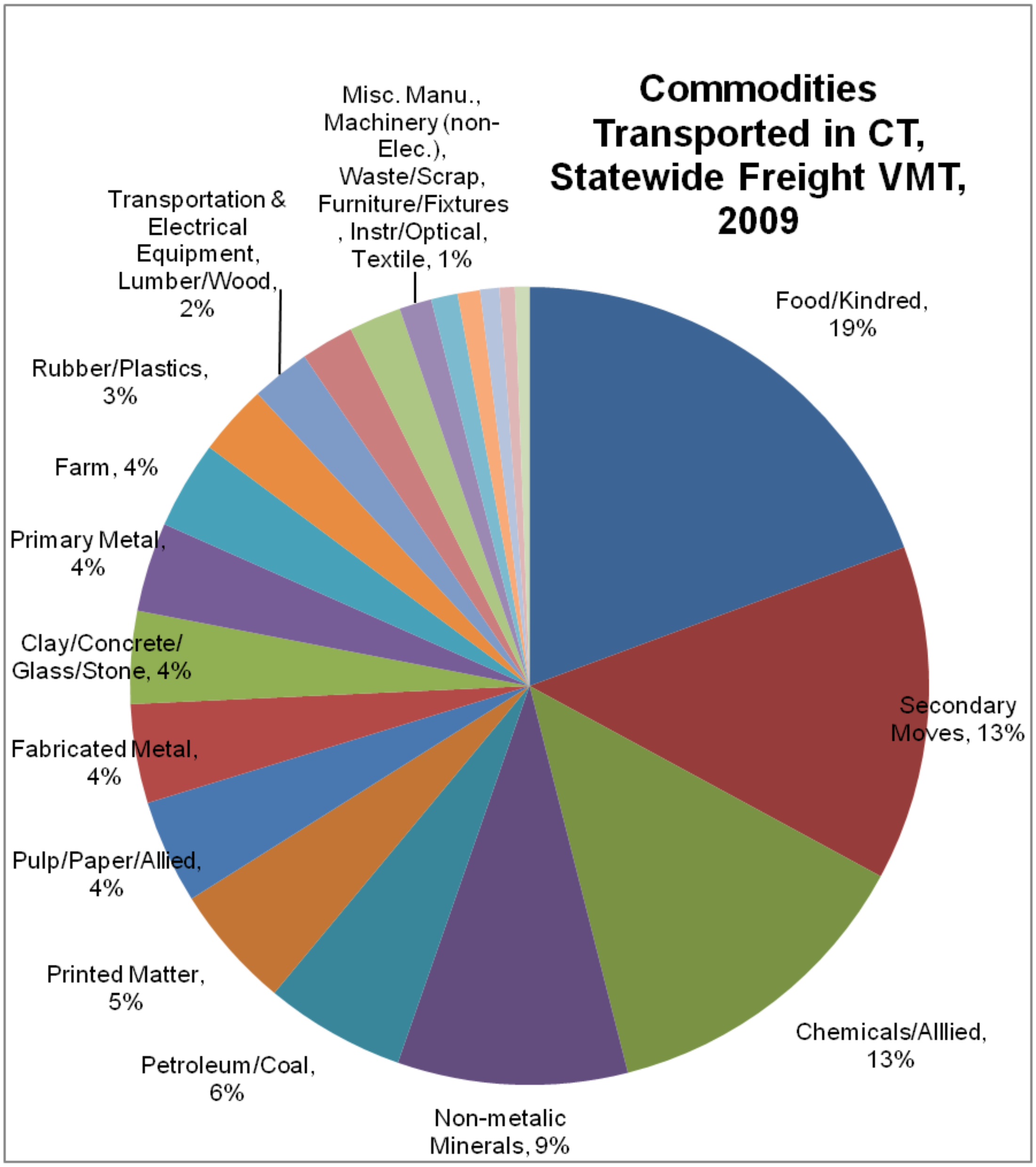
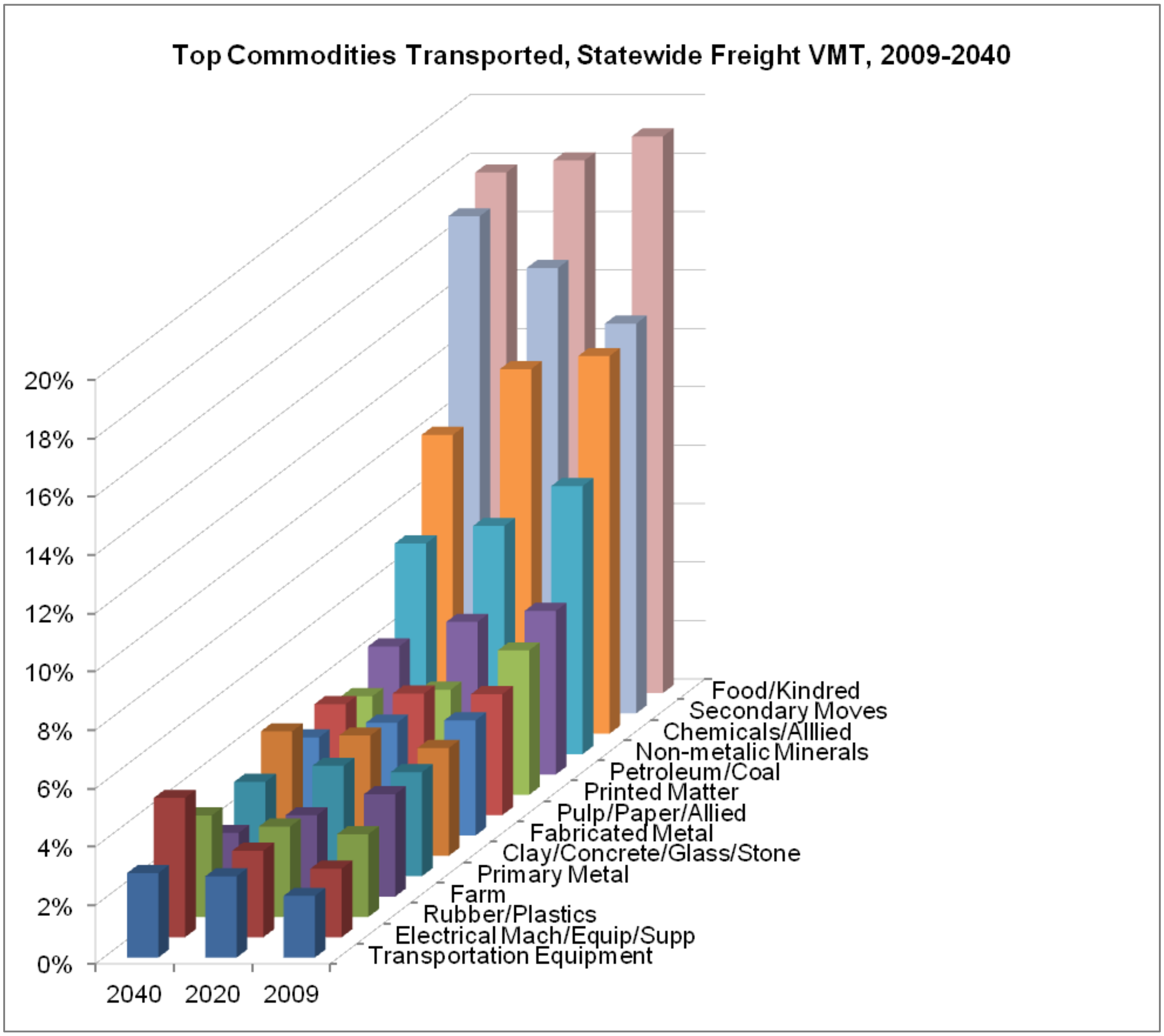

Commodities Transported in CT, Statewide Freight VMT, 2009
Misc. Manu., Machinery (non-Elec.), Waste/Scrap, Furniture/Fixtures, Instr/Optical, Textile, 1%
Transportation & Electrical Equipment, Lumber/Wood, 2%
Rubber/Plastics, 3%
Farm, 4%
Primary Metal, 4%
Clay/Concrete/Glass/Stone, 4%
Fabricated Metal, 4%
Pulp/Paper/Allied, 4%
Printed Matter, 5%
Petroleum/Coal, 6%
Non-metalic Minerals, 9%
Chemicals/Alllied, 13%
Secondary Moves, 13%
Food/Kindred, 19%

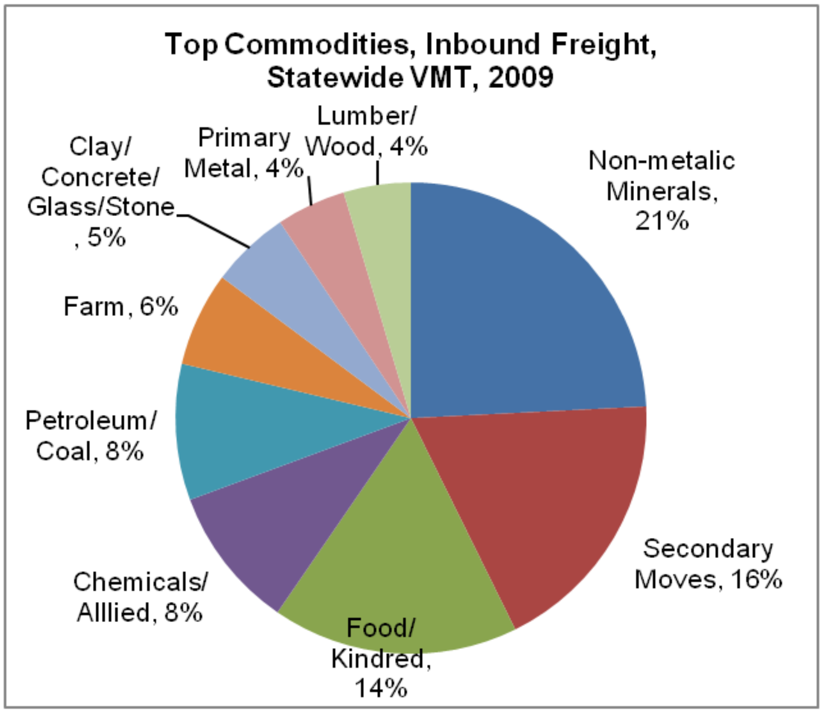
Figure 7



INBOUND FREIGHT

Inbound freight accounts for 25% of the freight-related VMT in Connecticut. In 2009, the commodities most transported inbound are non-metallic minerals, secondary moves, and food products with 21%, 16%, and 14% of the state VMT total, respectively. Following these three commodities, which account for half of the total inbound freight, four additional commodities range between 5 to 8%: chemicals/allied materials, petroleum/coal, farm goods, and clay/concrete/glass/stone. The remaining 26 commodities account for less than 5% of the total VMT, including 16 commodities that account for less than 1% of the total. Figure 8 represents the top commodities classified in inbound freight.

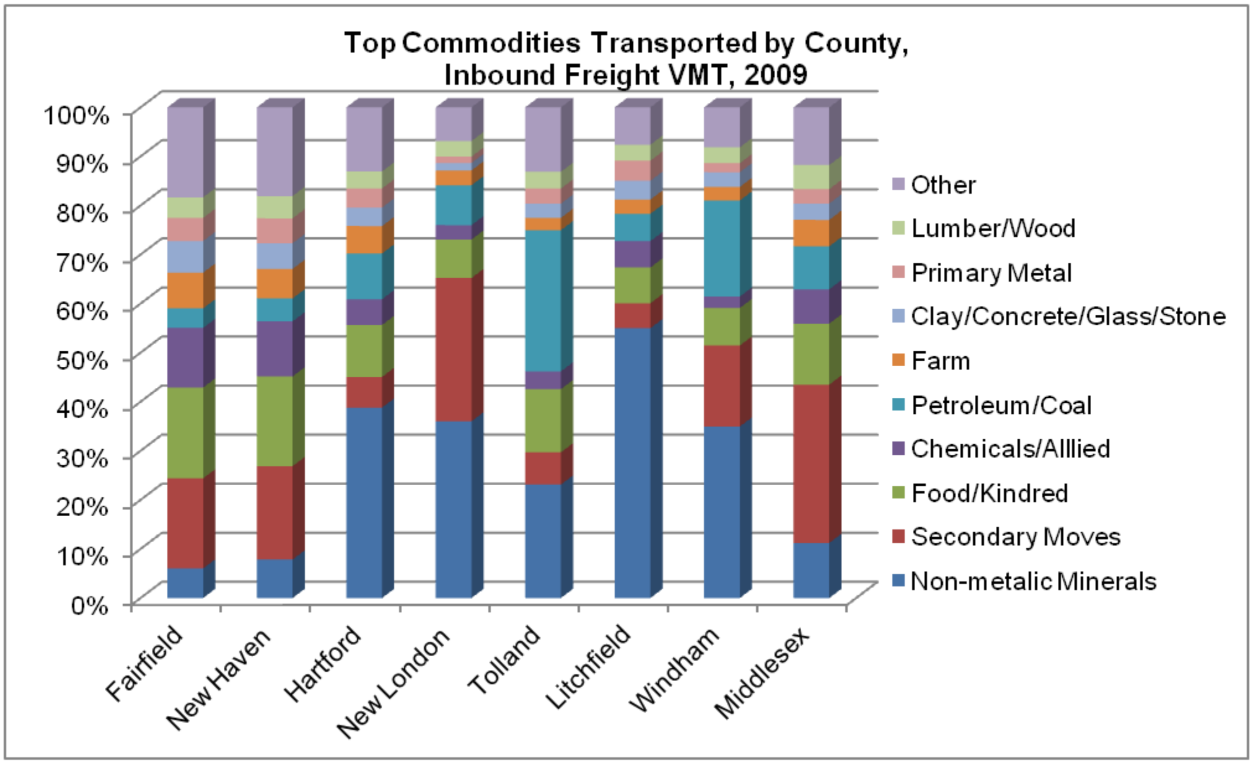
Figure 8



73% of Connecticut's total inbound VMT occurs in Fairfield, New Haven, and Hartford counties. Fairfield and New Haven counties have less transport of non-metallic minerals compared to the state, with 6% and 8%, respectively. These counties have a greater transport of secondary moves and food products ranging between 18% and 19%. Movement of non-metallic minerals is dominant in both Hartford and New London counties, with 39% and 36%, respectively. Much of the activity in this category is related to construction activity (buildings, roads, etc.) since it includes sand and gravel, so the higher percentages in those counties could reflect higher than average construction activity. Secondary moves comprise 29% of freight in New London County. In Tolland County, petroleum/coal accounts for 29% of the VMT. Figure 9 presents the share of the top commodities across all counties.

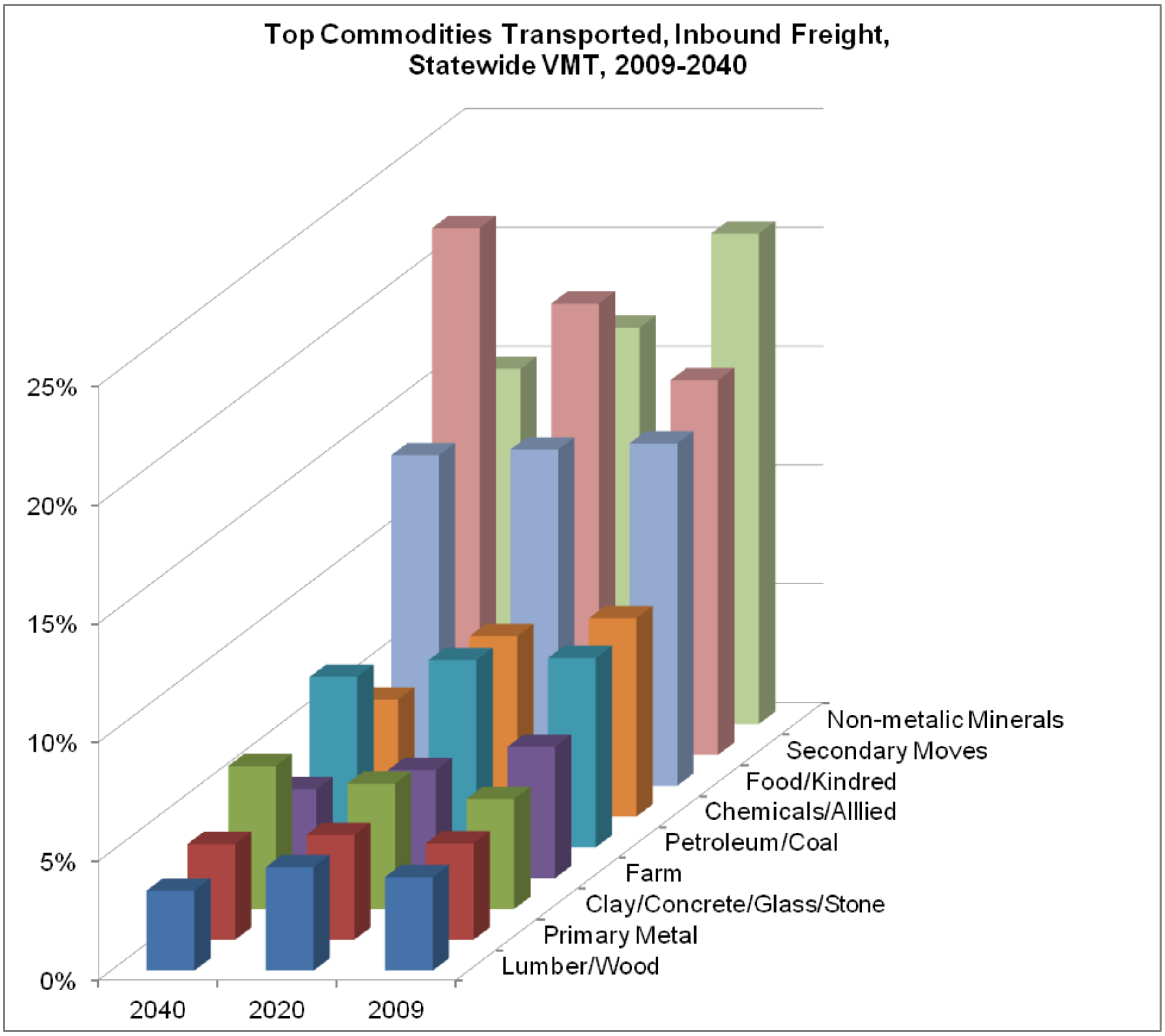
Note: In the following chart and others presenting top commodities transported by county, the "Other" category is included so that each county's data totals to 100%. "Other" is comprised of all remaining commodities.

Figure 9



When reviewing the predicted trends in Connecticut inbound freight transport for 2020 and 2040 (depicted in Figure 10), the same commodities appear with the largest percentages, but vary in their order and growth. Inbound freight of non-metallic minerals, which holds the largest share in 2009 at the state levels, only achieves a nominal 1% growth by 2020. VMT associated with non-metallic minerals increases by 19% between 2020 and 2040, but does not keep pace with other commodities, losing share from 21% in 2009 to 17% in 2020 and 15% in 2040. VMT associated with secondary moves is projected to grow faster than other categories with a 50% growth rate between 2009 and 2040. Accordingly, share of VMT for secondary moves increases to 19% in 2020 and 22% in 2040. Among other top commodities in 2009, the share for food products and petroleum/coal remains about the same in the future. The share for chemicals/allied materials stays about the same through 2020, but then drops for 2040.

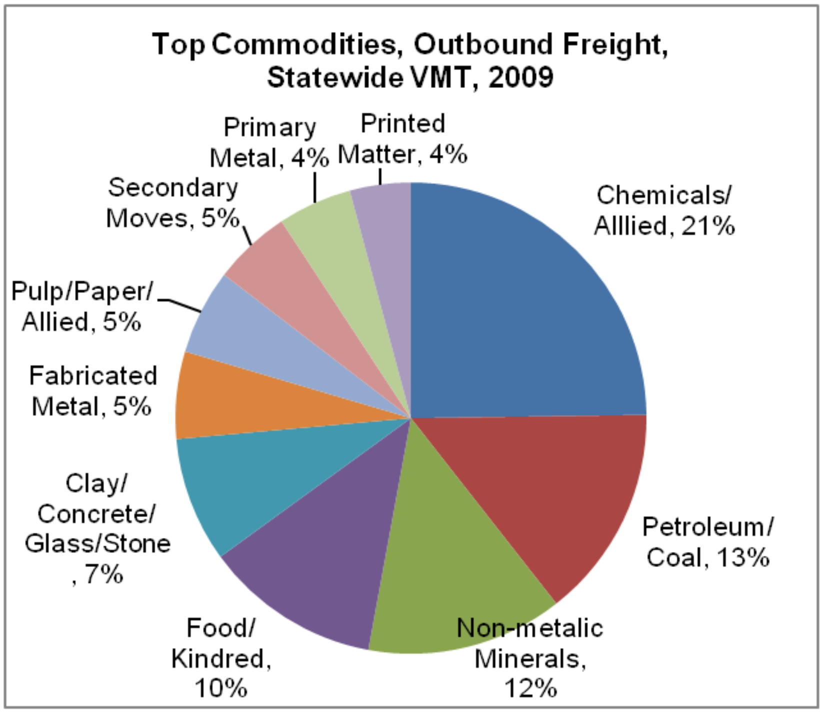
Figure 10



OUTBOUND FREIGHT

Outbound freight accounts for 15% of the freight-related VMT in Connecticut. Among outbound freight in Connecticut in 2009, the most transported commodity is chemicals/allied materials, comprising 21% of the state's total outbound freight. Petroleum/coal, non-metallic minerals and food products followed with 13%, 12% and 10% of the VMT total, respectively. Clay/concrete/glass/stone, fabricated metal, pulp/paper/allied materials, and secondary moves have percentage shares ranging between 5 to 7%. Among the remaining 25 commodities, which total 21% of the state's VMT total, 13 have percentages less than 1%. Top commodities in outbound freight are represented in Figure 11.

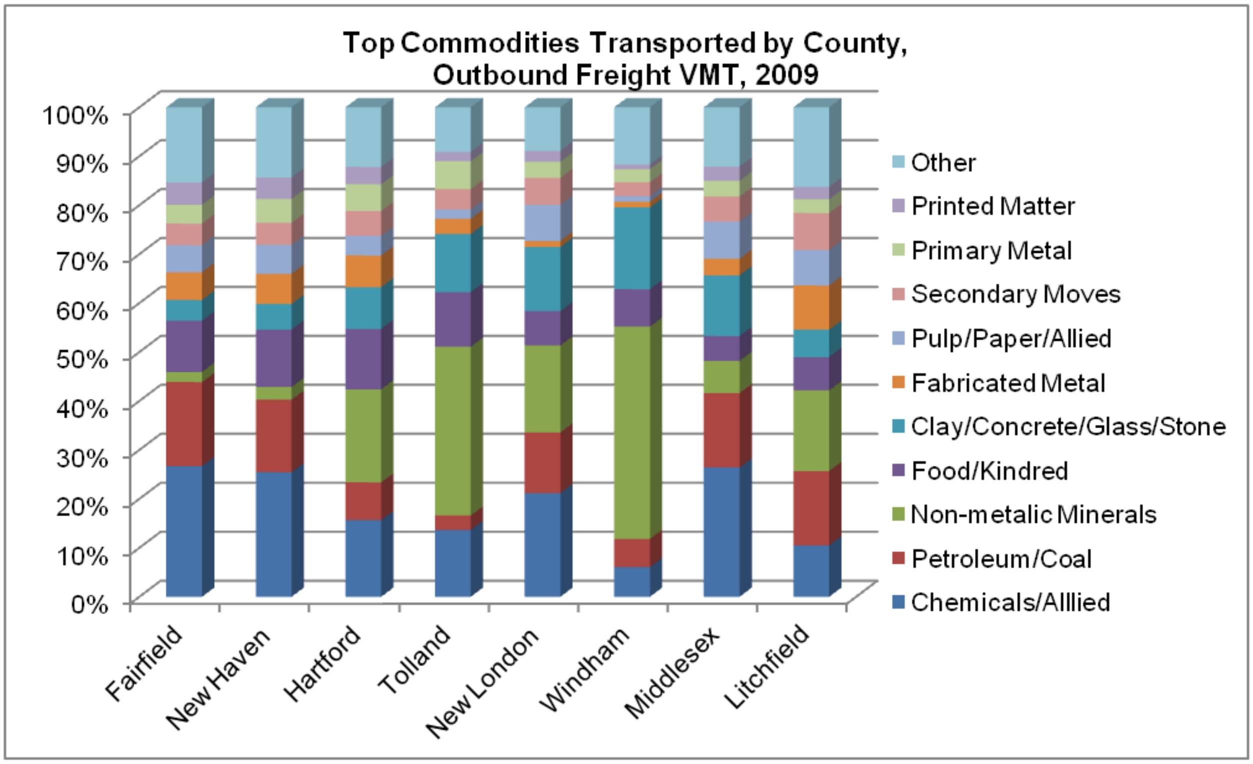
Figure 11



As with inbound freight, 73% of outbound freight in Connecticut is contained in three counties: Fairfield, New Haven, and Hartford counties. In Fairfield and New Haven counties, transport of chemicals/allied materials has the largest share, with 27% and 25% of total outbound VMT, respectively. In Hartford, Tolland, Windham, and Litchfield counties, non-metallic minerals have the largest share. Hartford, Tolland and Windham counties have 19%, 35% and 43%, respectively, of outbound freight for non-metallic minerals. Additionally, a greater share of the outbound VMT in the larger counties is due to transport of food products. County outbound freight is presented in Figure 12.

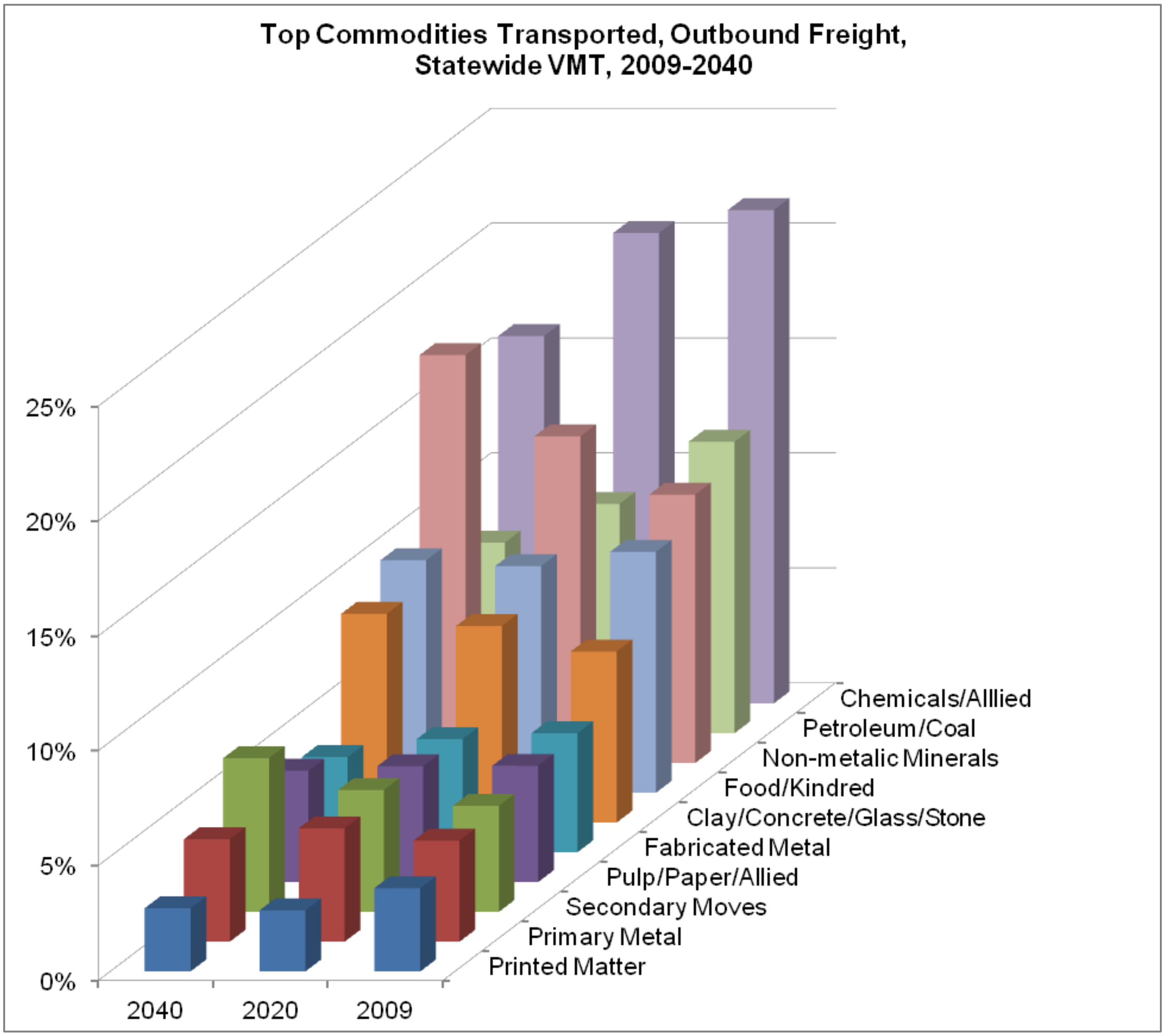
Chemicals/allied materials will maintain growth in outbound VMT to 2020, holding the largest share of the State's total with 20%. But, between 2020 and 2040, transportation of this commodity is estimated by modeling to have 0% growth, reducing its percentage share to 16%. With consistent 61% growth from 2009 to 2040, outbound VMT of non-metallic minerals assumes the largest share. Increasing from 12% of the state total in 2009, non-metallic minerals will account for 14% in 2020 and 18% of the outbound VMT in 2040. Among other commodities, petroleum/coal lags behind the overall growth trend, falling 5% points to 8% of total outbound VMT by 2040. VMT associated with food products maintains a 10% share of the total outbound VMT from 2009 through 2040. Figure 13 shows forecasts for outbound freight.

Figure 12



Top Commodities Transported by County, Outbound Freight VMT, 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fairfield
New Haven
Hartford
Tolland
New London
Windham
Middlesex
Litchfield
Other
Printed Matter
Primary Metal
Secondary Moves
Pulp/Paper/Allied
Fabricated Metal
Clay/Concrete/Glass/Stone
Food/Kindred
Non-metalic Minerals
Petroleum/Coal
Chemicals/Alllied

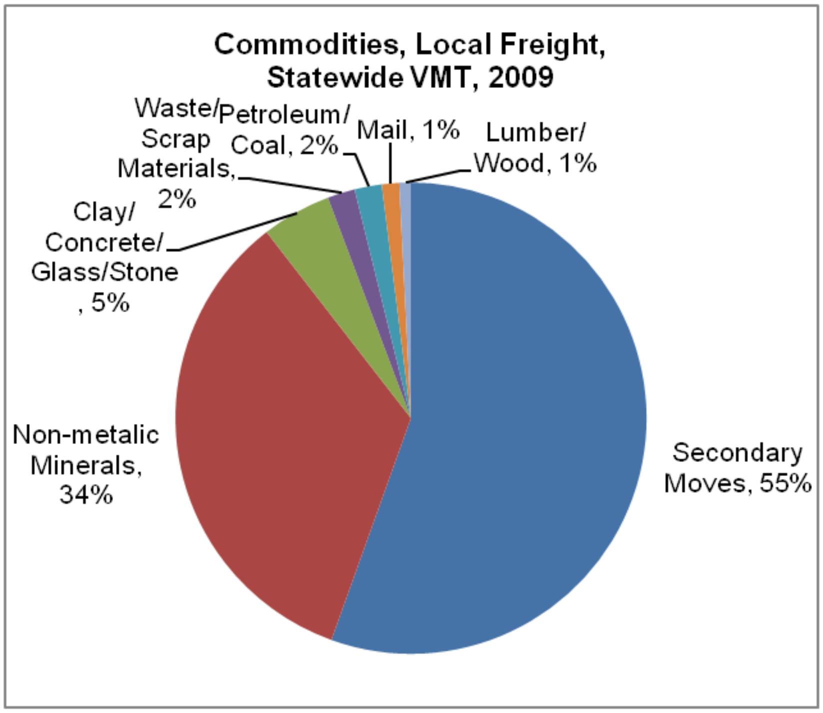
Figure 13



LOCAL FREIGHT

Local freight accounts for 6% of the freight-related VMT in Connecticut. In 2009, secondary moves, which often describe transportation of goods before or after a rail or air transfer, comprise 55% of local VMT in Connecticut. Non-metallic minerals make up 34% of the 2009 state total. Though significantly less, clay/concrete/glass/stone account for 5% of total local VMT. Of the remaining 30 commodities, 26 commodity classes represent less than 1% of the local VMT total. Indicated by the dominance of secondary moves and non-metallic minerals and the absence of most commodities, local transport lacks the diversity of other freight types. Shares of all local freight commodities are presented in Figure 14.

Figure 14



Four counties, with New London joining Fairfield, New Haven, and Hartford counties with the largest shares, represent 82% of all Connecticut's local freight. Though the top two commodities on a state level continue to lead, counties with the largest shares of local freight have a greater presence of secondary moves than non-metallic minerals. On average, secondary moves account for 61% of local VMT in large counties, while non-metallic minerals have 28%. Small counties display the opposite, with 29% for secondary moves and 56% for non-metallic minerals. See Figure 15 for a full breakdown of local freight on the county level.

Between 2009 and 2040, secondary moves will increase its majority share of Connecticut's local VMT total. Outpacing other commodities, secondary moves is projected to grow to 64% of total in 2020 and 69% in 2040. Though maintaining a large percentage of local VMT, non-metallic minerals lags behind the growth trend, with 1% growth to 2020 and 18% growth to 2040. As a result, non-metallic minerals, with 34% of VMT total in 2009, decreases to 26% in 2020 and 22% in 2040. Clay/concrete/glass/stone, which holds 5% share in 2009, stays consistent with growth to 2040. Figure 16 shows predictive trends for locally transported freight.

Figure 15

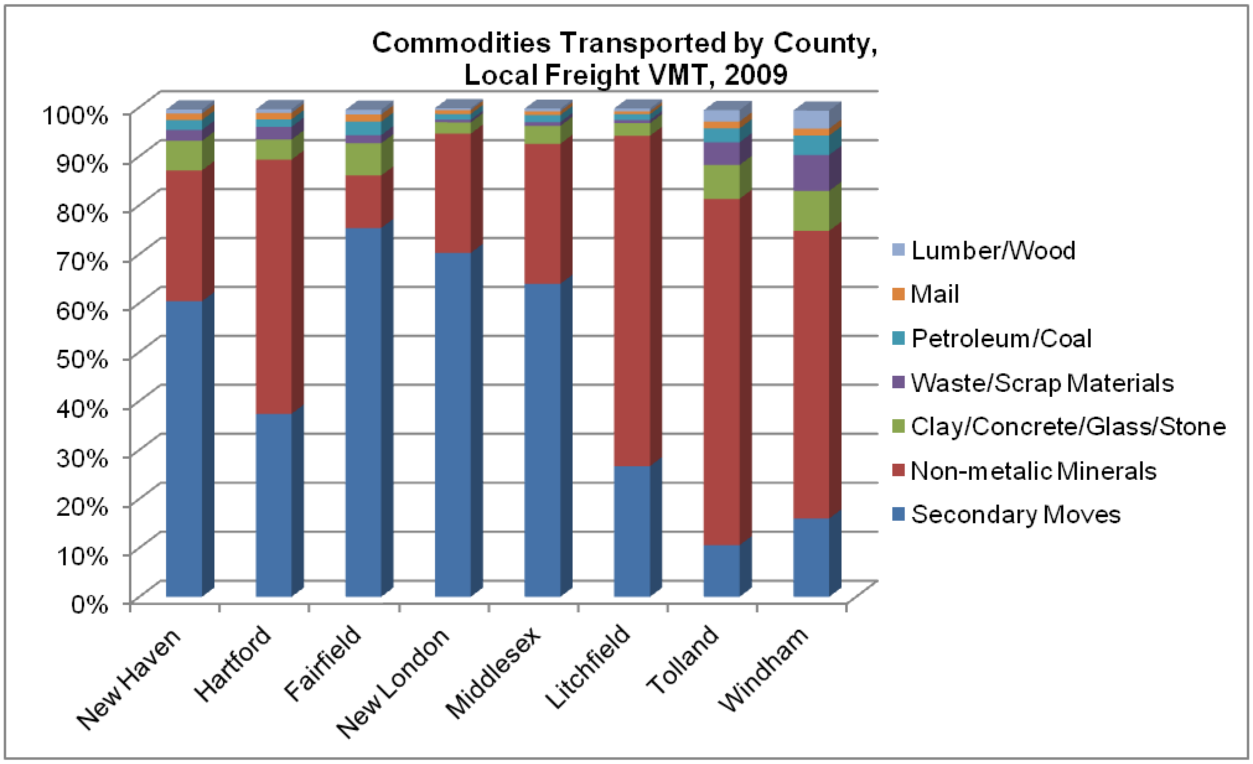
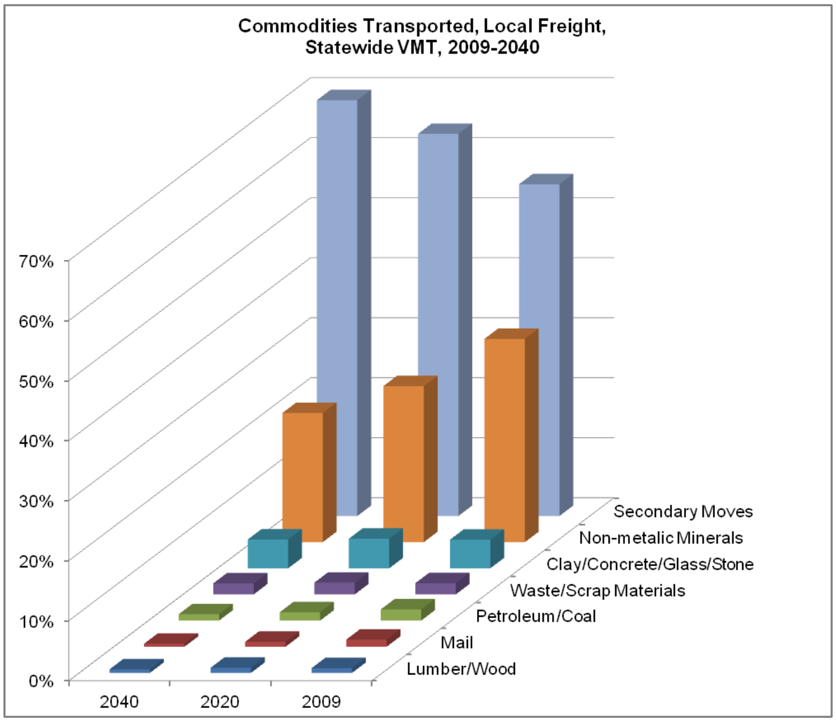

Commodities Transported by County,
Local Freight VMT, 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
New Haven
Hartford
Fairfield
New London
Middlesex
Litchfield
Tolland
Windham
Lumber/Wood
Mail
Petroleum/Coal
Waste/Scrap Materials
Clay/Concrete/Glass/Stone
Non-metalic Minerals
Secondary Moves

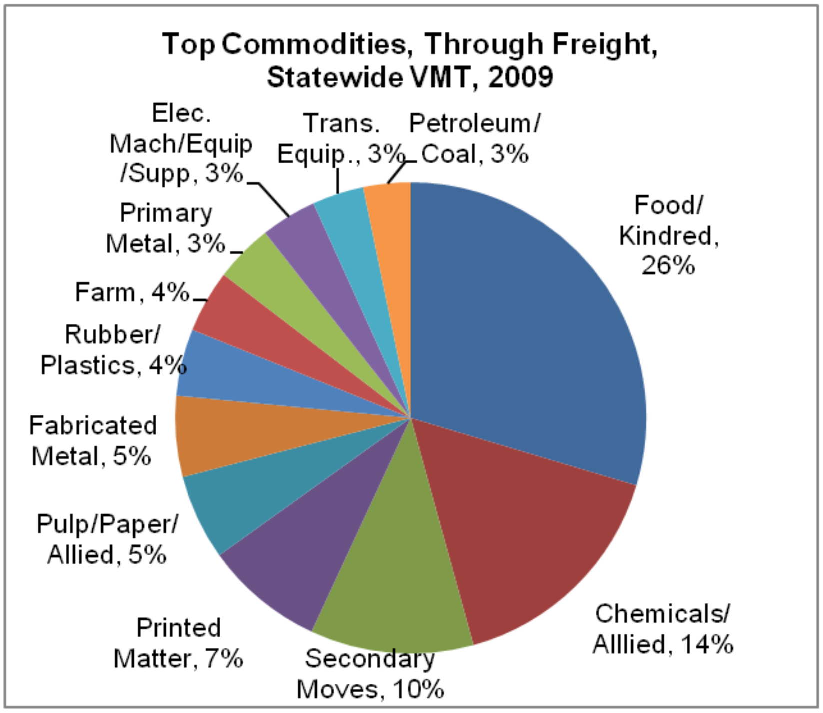
Figure 16



THROUGH FREIGHT

Through freight accounts for 53% of the freight-related VMT in Connecticut. In other states, an average of 25% of total tonnage is through freight. The higher value for Connecticut makes sense due to its size and location. As presented in Figure 17, 26% of through freight in Connecticut in 2009 is transported food products. Chemicals/allied materials and secondary moves account for significant shares of through freight, with 14% and 10% of VMT, respectively. Contributing an additional 17% cumulatively, a group of three commodities comprise between 5-7% of the state through freight total: printed matter, pulp/paper/allied materials, fabricated metal. The remaining 27 commodities total a third of all through freight VMT in Connecticut. With 12 of these commodities accounting for less than 1%, through freight carries a more diverse group of commodities than other types of transport.

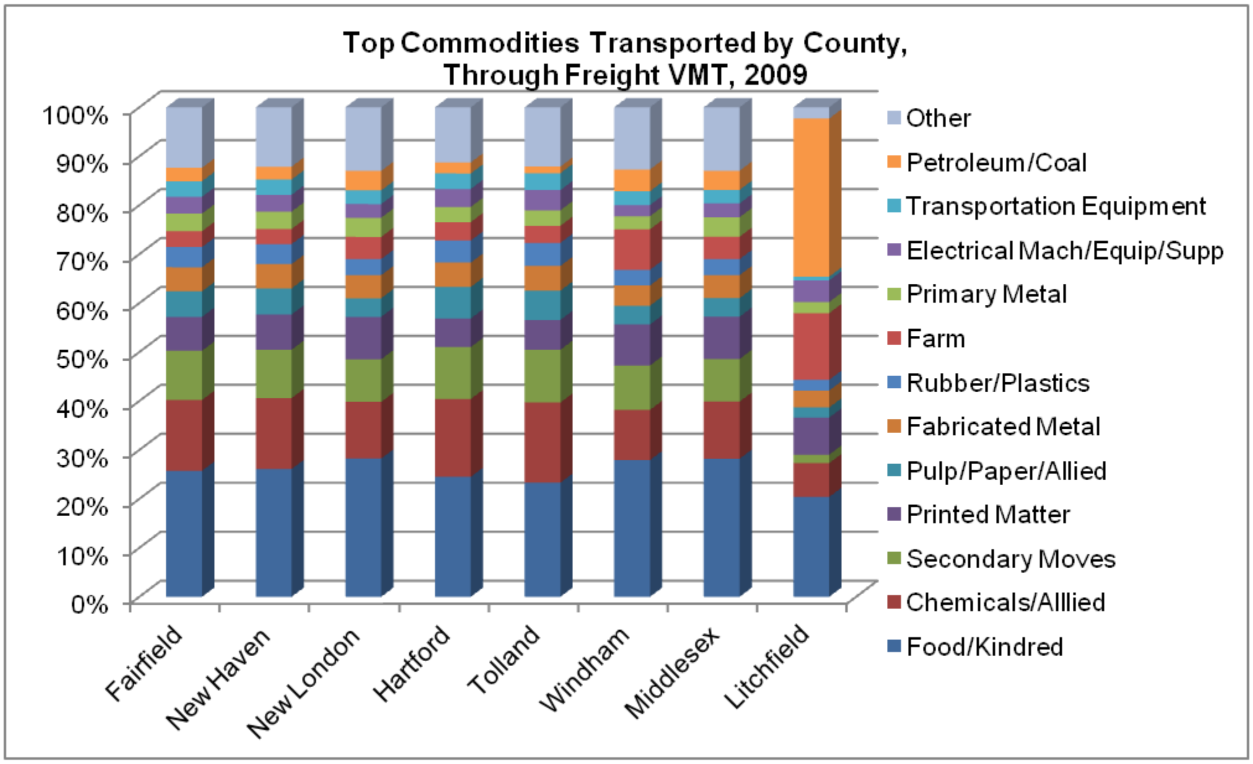
Figure 17



New London, Fairfield, New Haven, and Hartford counties account for 80% of Connecticut's total VMT for through freight. The percentage shares of top commodities vary minimally across the counties (see Figure 18 for through freight within each county). Litchfield County, which holds the smallest share of through freight, stands out with 32% of transport for petroleum/coal and 14% for farm products.

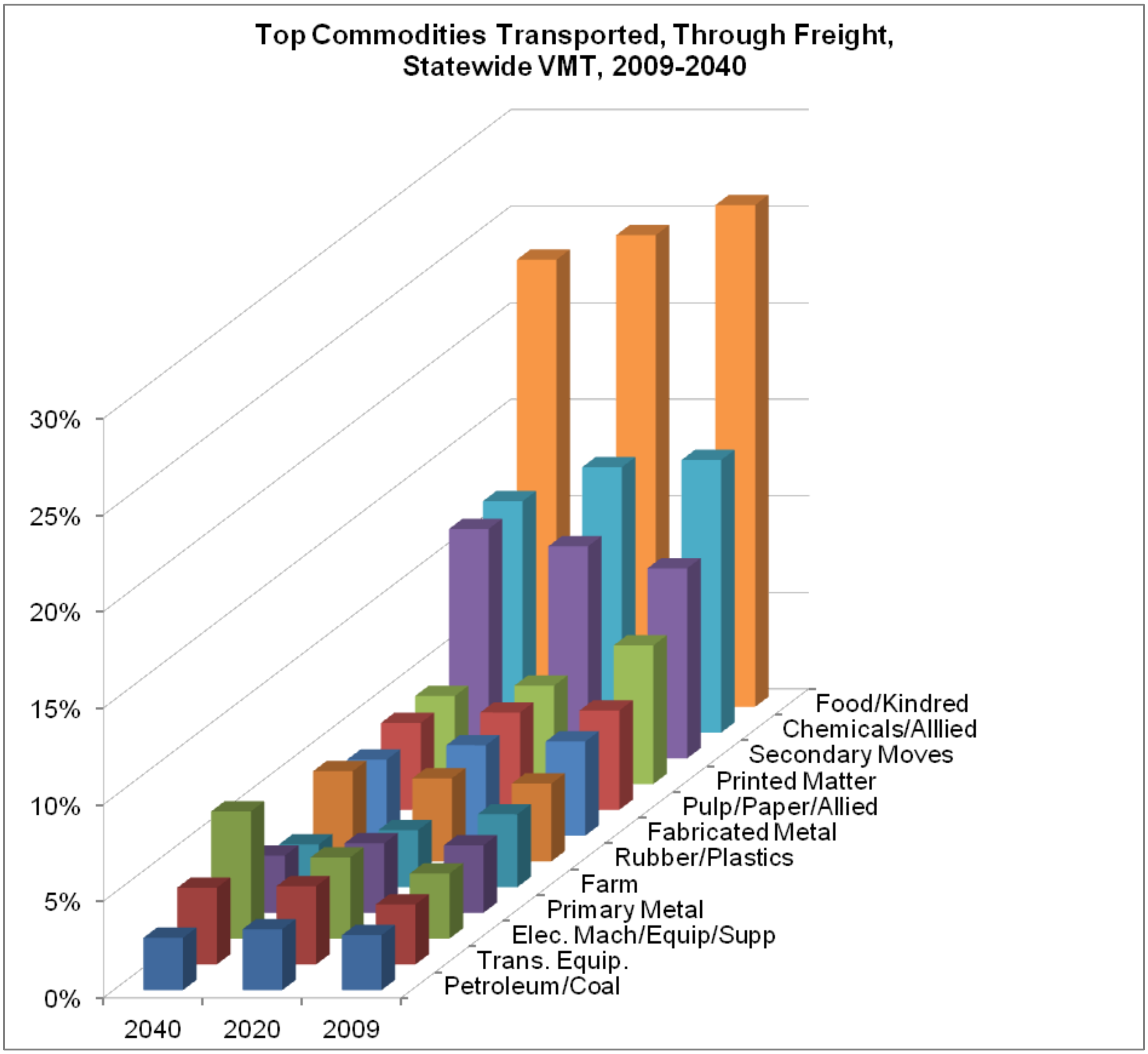
Food products, chemicals/allied materials and secondary moves maintain the largest shares of Connecticut's through freight VMT through 2040. Food products stay steady with the overall pace, with 24% share in 2020 and 23% in 2040 of the through freight. The difference in VMT between chemicals/allied materials and secondary moves narrows slightly. From 14% for chemicals/allied materials and 10% for secondary moves in 2009, the two commodities equally represent 12% of the state's through freight VMT by 2040. Though less significant when compared to the major commodities, printed matter slightly decreases in share of through freight VMT from 7% in 2009 to 5% in 2020. Figure 19 presents through freight trends through 2040.

Figure 18



Top Commodities Transported by County, Through Freight VMT, 2009
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fairfield
New Haven
New London
Hartford
Tolland
Windham
Middlesex
Litchfield
Other
Petroleum/Coal
Transportation Equipment
Electrical Mach/Equip/Supp
Primary Metal
Farm
Rubber/Plastics
Fabricated Metal
Pulp/Paper/Allied
Printed Matter
Secondary Moves
Chemicals/Alllied
Food/Kindred

Figure 19



CONCLUSIONS

A wide variety of commodities are transported in Connecticut. No single commodity class dominates freight movement, so control measures must apply to all trucks in general. In addition, over 90% of the freight falls into the categories of inbound, outbound, and through freight. As a result, regional coordination with other northeast states may enhance the emissions benefits from any control measures that may be proposed in the future strategy.

APPENDIX A.1: GLOSSARY OF TERMS

TERM	DEFINITION
Inbound Freight	Traffic from external origin to internal destination
Local Freight	Traffic with an internal/intrastate origin and destination
Outbound Freight	Traffic from internal origin to external destination
Secondary Moves	Movement of unknown commodities. A majority of the freight in this category is associated with distribution centers and warehousing. Also includes the drayage portion of a rail or air move.
Standard Transportation Commodity Codes (STCC)	Set of codes used to categorize commodities transported. Allows for comparability to STB Waybill data as well as other international codes.
Through Freight	Traffic travelling through the state; external origin and destination

APPENDIX A.2: TABLE OF STANDARD TRANSPORTATION COMMODITY CODES (STCC)

#	COMMODITY	EXAMPLE GOODS
01	**Farm**	Cotton, grain, field seeds, fruits, vegetables, livestock
08	**Forest**	Crude barks or gums
09	**Fish/Marine**	Fresh fish or whale products
10	**Metallic Ores**	Iron ores, lead and zinc ores combined, bauxite
11	**Coal**	Anthracite, bituminous coal
13	**Crude Petroleum/Natural Gas**	Crude petroleum
14	**Non-metallic Minerals**	Stone, gravel, sand, clay ceramic
19	**Ordinance/Accessories**	Guns, ammunition, small arms
20	**Food/Kindred**	Meat, poultry, butter, cheese, canned products, pet food, alcohol beverages
21	**Tobacco**	Cigarettes, cigars, chewing tobacco
22	**Textile Mill**	Cotton, silk, and wool fabrics, woven carpets, yarn
23	**Apparel**	Clothing, fur goods, gloves, belts, curtains
24	**Lumber/Wood**	Primary forest materials, lumber, millwork, cabinetwork
25	**Furniture/Fixtures**	Tables, sofas, office furniture
26	**Pulp/Paper/Allied**	Paper, pulp mill products, envelopes, wallpaper, sanitary paper products
27	**Printed Matter**	Newspaper, periodicals, books, greeting cards
28	**Chemicals/Allied**	Potassium and sodium compounds, industrial gases, crude products of coal/gas/petroleum, drugs, paints
29	**Petroleum/Coal**	Petroleum refining products, liquefied gases, coal and petroleum, asphalt products
30	**Rubber/Plastics**	Tires, rubber footwear, plastic hose and belting
31	**Leather**	Finished or tanned leather

32	**Clay/Concrete/Glass/Stone**	Flat glass, glass containers, clay tile, household china items, ready-mix concrete (wet)
33	**Primary Metal**	Primary iron or steel products, copper smelter products, castings, forgings
34	**Fabricated Metal**	Metal cans, cutlery (non-electrical), saws, plumbing fixtures, sheet metal products
35	**Machinery Excluding Electrical**	Steam engines, farm machinery, oil field machinery, scales
36	**Electrical Machinery/ Equipment/Supplies**	Transformers, motors/generators, household appliances, radios, televisions, batteries
37	**Transportation Equipment**	Motor vehicles, aircraft, ships/boats
38	**Instruments/Optical/ Watches/Clocks**	Scientific equipment, medical equipment, photographic supplies
39	**Miscellaneous Manufacturing**	Jewelry, sporting goods, signs and advertising displays, games and toys
40	**Waste/Scrap Materials**	Metal and textile scraps, chemical waste
41	**Miscellaneous Shipping**	Miscellaneous freight shipments
42	**Shipping Containers**	Shipping containers, semi-trailers returned empty
43	**Mail**	Mail and express traffic
50	**Secondary Moves**	Intermodal transport (rail to ramp/truck), air freight to/from airport

APPENDIX B: EMISSIONS INVENTORY ASSOCIATED WITH FREIGHT MOVEMENT

de la Torre Klausmeier Consulting, Inc.

Cambridge Systematics

Eastern Research Group

This appendix documents the results of the task to develop an emissions inventory for freight movement activities. Emissions totals associated with freight movement in Connecticut were estimated for on-road trucks, rail, and marine sources for 2009, 2020 and 2040. EPA's Motor Vehicle Emission Simulator, MOVES2010a, was used to calculate emission rates for trucks in grams per mile traveled. The TRANSEARCH database was analyzed to determine vehicle miles traveled (VMT) for trucks used to transport freight. Table 1 shows the MOVES source types that correspond to freight vehicles used in this analysis. Emission estimates for Rail and Marine activities were estimated by applying EPA emission factors to activity factors that were derived from TRANSEARCH and other data sources.

Table 1. MOVES Source Types Associated with Freight Movement

MOVES Source Type ID	Source Type Name
32	Light Commercial Truck (e.g., panel trucks, walk-in vans)
52	Single Unit Short-haul Truck (e.g., delivery "box" trucks)
53	Single Unit Long-haul Truck
61	Combination Short-haul Truck
62	Combination Long-haul Truck (e.g., tractor-trailers, tankers, etc.)

Statewide tons per year totals for 2009, 2020, and 2040 are presented in Table 2. On-road trucks account for almost all the emissions associated from freight movement activities. Looking to 2020 and 2040, NOx and $PM_{2.5}$ emissions drop dramatically. Across all modes, CO_2 emissions increase from 2009 to 2040. County-level emissions totals are presented in subsequent sections.

Table 2. Statewide Freight Emissions by Mode – 2009-2040 (Tons/Year)

Type	NOx	PM2.5	VOC	CO	CO2
2009					
On-Road	14,635	539	1,322	8,734	1,729,027
Rail	173	4	11	23	8,605
Marine	638	38	33	82	50,175
Total	15,446	581	1,366	8,839	1,787,807
2020					
On-Road	7,069	113	731	6,644	2,292,949
Rail	141	3	7	26	9,682
Marine	492	12	18	87	55,938
Total	7,701	129	757	6,757	2,358,568
2040					
On-Road	8,058	53	809	8,450	2,808,804
Rail	56	1	3	33	12,425
Marine	263	11	19	82	59,520
Total	8,376	65	830	8,566	2,880,749

ESTIMATING ON-ROAD EMISSIONS

Overall Methodology

Total on-road emissions were calculated by multiplying estimated emissions in grams per mile by vehicle miles traveled (VMT) estimates. Grams per mile estimates were derived from MOVES mass emissions outputs using the Connecticut-specific inputs as described below. Eastern Research Group (ERG) calculated grams per mile emission rates by running MOVES2010a in "emissions inventory" mode to generate emissions and dividing those totals by the corresponding MOVES VMT activity outputs. Actual VMT estimates were generated by multiplying TRANSEARCH miles by the resulting MOVES based emission factors.

Vehicle Miles Traveled

To develop Vehicle Miles Traveled (VMT), Cambridge Systematics (CS) utilized a TRANSEARCH dataset for the year 2009 furnished to the Connecticut Department of Transportation by IHS-Global Insight. Using a combination of actual data and modeled behavior, TRANSEARCH provides aggregated annual volume summaries on a historical and forecast basis by origin-destination geography, mode, and commodity. In the case of Connecticut's dataset, geography was provided at the county level for Connecticut and adjacent states, with flows broken down by commodity type (Standard Transportation Commodity Code - STCC4) measured in tons and value, for truck, air and water modes.

Truck flows were then assigned to the Federal Highway Administration (FHWA) Freight Analysis Framework (FAF) highway network to estimate weekday truck VMT by Connecticut county, road type, commodity type and traffic direction (i.e., inbound, outbound, intrastate and through), for the base and forecast years. Weekday truck volumes were estimated to be 1/295th of the annual volume totals, which accounts for lower weekend and holiday traffic[1]. The number of truck units was calculated by dividing tonnages reported in TRANSEARCH by 18 tons/unit, the typical tonnage handled by a tractor-trailer combination vehicle. The daily truck count estimates were then compared to truck counts provided by CTDOT for validation. The truck count estimates from TRANSEARCH were about 43 percent of the CTDOT truck counts on average. This is to be expected since TRANSEARCH includes primarily long-distance freight truck traffic, rather than all truck traffic.

dKC further processed the data and delivered summarized tables to ERG for inclusion in the MOVES emissions inventory modeling runs. dKC prepared summary spreadsheets with the following information: VMT by STCC (commodity class), by road type and by county. Four spreadsheets were developed; one for each type of freight movement: in-bound (to Connecticut), outbound (from Connecticut), through, and intrastate.

ERG then utilized the daily VMT summarized by county, road types, and trip pattern assignments (local, inbound, outbound, and through) for 2009, 2020, and 2040. This appendix only addresses activity and emissions in 2009. For the emissions inventory, truck VMT needed to be assigned to single-unit and

[1] This factor results in weekend freight movement being 33% of weekday freight movement on a daily average basis.

combination truck classes (i.e., MOVES classes 51, 52, 61, and 62). With TRANSEARCH'S primary focus being on intercity traffic, TRANSEARCH truck VMT was assigned to all truck classes on rural highways, but only to combination truck VMT on urban highways. This is because most truck shipments included in TRANSEARCH are longer-distance moves, which primarily includes movement outside urban areas, as well as combination trucks moving in and out of urban areas.

Intrastate (local) VMT was assigned to combination short haul trucks (MOVES source type 61). VMT for inbound, outbound, and through trucks were summed and assigned to combination long haul trucks (MOVES source type 62). The daily VMT in the TRANSEARCH data was annualized by multiplying by 295, and then allocated across all road types by county and source type for combination trucks (source types 61 and 62).[2]

Estimating VMT for single-unit freight trucks required three additional data sources:

1. FHWA's Highway Performance Monitoring System (HPMS) data, which includes statewide VMT by vehicle type and roadway type. HPMS data were obtained for 2008 to provide a breakout of annual single-unit and combination truck VMT by roadway type (rural vs. urban, freeway vs. principal arterial vs. other).

2. MCS-150 reporting data, which was obtained for December 2009 from Performance and Registration Information Systems Management (PRISM) Office of the Federal Motor Carrier Safety Administration at the Volpe Center in Cambridge, MA. MCS-150 is an annual identification report required from all motor carriers to obtain a USDOT registration number.[3] This dataset was used to estimate the fraction of truck VMT that is attributable to freight trucks as well as non-freight trucks (such as construction and utility trucks), since both are included in the HPMS data. MCS-150 has self-reported data by motor carrier operators that includes the types of cargo carried, total number of vehicles by type (single-unit truck vs. tractors), and total fleet mileage. Many carriers reported multiple cargo types, some freight and some non-freight, making it uncertain what fraction of their mileage was for freight vs. non-freight travel.[4] Considering this uncertainty, it was estimated that between 30 and 68 percent (average 49 percent) of single-unit heavy-duty vehicle VMT was attributable to freight movement, and between 39 and 49 percent (average 44 percent) of combination heavy-duty vehicle VMT was attributable to freight movement, with the remainder for non-freight purposes[5].

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[2] Because VMT is imported into MOVES at the HPMS vehicle type level, in order to maintain the disaggregated VMT between combination short haul and combination long haul trucks, it was necessary perform separate modeling runs for these source types.

[3] Truck movement in registered fleets (i.e., a company's own fleet such as Staples delivery trucks) and movement by through trucks not registered in Connecticut is not included in the MCS-150 reporting data for Connecticut carriers.

[4] The MCS-150 cargo types identified as "non-freight" included driveaway/towaway, mobile homes, garbage/refuse/trash, US mail, utility, construction, water well, and "other." Passenger-carrying vehicles were excluded from both the freight and non-freight categories.

[5] The uncertainty is a result of many carriers reporting multiple cargo types, some freight and some non-freight. The percentage for individual carriers could not be determined from the MCS-150 report. The lower end of the

3. The 2002 Vehicle Inventory and Use Survey (VIUS), which obtained survey responses to characterize the physical and operational characteristics of the nation's private and commercial truck population. The survey was conducted as part of the U.S. Economic Census. The VIUS data was used to estimate the fraction of VMT split between gasoline and diesel freight trucks, by MOVES source type. Based on national level averages, diesel fuel was used for the following percentages of VMT for each MOVES source type of interest: 31% for light commercial trucks, 82% for single unit short haul, 66% for single unit long haul, and 100% for both short and long haul combination trucks. VIUS data was also used to estimate total VMT for light commercial trucks, as described below.

Single-unit freight truck VMT for the urban roadway classes (i.e., the subset of freight VMT assumed to be excluded from the TRANSEARCH data) was estimated by multiplying single-unit truck VMT (by class) from the HPMS data by 49 percent. The end result estimated that single-unit trucks accounted for 36 percent of total freight truck VMT, and the TRANSEARCH VMT were increased by this amount.

The calculated VMT for single unit trucks was further allocated between HPMS vehicle types “Other 2 axle-4 tire vehicles” (30) and single unit trucks (50) to account for the split of freight vehicles between single unit trucks (MOVES source types 52 and 53) and light commercial trucks (MOVES source type 32). The associated allocation percentages were developed using VIUS data. VIUS has not been updated since 2002 and therefore this is the most recent dataset available that allows such an allocation to be developed. Several filters were first applied to the VIUS data set to isolate 2 axle single unit trucks (excluding tractor/trailers) that carry freight. The field "VIUS_GVW" was used to split the filtered data set into Class 3/4/5 (which are assumed to be 100% light commercial trucks in MOVES), and Class 6/7 (corresponding to single unit trucks in MOVES). This analysis found 48% of the single unit VMT was assigned to light commercial trucks (MOVES source type 32) and 52% of the single unit VMT was assigned to single unit trucks (MOVES source types 52 and 53).

An additional adjustment was made to redistribute the VMT among the single unit trucks. As per EPA definition, “short hauls” are trips of less than 200 miles, and long hauls are greater than 200 miles. ERG initially assigned TRANSEARCH “local” VMT to MOVES short haul source types, and inbound, outbound, and through VMT to MOVES long haul source types. However, given the highly dense geographic distribution of origin/destination points throughout the northeast, ERG allocated a fraction of the inbound and outbound VMT to short haul trips, based on a query of the TRANSEARCH VMT trip lengths – with 82% of inbound and 88% of outbound VMT reassigned the short haul designation. TRANSEARCH through trips were not reallocated, and assumed to be 100% long haul.

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estimate (30% of single-unit truck VMT for freight) assumes that all carriers operating SU trucks and carrying both freight and non-freight cargo carried 100% non-freight cargo. The high end of the estimate (68% of single-unit truck VMT for freight) assumes that all carriers operating single-unit trucks carrying both freight and non-freight cargo carried 100% freight cargo. Clearly neither the lower bound nor the upper bound are reasonable and the true amount must lie somewhere between the two values.

Monthly, Daily, and Hourly VMT Fractions

The monthly, daily, and hourly VMT fractions were provided by Connecticut DEEP. The 2009 base year uses the 2009 MOVES input files, while the 2020 and 2040 out years use the 2020 and 2050 MOVES input files provided by DEEP. 2050 data inputs from DEEP were used for the 2040 MOVES runs to align with the available Transearch data.

Road Type Distribution

The road type distribution for combination long-haul trucks and combination short-haul trucks, MOVES source types 62 and 61 respectively, are calculated based on TRANSEARCH VMT data. These TRANSEARCH road classifications are mapped to MOVES road types according to Table 3.

Table 2. TRANSEARCH to MOVES Road Type Assignments

TRANSEARCH FClass	TRANSEARCH FClass Definition	Moves Road Type ID	MOVES Road Type Description
0	Unclassified	5	Urban Unrestricted Access
1	Principal Arterial - Interstate (Rural)	2	Rural Restricted Access
2	Principal Arterial - Other (Rural)	3	Rural Unrestricted Access
5	Unclassified	5	Urban Unrestricted Access
6	Minor Arterial (Rural)	3	Rural Unrestricted Access
7	Major Collector (Rural)	3	Rural Unrestricted Access
8	Minor Collector (Rural)	3	Rural Unrestricted Access
9	Local (Rural)	3	Rural Unrestricted Access
11	Principal Arterial - Interstate (Urban)	2	Urban Restricted Access
12	Principal Arterial - Other Freeways & Expressways (Urban)	2	Urban Restricted Access
14	Principal Arterial - Other (Urban)	5	Urban Unrestricted Access
16	Minor Arterial (Urban)	5	Urban Unrestricted Access
17	Collector (Urban)	5	Urban Unrestricted Access
19	Local (Urban)	5	Urban Unrestricted Access

All other MOVES source types use the road type distribution data provided by Connecticut DEEP. The 2009 base year uses the 2009 MOVES input files provided by DEEP. The years 2020 and 2040 use the 2020 and 2050 MOVES input files provided by DEEP.

Source Type Population

The MOVES source type population files use population data provided by Connecticut DEEP. Table 1 describes the MOVES source types associated with freight movement. Population files include the source types for light commercial trucks, single unit short haul trucks, single unit long haul trucks, combination short haul trucks, and combination long haul trucks, MOVES source types 32, 52, 53, 61, and 62 respectively. This study focuses on vehicles used for freight movement. For this reason vehicle populations were set to zero for non-freight-related source types. For example, the VMT for HPMS vehicle type 50 for single unit trucks is assigned only to single unit short haul and single unit long haul trucks, MOVES source types 52 and 53 respectively, and excludes assigning VMT to refuse trucks and motor homes, MOVES source types 51 and 54 respectively. VMT splits between gasoline and diesel vehicles within a source type are based on the VIUS data described above.

Upon inspection it was determined that the TRANSEARCH VMT data and the DEEP truck population data were not consistent. For example, combining the VMT attributed to source type 52 (short haul single unit trucks) with the DEEP population estimates resulted in a very low value for average miles per year per truck (< 1,000 miles/year). Accordingly ERG used the average miles per year values from the VIUS data set, by source type and fuel type, to adjust the MOVES population estimates. These adjustments impacted those MOVES emission types tied to population counts (i.e., starts, evaporative emissions, and extended idle), but not those emissions tied directly to miles travelled (e.g., running emissions).

Source Type Age Distribution

The source type age distribution is based on registration data provided by Connecticut DEEP.

Average Speed Distribution

The average speed distribution was provided by Connecticut DEEP. The 2009 base year uses the 2009 MOVES input files, while the 2020 and 2040 out years are based on the 2020 and 2050 MOVES input files provided by DEEP.

Inspection and Maintenance Programs

Connecticut DEEP provided the I/M MOVES input files that were based on its I/M program evaluation and program design for 2009 and future years.

Fuel Formulation and Fuel Supply

The fuel formulation and fuel supply data were provided by Connecticut DEEP. The 2009 base year uses the 2009 MOVES input files, while the 2020 and 2040 out years are based on the 2020 and 2050 MOVES input files provided by DEEP.

Meteorology

The meteorology data were provided by Connecticut DEEP. The 2009 base year uses the 2009 MOVES input files, while the 2020 and 2040 out years are based on the 2020 and 2050 MOVES input files provided by Connecticut DEEP.

Clean Vehicle Program

MOVES inputs for the State of Connecticut's Clean Vehicle Program have accounted for the California Low Emission Vehicles (CA LEV) and the National Low Emission Vehicles, which was in place prior to the CA LEV program. The inputs for these programs were provided by Connecticut DEEP and are used in all the MOVES runs for this project.

Tables 4 and 5, which follow, summarize the emission factors for freight vehicles obtained using MOVES outputs.

Table 4. 2009 On-road Freight Primary Pollutant Emission Factors (g/mi)

County	SourceTypeID	SourceTypeDesc	CO	NOx	$PM_{2.5}$	VOC	CO_2
Fairfield	32	Light Commercial – Gas	12.23	1.60	0.028	1.01	523
		Light Commercial – Diesel	3.15	4.76	0.286	0.76	700
	52	Single Unit Short-haul – Gas	47.08	4.76	0.042	2.19	1,073
		Single Unit Short-haul – Diesel	3.00	7.54	0.387	0.79	1,120
	53	Single Unit Long-haul – Gas	26.29	3.86	0.017	1.71	932
		Single Unit Long-haul – Diesel	2.42	6.17	0.327	0.73	946
	61	Combination Short-haul – Diesel	3.68	15.04	0.724	0.70	2,154
	62	Combination Long-haul - Diesel	5.55	20.68	0.763	1.73	2,324
Hartford	32	Light Commercial – Gas	12.44	1.58	0.029	1.00	504
		Light Commercial – Diesel	2.97	4.51	0.267	0.72	677
	52	Single Unit Short-haul – Gas	46.93	4.64	0.044	2.04	988
		Single Unit Short-haul – Diesel	2.72	6.74	0.338	0.67	1,005
	53	Single Unit Long-haul – Gas	39.11	4.13	0.023	2.18	915
		Single Unit Long-haul – Diesel	2.66	6.04	0.309	0.71	918
	61	Combination Short-haul – Diesel	3.34	14.22	0.679	0.59	2,037
	62	Combination Long-haul - Diesel	5.30	19.91	0.769	1.58	2,275
Litchfield	32	Light Commercial – Gas	12.25	1.55	0.029	1.02	496
		Light Commercial – Diesel	3.01	4.49	0.265	0.74	670
	52	Single Unit Short-haul – Gas	45.98	4.57	0.048	1.97	936
		Single Unit Short-haul – Diesel	2.66	6.31	0.319	0.65	935
	53	Single Unit Long-haul – Gas	47.71	4.25	0.028	2.63	901
		Single Unit Long-haul – Diesel	3.01	6.15	0.312	0.77	914
	61	Combination Short-haul – Diesel	3.17	13.83	0.654	0.56	1,971
	62	Combination Long-haul - Diesel	5.59	20.25	0.827	1.65	2,288
Middlesex	32	Light Commercial – Gas	12.09	1.59	0.029	0.92	472
		Light Commercial – Diesel	2.37	3.83	0.234	0.60	633
	52	Single Unit Short-haul – Gas	31.95	4.26	0.033	1.19	875

Table 4. 2009 On-road Freight Primary Pollutant Emission Factors (g/mi)

County	SourceTypeID	SourceTypeDesc	CO	NOx	$PM_{2.5}$	VOC	CO_2
		Single Unit Short-haul – Diesel	2.06	5.35	0.276	0.50	825
	53	Single Unit Long-haul – Gas	33.16	4.04	0.022	1.65	834
		Single Unit Long-haul – Diesel	2.19	4.81	0.256	0.55	756
	61	Combination Short-haul – Diesel	2.66	13.01	0.513	0.47	1,843
	62	Combination Long-haul - Diesel	4.15	17.16	0.572	1.18	2,031
New Haven	32	Light Commercial – Gas	12.14	1.59	0.030	0.92	472
		Light Commercial – Diesel	2.37	3.84	0.235	0.61	632
	52	Single Unit Short-haul – Gas	36.54	4.42	0.039	1.41	887
		Single Unit Short-haul – Diesel	2.16	5.41	0.279	0.52	831
	53	Single Unit Long-haul – Gas	26.63	3.91	0.020	1.36	829
		Single Unit Long-haul – Diesel	2.02	4.79	0.257	0.54	753
	61	Combination Short-haul – Diesel	2.70	13.05	0.511	0.47	1,842
	62	Combination Long-haul - Diesel	4.09	17.16	0.567	1.18	2,024
New London	32	Light Commercial – Gas	11.94	1.59	0.027	0.91	470
		Light Commercial – Diesel	2.34	3.80	0.232	0.60	630
	52	Single Unit Short-haul – Gas	29.60	4.15	0.030	1.10	862
		Single Unit Short-haul – Diesel	2.04	5.36	0.278	0.51	821
	53	Single Unit Long-haul – Gas	26.28	3.82	0.018	1.34	801
		Single Unit Long-haul – Diesel	2.00	4.62	0.249	0.53	725
	61	Combination Short-haul – Diesel	2.69	13.12	0.525	0.47	1,857
	62	Combination Long-haul - Diesel	4.05	17.08	0.559	1.16	2,019
Tolland	32	Light Commercial – Gas	11.99	1.60	0.029	0.93	469
		Light Commercial – Diesel	2.30	3.78	0.229	0.60	627
	52	Single Unit Short-haul – Gas	59.37	4.95	0.061	2.53	882
		Single Unit Short-haul – Diesel	2.70	5.43	0.275	0.57	812
	53	Single Unit Long-haul – Gas	20.93	3.66	0.016	1.34	801
		Single Unit Long-haul – Diesel	1.85	4.44	0.241	0.53	725

Table 4. 2009 On-road Freight Primary Pollutant Emission Factors (g/mi)

County	SourceTypeID	SourceTypeDesc	CO	NOx	$PM_{2.5}$	VOC	CO_2
	61	Combination Short-haul – Diesel	2.94	13.26	0.522	0.50	1,858
	62	Combination Long-haul - Diesel	3.94	17.08	0.543	1.16	2,019
Windham	32	Light Commercial – Gas	12.28	1.58	0.030	0.96	483
		Light Commercial – Diesel	2.62	4.12	0.247	0.66	650
	52	Single Unit Short-haul – Gas	81.74	5.52	0.077	3.71	993
		Single Unit Short-haul – Diesel	3.48	6.61	0.328	0.72	971
	53	Single Unit Long-haul – Gas	25.04	3.79	0.018	1.40	848
		Single Unit Long-haul – Diesel	2.11	5.31	0.278	0.60	822
	61	Combination Short-haul – Diesel	3.72	14.00	0.678	0.62	2,002
	62	Combination Long-haul - Diesel	4.58	18.34	0.675	1.34	2,135

Table 5. 2009 On-road Freight Hazardous Air Pollutant Emission Factors (g/mi)

CntyFIPS	Source TypeID	SourceTypeDesc	1,3-Butadiene	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Naphthalene
Fairfield	32	Light Commercial – Gas	0.0053	0.0106	0.000499	0.0302	0.0114	0.00273
		Light Commercial – Diesel	0.0047	0.0221	0.002691	0.0081	0.0601	0.00038
	52	Single Unit Short-haul – Gas	0.0118	0.0233	0.003598	0.0667	0.0253	0.00418
		Single Unit Short-haul – Diesel	0.0050	0.0234	0.002843	0.0085	0.0635	0.00051
	53	Single Unit Long-haul – Gas	0.0064	0.0127	0.001937	0.0384	0.0138	0.00191
		Single Unit Long-haul – Diesel	0.0042	0.0199	0.002418	0.0073	0.0540	0.00043
	61	Combination Short-haul – Diesel	0.0043	0.0205	0.002495	0.0075	0.0558	0.00096
	62	Combination Long-haul - Diesel	0.0106	0.0500	0.006072	0.0182	0.1357	0.00101
Hartford	32	Light Commercial – Gas	0.0048	0.0102	0.000498	0.0313	0.0111	0.00285
		Light Commercial – Diesel	0.0044	0.0210	0.002552	0.0077	0.0570	0.00035
	52	Single Unit Short-haul – Gas	0.0099	0.0207	0.003318	0.0641	0.0229	0.00434
		Single Unit Short-haul – Diesel	0.0042	0.0200	0.002427	0.0073	0.0542	0.00045
	53	Single Unit Long-haul – Gas	0.0084	0.0175	0.002768	0.0559	0.0192	0.00254
		Single Unit Long-haul – Diesel	0.0041	0.0194	0.002353	0.0071	0.0526	0.00041
	61	Combination Short-haul – Diesel	0.0037	0.0174	0.002114	0.0063	0.0472	0.00090
	62	Combination Long-haul - Diesel	0.0096	0.0454	0.005515	0.0165	0.1232	0.00102
Litchfield	32	Light Commercial – Gas	0.0049	0.0105	0.000513	0.0321	0.0115	0.00286
		Light Commercial – Diesel	0.0046	0.0217	0.002636	0.0079	0.0589	0.00035
	52	Single Unit Short-haul – Gas	0.0096	0.0201	0.003214	0.0620	0.0221	0.00469
		Single Unit Short-haul – Diesel	0.0041	0.0192	0.002332	0.0070	0.0521	0.00042
	53	Single Unit Long-haul – Gas	0.0105	0.0222	0.003496	0.0699	0.0243	0.00298
		Single Unit Long-haul – Diesel	0.0045	0.0210	0.002556	0.0077	0.0571	0.00041
	61	Combination Short-haul – Diesel	0.0035	0.0165	0.002003	0.0060	0.0448	0.00087
	62	Combination Long-haul - Diesel	0.0100	0.0474	0.005758	0.0173	0.1287	0.00110
Middlesex	32	Light Commercial – Gas	0.0045	0.0095	0.000465	0.0291	0.0104	0.00279
		Light Commercial – Diesel	0.0037	0.0176	0.002141	0.0064	0.0478	0.00031

Table 5. 2009 On-road Freight Hazardous Air Pollutant Emission Factors (g/mi)

CntyFIPS	Source TypeID	SourceTypeDesc	1,3-Butadiene	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Naphthalene
	52	Single Unit Short-haul – Gas	0.0058	0.0121	0.001944	0.0376	0.0134	0.00325
		Single Unit Short-haul – Diesel	0.0032	0.0150	0.001818	0.0055	0.0406	0.00037
	53	Single Unit Long-haul – Gas	0.0062	0.0130	0.002057	0.0416	0.0143	0.00232
		Single Unit Long-haul – Diesel	0.0032	0.0150	0.001828	0.0055	0.0409	0.00034
	61	Combination Short-haul – Diesel	0.0029	0.0137	0.001667	0.0050	0.0373	0.00068
	62	Combination Long-haul - Diesel	0.0071	0.0337	0.004101	0.0123	0.0916	0.00076
New Haven	32	Light Commercial – Gas	0.0045	0.0096	0.000469	0.0294	0.0105	0.00289
		Light Commercial – Diesel	0.0038	0.0177	0.002153	0.0065	0.0481	0.00031
	52	Single Unit Short-haul – Gas	0.0068	0.0142	0.002269	0.0439	0.0156	0.00380
		Single Unit Short-haul – Diesel	0.0032	0.0153	0.001864	0.0056	0.0417	0.00037
	53	Single Unit Long-haul – Gas	0.0048	0.0101	0.001594	0.0326	0.0111	0.00210
		Single Unit Long-haul – Diesel	0.0031	0.0147	0.001781	0.0053	0.0398	0.00034
	61	Combination Short-haul – Diesel	0.0030	0.0139	0.001693	0.0051	0.0378	0.00068
	62	Combination Long-haul - Diesel	0.0071	0.0336	0.004086	0.0123	0.0913	0.00075
New London	32	Light Commercial – Gas	0.0044	0.0095	0.000462	0.0290	0.0103	0.00269
		Light Commercial – Diesel	0.0037	0.0175	0.002128	0.0064	0.0476	0.00031
	52	Single Unit Short-haul – Gas	0.0054	0.0114	0.001819	0.0351	0.0125	0.00294
		Single Unit Short-haul – Diesel	0.0032	0.0152	0.001851	0.0056	0.0414	0.00037
	53	Single Unit Long-haul – Gas	0.0047	0.0099	0.001564	0.0320	0.0109	0.00192
		Single Unit Long-haul – Diesel	0.0031	0.0145	0.001760	0.0053	0.0393	0.00033
	61	Combination Short-haul – Diesel	0.0030	0.0140	0.001698	0.0051	0.0379	0.00070
	62	Combination Long-haul - Diesel	0.0070	0.0332	0.004033	0.0121	0.0901	0.00074
Tolland	32	Light Commercial – Gas	0.0045	0.0097	0.000475	0.0297	0.0106	0.00283
		Light Commercial – Diesel	0.0037	0.0175	0.002130	0.0064	0.0476	0.00030
	52	Single Unit Short-haul – Gas	0.0115	0.0243	0.003895	0.0757	0.0267	0.00607
		Single Unit Short-haul – Diesel	0.0036	0.0170	0.002061	0.0062	0.0461	0.00036

Table 5. 2009 On-road Freight Hazardous Air Pollutant Emission Factors (g/mi)

CntyFIPS	Source TypeID	SourceTypeDesc	1,3-Butadiene	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Naphthalene
	53	Single Unit Long-haul – Gas	0.0036	0.0062	0.000414	0.0246	0.0082	0.00172
		Single Unit Long-haul – Diesel	0.0030	0.0097	0.001109	0.0051	0.0379	0.00032
	61	Combination Short-haul – Diesel	0.0031	0.0147	0.001788	0.0054	0.0400	0.00069
	62	Combination Long-haul - Diesel	0.0069	0.0283	0.003413	0.0118	0.0880	0.00072
Windham	32	Light Commercial – Gas	0.0047	0.0100	0.000487	0.0305	0.0109	0.00293
		Light Commercial – Diesel	0.0041	0.0192	0.002331	0.0070	0.0521	0.00033
	52	Single Unit Short-haul – Gas	0.0169	0.0355	0.005688	0.1106	0.0391	0.00766
		Single Unit Short-haul – Diesel	0.0046	0.0215	0.002613	0.0078	0.0584	0.00044
	53	Single Unit Long-haul – Gas	0.0049	0.0102	0.001615	0.0332	0.0112	0.00194
		Single Unit Long-haul – Diesel	0.0035	0.0163	0.001983	0.0059	0.0443	0.00037
	61	Combination Short-haul – Diesel	0.0039	0.0182	0.002210	0.0066	0.0494	0.00090
	62	Combination Long-haul - Diesel	0.0082	0.0385	0.004676	0.0140	0.1045	0.00090

Table 6 presents the 2009 annual vehicle miles traveled as derived from the TRANSEARCH VMT data.

Table 6. 2009 Vehicle Miles Traveled

County	Source Type ID					
	32	52	53	61	62	County Total
Fairfield	45,376,086	38,294,830	56,436,038	6,505,634	163,957,553	**310,570,141**
Hartford	24,682,139	26,545,746	24,982,728	8,705,510	83,926,022	**168,842,145**
Litchfield	4,089,625	7,124,356	1,413,483	2,107,379	11,526,871	**26,261,714**
Middlesex	6,995,428	5,767,250	8,836,983	2,993,237	23,261,204	**47,854,102**
New Haven	42,249,711	33,398,551	54,805,440	9,705,493	149,060,044	**289,219,239**
New London	17,476,987	11,433,884	25,052,519	5,391,914	59,901,882	**119,257,186**
Tolland	14,945,154	9,812,032	21,388,708	797,505	48,672,127	**95,615,526**
Windham	7,886,212	5,728,524	10,735,383	404,991	24,939,898	**49,695,008**
State Total	**163,701,343**	**138,105,174**	**203,651,283**	**36,611,663**	**565,245,602**	***1,107,315,064***[7]

The following tables summarize the annual on-road emissions from freight vehicles obtained from MOVES outputs.

Table 7. 2009 On-road Freight Primary Pollutant Emissions (TPY)

County FIPS	Source Type ID	Source Type Description	CO	NO_X	PM2.5	VOC	CO_2
Fairfield County	32	Light Commercial – Gas	422.2	55.3	0.96	34.9	18,059
		Light Commercial – Diesel	48.8	73.8	4.44	11.7	10,850
	52	Single Unit Short-haul – Gas	357.7	36.2	0.32	16.7	8,155
		Single Unit Short-haul – Diesel	103.7	260.8	13.38	27.2	38,760
	53	Single Unit Long-haul – Gas	556.2	81.7	0.36	36.1	19,711
		Single Unit Long-haul – Diesel	99.4	253.5	13.42	30.0	38,858
	61	Combination Short-haul – Diesel	26.4	107.8	5.19	5.0	15,448
	62	Combination Long-haul - Diesel	1002.3	3737.9	137.90	313.1	419,987
Hartford County	32	Light Commercial – Gas	233.5	29.7	0.55	18.7	9,457
		Light Commercial – Diesel	25.0	38.0	2.25	6.0	5,710
	52	Single Unit Short-haul – Gas	247.2	24.4	0.23	10.7	5,206
		Single Unit Short-haul – Diesel	65.2	161.6	8.12	16.1	24,118
	53	Single Unit Long-haul – Gas	366.2	38.7	0.22	20.4	8,569
		Single Unit Long-haul – Diesel	48.4	109.8	5.62	12.9	16,689
	61	Combination Short-haul – Diesel	32.0	136.4	6.51	5.7	19,552
	62	Combination Long-haul - Diesel	490.6	1842.2	71.14	145.9	210,442

[7] Total weekday VMT is calculated to be 3.7 million miles/day. Total daily highway VMT in CT (all modes and all trip purposes) is 87 million miles. Heavy-duty diesel trucks, account for about half of the 3.7 million VMT associated with freight movement. These vehicles have much higher NOx emissions than passenger vehicles. As a result, freight movement accounts for a significant share of statewide NOx emissions.

Table 7. 2009 On-road Freight Primary Pollutant Emissions (TPY)

County FIPS	Source Type ID	Source Type Description	CO	NO_X	PM2.5	VOC	CO_2
Litchfield County	32	Light Commercial – Gas	38.1	4.8	0.09	3.2	1,544
		Light Commercial – Diesel	4.2	6.3	0.37	1.0	936
	52	Single Unit Short-haul – Gas	65.0	6.5	0.07	2.8	1,324
		Single Unit Short-haul – Diesel	17.1	40.7	2.05	4.2	6,024
	53	Single Unit Long-haul – Gas	25.3	2.3	0.01	1.4	477
		Single Unit Long-haul – Diesel	3.1	6.3	0.32	0.8	940
	61	Combination Short-haul – Diesel	7.4	32.1	1.52	1.3	4,579
	62	Combination Long-haul - Diesel	71.0	257.3	10.51	20.9	29,076
Middlesex County	32	Light Commercial – Gas	64.3	8.5	0.15	4.9	2,512
		Light Commercial – Diesel	5.7	9.2	0.56	1.4	1,513
	52	Single Unit Short-haul – Gas	36.6	4.9	0.04	1.4	1,001
		Single Unit Short-haul – Diesel	10.7	27.9	1.44	2.6	4,301
	53	Single Unit Long-haul – Gas	109.8	13.4	0.07	5.4	2,762
		Single Unit Long-haul – Diesel	14.1	30.9	1.65	3.6	4,857
	61	Combination Short-haul – Diesel	8.8	42.9	1.69	1.5	6,081
	62	Combination Long-haul - Diesel	106.5	439.9	14.66	30.3	52,086
New Haven County	32	Light Commercial – Gas	390.2	51.2	0.95	29.7	15,170
		Light Commercial – Diesel	34.2	55.5	3.39	8.8	9,129
	52	Single Unit Short-haul – Gas	242.2	29.3	0.26	9.3	5,878
		Single Unit Short-haul – Diesel	65.3	163.4	8.41	15.6	25,093
	53	Single Unit Long-haul – Gas	547.0	80.3	0.41	27.9	17,029
		Single Unit Long-haul – Diesel	80.4	190.8	10.23	21.6	30,042
	61	Combination Short-haul – Diesel	28.9	139.6	5.47	5.1	19,707
	62	Combination Long-haul - Diesel	671.6	2819.2	93.17	193.4	332,517
New London County	32	Light Commercial – Gas	158.8	21.1	0.37	12.1	6,250
		Light Commercial – Diesel	14.0	22.7	1.39	3.6	3,765
	52	Single Unit Short-haul – Gas	67.2	9.4	0.07	2.5	1,955
		Single Unit Short-haul – Diesel	21.1	55.4	2.87	5.3	8,489
	53	Single Unit Long-haul – Gas	246.7	35.9	0.17	12.6	7,523
		Single Unit Long-haul – Diesel	36.5	84.2	4.54	9.7	13,217
	61	Combination Short-haul – Diesel	16.0	78.0	3.12	2.8	11,036
	62	Combination Long-haul - Diesel	267.4	1127.9	36.89	76.7	133,342
Tolland County	32	Light Commercial – Gas	136.3	18.2	0.33	10.6	5,326
		Light Commercial – Diesel	11.7	19.3	1.17	3.1	3,203
	52	Single Unit Short-haul – Gas	115.6	9.6	0.12	4.9	1,716
		Single Unit Short-haul – Diesel	24.0	48.2	2.44	5.1	7,201
	53	Single Unit Long-haul – Gas	167.8	29.3	0.13	12.6	7,523
		Single Unit Long-haul – Diesel	28.7	69.0	3.75	9.7	13,217
	61	Combination Short-haul – Diesel	2.6	11.7	0.46	0.4	1,633

Table 7. 2009 On-road Freight Primary Pollutant Emissions (TPY)

County FIPS	Source Type ID	Source Type Description	CO	NO_X	PM2.5	VOC	CO_2
	62	Combination Long-haul - Diesel	211.4	916.5	29.11	76.7	133,342
Windham County	32	Light Commercial – Gas	73.6	9.5	0.18	5.8	2,898
		Light Commercial – Diesel	7.0	11.1	0.66	1.8	1,750
	52	Single Unit Short-haul – Gas	92.9	6.3	0.09	4.2	1,128
		Single Unit Short-haul – Diesel	18.0	34.2	1.70	3.7	5,028
	53	Single Unit Long-haul – Gas	100.7	15.2	0.07	5.6	3,412
		Single Unit Long-haul – Diesel	16.5	41.5	2.17	4.7	6,418
	61	Combination Short-haul – Diesel	1.7	6.2	0.30	0.3	894
	62	Combination Long-haul - Diesel	125.9	504.1	18.55	36.9	58,691
State Total - 32	**32**	**Light Commercial – Gas**	**1,517**	**198**	**3.57**	**119.85**	**61,216**
		Light Commercial – Diesel	**151**	**236**	**14.23**	**37.41**	**36,856**
State Total – 52	**52**	**Single Unit Short-haul – Gas**	**1,224**	**127**	**1.19**	**52.48**	**26,364**
		Single Unit Short-haul – Diesel	**325**	**792**	**40.41**	**79.84**	**119,014**
State Total – 53	**53**	**Single Unit Long-haul – Gas**	**2,120**	**297**	**1.45**	**109.48**	**59,484**
		Single Unit Long-haul – Diesel	**327**	**786**	**41.70**	**83.32**	**111,021**
State Total – 61	**61**	**Combination Short-haul – Diesel**	**124**	**555**	**24.27**	**22.07**	**78,929**
State Total – 62	**62**	**Combination Long-haul - Diesel**	**2,947**	**11645**	**411.93**	**817.31**	**1,236,141**
State Total – All Freight	***All***	***All***	***8,734***	***14,635***	***539***	***1,322***	***1,729,027***

Table 8. 2009 On-road Freight Hazardous Air Pollutant Emissions (TPY)

County FIPS	Source Type ID	Source Type Description	1,3-Butadiene	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Naphthalene
Fairfield County	32	Light Commercial – Gas	0.1822	0.3651	0.0172	1.0421	0.3924	0.0941
		Light Commercial – Diesel	0.0727	0.3434	0.0417	0.1252	0.9325	0.0059
	52	Single Unit Short-haul – Gas	0.0897	0.1771	0.0273	0.5068	0.1925	0.0317
		Single Unit Short-haul – Diesel	0.1716	0.8100	0.0984	0.2953	2.1995	0.0178
	53	Single Unit Long-haul – Gas	0.1363	0.2684	0.0410	0.8121	0.2918	0.0403
		Single Unit Long-haul – Diesel	0.1731	0.8172	0.0993	0.2979	2.2189	0.0178
	61	Combination Short-haul – Diesel	0.0312	0.1473	0.0179	0.0537	0.3999	0.0069
	62	Combination Long-haul - Diesel	1.9128	9.0310	1.0973	3.2923	24.5225	0.1832
Hartford County	32	Light Commercial – Gas	0.0899	0.1916	0.0094	0.5871	0.2087	0.0535
		Light Commercial – Diesel	0.0375	0.1771	0.0215	0.0646	0.4810	0.0030
	52	Single Unit Short-haul – Gas	0.0522	0.1092	0.0175	0.3377	0.1204	0.0228
		Single Unit Short-haul – Diesel	0.1015	0.4792	0.0582	0.1747	1.3012	0.0108
	53	Single Unit Long-haul – Gas	0.0783	0.1641	0.0259	0.5233	0.1802	0.0238
		Single Unit Long-haul – Diesel	0.0746	0.3520	0.0428	0.1283	0.9559	0.0075
	61	Combination Short-haul – Diesel	0.0354	0.1669	0.0203	0.0609	0.4532	0.0087
	62	Combination Long-haul - Diesel	0.8893	4.1988	0.5102	1.5307	11.4013	0.0945
Litchfield County	32	Light Commercial – Gas	0.0153	0.0327	0.0016	0.0999	0.0356	0.0089
		Light Commercial – Diesel	0.0064	0.0303	0.0037	0.0111	0.0823	0.0005
	52	Single Unit Short-haul – Gas	0.0135	0.0284	0.0045	0.0877	0.0313	0.0066
		Single Unit Short-haul – Diesel	0.0262	0.1236	0.0150	0.0451	0.3357	0.0027
	53	Single Unit Long-haul – Gas	0.0056	0.0117	0.0019	0.0371	0.0129	0.0016
		Single Unit Long-haul – Diesel	0.0046	0.0216	0.0026	0.0079	0.0587	0.0004
	61	Combination Short-haul – Diesel	0.0081	0.0383	0.0047	0.0140	0.1040	0.0020
	62	Combination Long-haul - Diesel	0.1275	0.6021	0.0732	0.2195	1.6349	0.0140
Middlesex County	32	Light Commercial – Gas	0.0237	0.0506	0.0025	0.1549	0.0551	0.0148
		Light Commercial – Diesel	0.0089	0.0421	0.0051	0.0154	0.1144	0.0007
	52	Single Unit Short-haul – Gas	0.0067	0.0139	0.0022	0.0430	0.0153	0.0037

Table 8. 2009 On-road Freight Hazardous Air Pollutant Emissions (TPY)

County FIPS	Source Type ID	Source Type Description	1,3-Butadiene	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Naphthalene
		Single Unit Short-haul – Diesel	0.0165	0.0780	0.0095	0.0284	0.2118	0.0019
	53	Single Unit Long-haul – Gas	0.0206	0.0431	0.0068	0.1378	0.0473	0.0077
		Single Unit Long-haul – Diesel	0.0205	0.0967	0.0118	0.0353	0.2627	0.0022
	61	Combination Short-haul – Diesel	0.0096	0.0453	0.0055	0.0165	0.1229	0.0022
	62	Combination Long-haul - Diesel	0.1833	0.8654	0.1051	0.3155	2.3498	0.0195
New Haven County	32	Light Commercial – Gas	0.1447	0.3088	0.0151	0.9439	0.3362	0.0928
		Light Commercial – Diesel	0.0542	0.2558	0.0311	0.0933	0.6946	0.0045
	52	Single Unit Short-haul – Gas	0.0448	0.0938	0.0150	0.2910	0.1035	0.0252
		Single Unit Short-haul – Diesel	0.0981	0.4632	0.0563	0.1689	1.2578	0.0112
	53	Single Unit Long-haul – Gas	0.0990	0.2070	0.0327	0.6701	0.2275	0.0431
		Single Unit Long-haul – Diesel	0.1238	0.5845	0.0710	0.2131	1.5872	0.0136
	61	Combination Short-haul – Diesel	0.0316	0.1491	0.0181	0.0543	0.4048	0.0073
	62	Combination Long-haul - Diesel	1.1703	5.5256	0.6714	2.0144	15.0040	0.1238
New London County	32	Light Commercial – Gas	0.0590	0.1257	0.0061	0.3849	0.1370	0.0357
		Light Commercial – Diesel	0.0222	0.1046	0.0127	0.0381	0.2840	0.0018
	52	Single Unit Short-haul – Gas	0.0124	0.0258	0.0041	0.0797	0.0285	0.0067
		Single Unit Short-haul – Diesel	0.0333	0.1575	0.0191	0.0574	0.4275	0.0038
	53	Single Unit Long-haul – Gas	0.0444	0.0928	0.0147	0.3009	0.1020	0.0180
		Single Unit Long-haul – Diesel	0.0559	0.2639	0.0321	0.0962	0.7167	0.0060
	61	Combination Short-haul – Diesel	0.0176	0.0831	0.0101	0.0303	0.2255	0.0041
	62	Combination Long-haul - Diesel	0.4641	2.1914	0.2663	0.7989	5.9506	0.0490
Tolland County	32	Light Commercial – Gas	0.0517	0.1106	0.0054	0.3371	0.1203	0.0322
		Light Commercial – Diesel	0.0190	0.0895	0.0109	0.0326	0.2430	0.0016
	52	Single Unit Short-haul – Gas	0.0225	0.0473	0.0076	0.1473	0.0520	0.0118
		Single Unit Short-haul – Diesel	0.0319	0.1504	0.0183	0.0548	0.4084	0.0032
	53	Single Unit Long-haul – Gas	0.0288	0.0500	0.0033	0.1973	0.0661	0.0138
		Single Unit Long-haul – Diesel	0.0460	0.1503	0.0173	0.0791	0.5895	0.0050

Table 8. 2009 On-road Freight Hazardous Air Pollutant Emissions (TPY)

County FIPS	Source Type ID	Source Type Description	1,3-Butadiene	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Naphthalene
	61	Combination Short-haul – Diesel	0.0027	0.0129	0.0016	0.0047	0.0351	0.0006
	62	Combination Long-haul - Diesel	0.3684	1.5169	0.1831	0.6340	4.7227	0.0387
Windham County	32	Light Commercial – Gas	0.0281	0.0599	0.0029	0.1830	0.0652	0.0176
		Light Commercial – Diesel	0.0109	0.0517	0.0063	0.0188	0.1404	0.0009
	52	Single Unit Short-haul – Gas	0.0192	0.0403	0.0065	0.1257	0.0444	0.0087
		Single Unit Short-haul – Diesel	0.0236	0.1114	0.0135	0.0406	0.3024	0.0023
	53	Single Unit Long-haul – Gas	0.0197	0.0411	0.0065	0.1334	0.0452	0.0078
		Single Unit Long-haul – Diesel	0.0270	0.1274	0.0155	0.0465	0.3461	0.0029
	61	Combination Short-haul – Diesel	0.0017	0.0081	0.0010	0.0030	0.0220	0.0004
	62	Combination Long-haul - Diesel	0.2241	1.0580	0.1286	0.3857	2.8728	0.0246
State Total - 32	**32**	**Light Commercial – Gas**	**0.595**	**1.245**	**0.060**	**3.733**	**1.351**	**0.349**
		Light Commercial – Diesel	**0.232**	**1.095**	**0.133**	**0.399**	**2.972**	**0.019**
State Total – 52	**52**	**Single Unit Short-haul – Gas**	**0.261**	**0.536**	**0.085**	**1.619**	**0.588**	**0.117**
		Single Unit Short-haul – Diesel	**0.503**	**2.373**	**0.288**	**0.865**	**6.444**	**0.054**
State Total – 53	**53**	**Single Unit Long-haul – Gas**	**0.433**	**0.878**	**0.133**	**2.812**	**0.973**	**0.156**
		Single Unit Long-haul – Diesel	**0.525**	**2.414**	**0.292**	**0.904**	**6.736**	**0.055**
State Total – 61	**61**	**Combination Short-haul – Diesel**	**0.138**	**0.651**	**0.079**	**0.237**	**1.768**	**0.032**
State Total – 62	**62**	**Combination Long-haul - Diesel**	**5.340**	**24.989**	**3.035**	**9.191**	**68.459**	**0.547**
State Total – All Freight	***All***	***All***	***8.026***	***34.181***	***4.106***	***19.761***	***89.290***	***1.330***

ESTIMATING RAIL CARGO EMISSIONS

Railroad emissions sources are associated with the operation of line-haul locomotives that carry cargo from an origination point to a destination point and yard locomotives that disassemble and assemble trains at a rail yard. For this inventory emissions for these two different operations were developed using different approaches. For line-haul locomotives, EPA emission factors were compiled in terms of emissions per ton mile, these factors were applied directly to the county ton miles data developed from the TRANSEARCH data. For yard engines, operators were contacted to quantify the number of yard engines that operate in each county. An estimate of the amount of fuel a typical yard engine uses annually was developed based on Connecticut data provided by CSX. The annual yard engine fuel usage data was applied to the county yard engine census data to get yard engine fuel consumption by county. These fuel data were applied directly to the EPA's emission factor to estimate primary pollutant emissions. The primary pollutant estimates for both line-haul and yard engines were speciated into their HAP components using the HAP profiles presented in the EPA's 2008 National Emission Inventory.

It should be noted that this inventory focused on railroad activities related to the movement of freight, therefore passenger rail activities such as commuter rail and inter-city rail (Amtrak) were not included in this analysis.

Data on rail flows were obtained from the Surface Transportation Board's 2009 full Carload Waybill Sample. This dataset contains a stratified sampling of carload and rail intermodal traffic moving in the United States. For rail, traffic flows were assigned to a national rail network derived from the Oak Ridge National Laboratory Center for Transportation Analysis (ORNL/CTA) to obtain ton-miles by Connecticut county, commodity type and traffic direction (i.e., inbound, outbound, intrastate and through), for the base and forecast years. To estimate the line haul emission, the emission factors (grams of pollutant per cargo ton mile) developed for this inventory were applied directly to the sum of cargo ton miles for each county that has rail traffic.

The EPA published railroad emission factors for nitrogen oxides (NO_x), particulate matter (PM_{10}), carbon monoxide (CO) and hydrocarbons (HC) in terms of grams of pollutant per gallon (g/gal) of railroad diesel fuel combusted. These factors were developed for line-haul locomotives, which are involved in the movement of cargo over long distances and yard locomotives used to disassemble and assemble trains at a railway yard.

For this project, the EPA's HC emission factors are converted to VOC by multiplying the published factor by 1.053 as recommended in the EPA's locomotive emission factor guidance. It should be noted that nearly all of the PM emissions are less than 2.5 microns in diameter, therefore the $PM_{2.5}$ factor used is the same as the PM_{10} factor.

Sulfur dioxide (SO_2) and carbon dioxide (CO_2) are largely independent of engine parameters, but are dependent on fuel properties. Locomotive-specific emission rates are not provided by the EPA although EPA recommends SO_2 and CO_2 emission rates be calculated based on typical properties of railroad fuel.

The sulfur concentration of locomotive diesel fuel is 500 ppm for the 2009 inventory. While the vast majority of sulfur in the fuel is typically converted to SO_2, up to 5 percent of the sulfur is oxidized further to sulfate and forming secondary particulate matter; thus, the fraction of fuel sulfur emitted as SO_2 may be as low as 95 percent. Use of the 95 percent value may under estimate actual emissions. Though 100 percent SO_2 is unlikely, for this inventory we are recommending a midpoint value for this study of 97.5

For the purpose of this study, we assume that black carbon (BC) is 15 percent of $PM_{2.5}$. HAP emissions were estimated by speciating the PM emissions for metals and VOC for organic HAPs; the speciation profiles for locomotives were obtained from the EPA's National Emission Inventory Documentation and are provided in Appendix B.1.

In order to convert the EPA fuel-based factors to grams per ton-mile, fuel consumption rates and volume of cargo handled for CSX was obtained from their Federal Railroad Administration (FRA) R-1 data. Note that CSX is the only Class 1 railroad company operating in Connecticut, and as such it is the only one required to submit R-1 data to the FRA. Based on the R-1 data they submitted the total system-wide diesel fuel usage for CSX for 2010 was 490,049,749 gallons; this includes 441,779,849 for freight services and 48,269,900 for switch engines. The total gross ton-miles for all CSX trains in 2010 were 455,683,788,000 and the total ton-miles of freight were 230,507,431,000 with 229,172,569,000 associated with revenue ton-miles. These fuel and cargo data were used to ratios that convert the grams per gallon factors to grams per cargo ton mile factors, which are presented in Table 9.

TRANSEARCH rail cargo traffic data were compiled for each Connecticut county, quantifying the volume of cargo that originated from, arrive to or transited the county in terms of cargo ton miles. The converted emission factors (grams per cargo ton-mile) were applied directly to the 2009 TRANSEARCH rail cargo ton-miles data to estimate emissions.

Tables 9 to 11 summarize emissions associated with rail cargo.

Table 9. Line Haul Locomotive Emission Factors (gram/cargo ton miles)

Year	NO_x	$PM_{2.5}$	VOC	SO_2	CO_2	CO	Black Carbon
2009	0.318	0.009	0.018	0.0059	19.584	0.0513	0.0014

Table 10. Annual Primary Emissions for Line-Haul Locomotives (tons/yr)

County	NO_X	$PM_{2.5}$	PM_{10}	HC	VOC	SO_2	CO_2	CO	Black Carbon
Fairfield	5.659	0.160	0.160	0.304	0.320	0.105	348.515	0.913	0.025
Hartford	17.100	0.484	0.484	0.919	0.968	0.317	1,053.119	2.759	0.075
Litchfield	1.266	0.036	0.036	0.068	0.072	0.023	77.985	0.204	0.006
Middlesex	2.105	0.060	0.060	0.113	0.119	0.039	129.667	0.340	0.009
New Haven	11.994	0.339	0.339	0.645	0.679	0.223	738.624	1.935	0.053
New London	12.505	0.354	0.354	0.672	0.708	0.232	770.089	2.017	0.055
Tolland	6.790	0.192	0.192	0.365	0.384	0.126	418.161	1.095	0.030
Windham	4.662	0.132	0.132	0.251	0.264	0.086	287.089	0.752	0.021
State Total	**62.081**	**1.757**	**1.757**	**3.337**	**3.514**	**1.152**	**3,823.249**	**10.015**	**0.273**

Table 11. Annual HAP Emissions for Line-Haul Locomotives (tons/yr)

Pollutant Name	Fairfield	Hartford	Litchfield	Middlesex	New Haven	New London	Tolland	Windham	State Total
1,3 Butadiene	0.000765	0.002310	0.000171	0.000284	0.001620	0.001689	0.000917	0.000630	**0.008386**
2-2-4 Trimethylpentane	0.000718	0.002171	0.000161	0.000267	0.001522	0.001587	0.000862	0.000592	**0.00788**
Acenaphthene	0.000005	0.000015	0.000001	0.000002	0.000010	0.000011	0.000006	0.000004	**0.000054**
Acenaphthylene	0.000068	0.000207	0.000015	0.000025	0.000145	0.000151	0.000082	0.000056	**0.000749**
Acetaldehyde	0.004425	0.013371	0.000990	0.001646	0.009378	0.009777	0.005309	0.003645	**0.048541**
Acrolein	0.000736	0.002224	0.000165	0.000274	0.001559	0.001626	0.000883	0.000606	**0.008073**
Anthracene	0.000016	0.000049	0.000004	0.000006	0.000034	0.000036	0.000019	0.000013	**0.000177**
Arsenic	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	**0**
Benzene	0.000609	0.001840	0.000136	0.000227	0.001291	0.001346	0.000731	0.000502	**0.006682**
Benzo(a)anthracene	0.000003	0.000008	0.000001	0.000001	0.000005	0.000006	0.000003	0.000002	**0.000029**

Table 11. Annual HAP Emissions for Line-Haul Locomotives (tons/yr)

Pollutant Name	Fairfield	Hartford	Litchfield	Middlesex	New Haven	New London	Tolland	Windham	State Total
Benzo(a)pyrene	0.000000	0.000001	0.000000	0.000000	0.000001	0.000001	0.000001	0.000000	**0.000004**
Benzo(b)fluoranthene	0.000001	0.000003	0.000000	0.000000	0.000002	0.000002	0.000001	0.000001	**0.00001**
Benzo(ghi)perylene	0.000000	0.000002	0.000000	0.000000	0.000001	0.000001	0.000001	0.000000	**0.000005**
Benzo(k)fluoranthene	0.000001	0.000003	0.000000	0.000000	0.000002	0.000002	0.000001	0.000001	**0.00001**
Beryllium	0.000004	0.000014	0.000001	0.000002	0.000010	0.000010	0.000005	0.000004	**0.00005**
Cadmium	0.000004	0.000014	0.000001	0.000002	0.000010	0.000010	0.000005	0.000004	**0.00005**
Chromium (III)	0.000001	0.000002	0.000000	0.000000	0.000001	0.000001	0.000001	0.000001	**0.000007**
Chromium (VI)	0.000000	0.000001	0.000000	0.000000	0.000001	0.000001	0.000000	0.000000	**0.000003**
Chrysene	0.000002	0.000006	0.000000	0.000001	0.000004	0.000004	0.000002	0.000002	**0.000021**
Dibenz(a,h)anthracene	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	**0**
Ethylbenzene	0.000641	0.001936	0.000143	0.000238	0.001358	0.001416	0.000769	0.000528	**0.007029**
Fluoranthene	0.000012	0.000036	0.000003	0.000004	0.000025	0.000026	0.000014	0.000010	**0.00013**
Fluorene	0.000023	0.000068	0.000005	0.000008	0.000048	0.000050	0.000027	0.000019	**0.000248**
Formaldehyde	0.010196	0.030809	0.002281	0.003793	0.021608	0.022529	0.012233	0.008399	**0.111848**
Indeno(1,2,3-cd)pyrene	0.000000	0.000001	0.000000	0.000000	0.000001	0.000001	0.000001	0.000000	**0.000004**
Lead	0.000013	0.000041	0.000003	0.000005	0.000029	0.000030	0.000016	0.000011	**0.000148**
Manganese	0.000000	0.000001	0.000000	0.000000	0.000001	0.000001	0.000000	0.000000	**0.000003**
Mercury	0.000004	0.000014	0.000001	0.000002	0.000010	0.000010	0.000005	0.000004	**0.00005**
Napthalene	0.000413	0.001247	0.000092	0.000153	0.000874	0.000912	0.000495	0.000340	**0.004526**
n-Hexane	0.001762	0.005324	0.000394	0.000655	0.003734	0.003893	0.002114	0.001451	**0.019327**
Nickel	0.000001	0.000003	0.000000	0.000000	0.000002	0.000002	0.000001	0.000001	**0.00001**
Phenanthrene	0.000091	0.000274	0.000020	0.000034	0.000192	0.000201	0.000109	0.000075	**0.000996**
Propionaldehyde	0.001954	0.005904	0.000437	0.000727	0.004141	0.004318	0.002344	0.001610	**0.021435**
Pyrene	0.000017	0.000051	0.000004	0.000006	0.000036	0.000037	0.000020	0.000014	**0.000185**
Styrene	0.000673	0.002033	0.000151	0.000250	0.001426	0.001486	0.000807	0.000554	**0.00738**
Toluene	0.001025	0.003097	0.000229	0.000381	0.002172	0.002265	0.001230	0.000844	**0.011243**
Xylene	0.001538	0.004646	0.000344	0.000572	0.003259	0.003397	0.001845	0.001267	**0.016868**

Yard locomotives require a different approach than line haul locomotives. Railroad companies were contacted to solicit data on their yard fleet. For instance, CSX operates the Cedar Hill Rail Yard in Connecticut with three switcher locomotives. These include two B-23 four-axle switchers (2300 HP) and one GENSET locomotive (2100 HP through three 700 HP engines). The estimated total fuel usage for all their yard locomotives is 165,000 gallons of diesel fuel per year. The actual hours of operation are unknown, but the typical switch engine is estimated to operate 4,450 hours/year. Two of these engines are equipped with auxiliary power units (APUs) or idle reduction systems. Assuming that the CSX genset locomotive has a 30 percent improved fuel efficiency over the B-23 locomotives, the average annual fuel consumption per locomotives is 61,000 gallons of diesel per year.

ERG compiled data from the Bureau of Transportation Statistics (BTS) that indicated the location of intermodal yards including a rail component. ERG contacted each yard to obtain a more accurate assessment of their yard operations. ERG also contacted the port authorities to obtain data on their yard locomotives. ERG supplemented these interviews with satellite photos from Google Earth. A summary of yard locomotives that operate in Connecticut are provided in Table 12.

Table 12. Census of Connecticut Yard Engines

Name	Description	Revenues	City	Latitude	Longitude	# of Locomotives	Data Source
Post-Script Warehouse, Inc.-Norwich, CT	Farm products shipping and warehousing	< 0.5 million	Norwich	41.52611	-72.08793	Pending response from facility	NA
C.C. Lounsbury, Inc.	Lumber intermodal shipping	1-2.5 million	Willimantic	41.71731	-72.24423	2	Interview
Port of New London	Port		New London	41.35517	-72.09896	Pending response from port	NA
Port of Bridgeport	Port		Bridgeport	41.17676	-73.18683	Pending response from port	NA
Yellow-Middletown, CT Terminal	Freight Trucking		Middletown	41.57096	-72.72659	1	Interview
Port of New Haven	Port		New Haven	41.28921	-72.90305	0	Interview & Satellite Mapping
CSX - Cedar Hill Yard	Railroad company		North Haven	41.38167	-72.858333	3	Interview & Satellite Mapping
Providence & Worcester Railroad - New London	Railroad company		New London	41.35407	-72.10104	1	Interview

Yard locomotive primary emission estimates are presented in Table 13 and 14 and HAP emissions are presented in Table 15. Note that counties which data on the number of yard locomotives could not be obtained are not included in Tables 14 and 15.

Table 13. Annual Emissions per Yard Locomotive (grams/yard locomotive-year)

Year	NO_X	$PM_{2.5}$	VOC	SO_2	CO_2	CO	Black Carbon
2009	14,396,000	329,400	905,685	187,270	619,723,400	1,696,776	50,630

Table 14. Annual Primary Emissions for Yard Locomotives (tons)

County	NO_X	$PM_{2.5}$	PM_{10}	HC	VOC	SO_2	CO_2	CO	Black Carbon
Windham	31.7377	0.7262	0.7487	1.8962	1.9967	0.4129	1,366.26	3.741	0.1116
Middlesex	15.8689	0.3631	0.3743	0.9481	0.9983	0.2064	683.13	1.870	0.0558
New Haven	47.6066	1.0893	1.1230	2.8443	2.9950	0.6193	2,049.38	5.611	0.16.74
New London	15.8689	0.3631	0.3743	0.9481	0.9983	0.2064	683.13	1.870	0.0558
State Total	**111.0821**	**2.5417**	**2.6203**	**6.6367**	**6.9883**	**1.445**	**4781.9**	**13.093**	**0.2232**

Table 15. Annual HAP Emissions for Yard Locomotives (tons/yr)

Pollutant Name	Windham	Middlesex	New Haven	New London	State Total
1,3 Butadiene	0.003574	0.001787	0.005361	0.001787	**0.012509**
2-2-4 Trimethylpentane	0.004478	0.002239	0.006716	0.002239	**0.015672**
Acenaphthene	0.000023	0.000011	0.000034	0.000011	**0.000079**
Acenaphthylene	0.000320	0.000160	0.000480	0.000160	**0.00112**
Acetaldehyde	0.020684	0.010342	0.031025	0.010342	**0.072393**
Acrolein	0.003440	0.001720	0.005159	0.001720	**0.012039**
Anthracene	0.000076	0.000038	0.000113	0.000038	**0.000265**
Arsenic	0.000000	0.000000	0.000000	0.000000	**0**
Benzene	0.002846	0.001423	0.004270	0.001423	**0.009962**
Benzo(a)anthracene	0.000012	0.000006	0.000018	0.000006	**0.000042**
Benzo(a)pyrene	0.000002	0.000001	0.000003	0.000001	**0.000007**
Benzo(b)fluoranthene	0.000005	0.000002	0.000007	0.000002	**0.000016**
Benzo(ghi)perylene	0.000002	0.000001	0.000003	0.000001	**0.000007**
Benzo(k)fluoranthene	0.000004	0.000002	0.000006	0.000002	**0.000014**
Beryllium	0.000021	0.000010	0.000031	0.000010	**0.000072**
Cadmium	0.000021	0.000010	0.000031	0.000010	**0.000072**
Chromium (III)	0.000003	0.000001	0.000004	0.000001	**0.000009**
Chromium (VI)	0.000002	0.000001	0.000002	0.000001	**0.000006**
Chrysene	0.000009	0.000004	0.000013	0.000004	**0.00003**
Dibenz(a,h)anthracene	0.000000	0.000000	0.000000	0.000000	**0**

Table 15. Annual HAP Emissions for Yard Locomotives (tons/yr)

Pollutant Name	Windham	Middlesex	New Haven	New London	State Total
Ethylbenzene	0.003993	0.001997	0.005990	0.001997	**0.013977**
Fluoranthene	0.000056	0.000028	0.000084	0.000028	**0.000196**
Fluorene	0.000105	0.000053	0.000158	0.000053	**0.000369**
Formaldehyde	0.047659	0.023829	0.071488	0.023829	**0.166805**
Indeno(1,2,3-cd)pyrene	0.000002	0.000001	0.000003	0.000001	**0.000007**
Lead	0.000063	0.000031	0.000094	0.000031	**0.000219**
Manganese	0.000001	0.000001	0.000002	0.000001	**0.000005**
Mercury	0.000021	0.000010	0.000031	0.000010	**0.000072**
Napthalene	0.001928	0.000964	0.002892	0.000964	**0.006748**
n-Hexane	0.010982	0.005491	0.016473	0.005491	**0.038437**
Nickel	0.000005	0.000002	0.000007	0.000002	**0.000016**
Phenanthrene	0.000425	0.000212	0.000637	0.000212	**0.001486**
Propionaldehyde	0.012180	0.006090	0.018270	0.006090	**0.04263**
Pyrene	0.000079	0.000039	0.000118	0.000039	**0.000275**
Styrene	0.004193	0.002097	0.006290	0.002097	**0.014677**
Toluene	0.006389	0.003195	0.009584	0.003195	**0.022363**
Xylene	0.009584	0.004792	0.014376	0.004792	**0.033544**

ESTIMATING MARINE CARGO EMISSIONS

At this stage there is no official EPA Guidance on how to develop marine vessel emissions, ERG developed this inventory using data the EPA developed in support of recent rule making. It is consistent with the marine emission estimates developed by OTAQ for the EPA's National Emissions Inventory.

For marine vessels, the hours that a vessel operates underway in state waters and at Connecticut ports were matched to appropriate kilowatt rating of the vessel's propulsion and auxiliary engines and boilers to get kilowatt hours of operation. These activity data were applied to the EPA and California Air Resources Board emission factors to estimate underway and in-port emissions for the vessel's main propulsion and auxiliary engines and boilers. The primary pollutant estimates were speciated into their HAP components using the HAP profiles presented in the EPA's 2008 National Emission Inventory.

It should be noted that this inventory focused on marine vessel activities related to the movement of freight, therefore cruise boats, ferries, recreational boating and fishing were not included in this analysis. The emission factors used in this study were obtained from the EPA for vessels equipped with Category 1 and 2 propulsion engines (e.g., tugs) and ocean-going vessels equipped with Category 3 propulsion engines (e.g., cargo ships and tankers) and are summarized in Table 16.

HAP emissions were estimated by speciating the PM emissions for metals and VOC for organic HAPs; the speciation profiles for marine vessels were obtained from the EPA's National Emission Inventory documentation and are provided in Appendix B.

Table 16. Marine Vessels Emission Factors (g/kW-hr)

Year	NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO_2	CO	VOC	Black Carbon
Vessels equipped with Category 1 and 2 propulsion engines								
2009	9.82	0.355	0.344	0.194	678	1.924	0.217	0.052
Vessels equipped with Category 3 propulsion engines								
2009	15.98	1.352	1.243	10.080	621	1.352	0.595	0.186
Boilers								
2009	2.1	0.8	0.4	16.5	970	0.2	0.1	0.08

To use these factors for the base year inventory, activity data must be expressed in terms of kilowatt-hours. ERG compiled vessel specific data for ships and tugs that visit Connecticut ports. The U.S. Army Corps of Engineers maintains data of individual ship movements that were matched to Lloyd's Registry of Ships data to determine parameters such as ship type, tonnage, power (kilowatts), maximum vessel speed, draft, and other relevant factors. Table shows the fleet profiles that were developed for each port providing kilowatt hours by vessel type which was derived from the average kilowatt rating for main engines used in propulsion and auxiliary engines multiplied by the hours spent in state waters multiplied by the number of trips along the designed route. Trips were designated by the out of state origination or destination of the cargo. Theses kilowatt-hours could be applied directly the EPA emission factors to estimate underway emissions for each port's fleet.

Table 17. Fleet Profiles by Port

Port	Subtype	Trips In-Out	Traffic Direction	Main kW-hr	Aux kW-hr
Bridgeport	Auto Carrier	2	Eastbound	171,014	33,173
	Bulk	46	Eastbound	2,644,870	737,120
	Cargo	30	Eastbound	1,518,348	474,765
	Tankship	6	Eastbound	135,988	75,480
	Tank Barge	6	Eastbound	117,867	8,500
	Inland Tug	299	Westbound	5,410,721	116,489
	Inland Tug	75	Eastbound	2,872,129	61,835
	Ocean Tug	6	Eastbound	207,429	11,045
New Haven	Bulk	68	Eastbound	2,647,997	917,717
	Cargo	10	Eastbound	526,835	142,447
	Chemical Tanker	2	Eastbound	59,862	28,489
	Crude Tanker 1 - Handymax	2	Eastbound	83,336	28,489
	Crude Tanker 5 - VLCC	2	Eastbound	164,103	33,969

Table 17. Fleet Profiles by Port

Port	Subtype	Trips In-Out	Traffic Direction	Main kW-hr	Aux kW-hr
	General Cargo	22	Eastbound	782,828	258,079
	Products Tanker	82	Eastbound	3,605,595	1,156,447
	Tankship	184	Eastbound	7,802,317	2,657,327
	Inland Tug	168	Westbound	3,294,480	94,080
	Inland Tug	168	Eastbound	4,110,256	117,376
	Ocean Tug	2	Eastbound	57,709	3,136
New London	General Cargo	10	Eastbound	211,764	76,855
	Inland	6	Westbound	29,924	5,152
	Inland	6	Eastbound	13,196	2,272
	Products Tanker	2	Eastbound	72,098	19,837
	Tankship	2	Eastbound	43,417	16,781
Stamford	Inland Tug	259	Westbound	1,926,313	41,472
	Inland Tug	65	Eastbound	2,841,312	61,171

Because Connecticut ports import more than they export, TRANSEARCH's in-bound marine cargo data were matched to appropriate vessels. The TRANSEARCH origination and destination data were evaluated for each port to determine whether vessels head west to destinations in New York and northern New Jersey or east to all other locations. GIS tools were used to map the length of each east bound and west bound shipping lane. The length of the shipping lane was divided by typical vessel speeds (taking into consider movements in the reduced speed zone) to estimate hours of operation along the shipping lane.

Estimates were also developed for the time spend hoteling and offloading products based on the U.S. Army Corps of Engineers data and engineering judgement derived from implementing similar emission inventories at other ports. As the Category 1 and 2 vessels tend to be tugs which shut off their engines when dockside to save fuel, dock side estimates for auxiliary engines were only developed for the larger vessels equipped the Category 3 propulsion engines. Tankers and to a lesser extent other cargo carrying vessels typically use boilers to run steam pumps to move the product off of the vessel. For tankers the exhaust gas from these boilers are also used to flood the vessels storage tanks with CO_2 to reduce the risk of an explosion. The kilowatt rating of the boilers were estimated based on the type of vessel and cargo handled; tankers were assumed to have a kilowatt rating of 2,500 and all other vessels were assume to have a rating of 135. The rating was applied to estimates for the hours spent offloading product to get kilowatt hours. Typical tanker offloading time was assumed to be 46 hours, all other vessels were assumed to be 70 hours. Marine vessel boiler emission factors were obtained from the California Air Resources Board. As mentioned earlier, HAP emissions were estimated by using HAP profiles for PM and VOC obtained from the EPA's 2008 National Emission Inventory.

Note that these data do not assign underway emissions to counties that vessels transit. For example vessels from Bridgeport head east traveling through waters associated with the counties of New Haven, Middlesex, and New London. These preliminary emission estimates are only assigned to the ports for which the cargo originates or is destined. Underway emissions will be assigned to all counties that a vessel travels through in the final emissions dataset based on the length of the shipping lane in each county. In addition, these estimates do not include vessels that travel through the Long Island Sound and do not visit Connecticut ports. It is believed that most of the marine traffic in the Sound is associated with Connecticut ports, so this additional non-Connecticut traffic is anticipated to be relatively small.

Marine vessel primary emission estimates are presented in and HAP emissions are presented in Tables 18 and 19.

Table 18. Annual Primary Emissions for Marine Vessels (tons/yr)

Port	Category	2009 Emissions (tons)							
		NO_X	$PM_{2.5}$	PM_{10}	VOC	SO_2	CO2	CO	Black Carbon
Stamford	Transit (Category 1&2)	38.51	1.35	1.40	0.84	0.76	2658.18	7.54	0.20
	Transit Aux	0.34	0.01	0.01	0.01	0.01	23.60	0.07	0.00
Bridgeport	Transit (Category 1&2)	45.49	1.60	1.66	0.99	0.90	3140.33	8.91	0.24
	Transit (Category 3)	78.72	6.11	6.66	2.92	49.67	3062.19	6.66	0.91
	Transit Aux	4.83	0.17	0.18	0.11	0.10	333.40	0.95	0.03
	Dwelling Aux	26.64	0.93	0.97	0.58	0.53	1,838.89	5.22	0.14
	Dwelling Boiler	1.65	0.16	0.08	0.63	12.98	762.96	0.00	0.06
	Maneuver Assist	0.58	0.02	0.02	0.01	0.01	40.36	0.11	0.00
New Haven	Transit (Category 1&2)	51.31	1.80	1.87	1.12	1.02	3541.81	10.05	0.27
	Transit (Category 3)	226.86	17.61	19.20	8.41	143.13	8824.30	19.20	2.61
	Transit Aux	14.91	0.52	0.54	0.33	0.30	1029.00	2.92	0.08
	Dwelling Aux	93.05	3.26	3.39	2.03	1.85	6,423.90	18.23	0.49
	Dwelling Boiler	37.30	3.55	1.78	14.21	293.06	17,228.25	0.04	1.42
	Maneuver Assist	4.83	0.17	0.18	0.11	0.10	333.22	0.95	0.03
New London	Transit (Category 1&2)	0.54	0.02	0.02	0.01	0.01	36.99	0.10	0.00
	Transit (Category 3)	7.20	0.56	0.61	0.27	4.55	280.24	0.61	0.08
	Transit Aux	0.40	0.01	0.01	0.01	0.01	27.80	0.08	0.00
	Dwelling Aux	4.10	0.14	0.15	0.09	0.08	283.35	0.80	0.02
	Dwelling Boiler	0.64	0.06	0.03	0.24	5.04	296.45	0.00	0.02
	Maneuver Assist	0.13	0.00	0.00	0.00	0.00	9.31	0.03	0.00
Total		638.03	38.07	38.75	32.91	514.10	50,174.54	82.47	6.62

Table 19. Annual HAP Emissions for Marine Vessels (tons/yr)

Pollutant Name	Stamford	Bridgeport	New Haven	New London	State Total
2,2,4-trimethylpentane	0.00021	0.00042	0.00090	0.00003	0.00156
Acenaphthene	0.00002	0.00004	0.00009	0.00000	0.00016
Acenaphthylene	0.00003	0.00007	0.00014	0.00000	0.00024
Acetaldehyde	0.03940	0.08174	0.22316	0.00626	0.35055
Acrolein	0.00186	0.00370	0.00784	0.00025	0.01365
Ammonia	0.02828	0.08823	0.21103	0.00668	0.33422
Anthracene	0.00003	0.00007	0.00014	0.00000	0.00024
Arsenic	0.00004	0.00125	0.00354	0.00011	0.00494
Benz[a]Anthracene	0.00003	0.00007	0.00015	0.00000	0.00026
Benzene	0.01079	0.02167	0.04800	0.00148	0.08193
Benzo[a]Pyrene	0.00001	0.00002	0.00005	0.00000	0.00008
Benzo[b]Fluoranthene	0.00001	0.00004	0.00009	0.00000	0.00015
Benzo[g,h,I,]Perylene	0.00001	0.00002	0.00003	0.00000	0.00006
Benzo[k]Fluoranthene	0.00001	0.00002	0.00005	0.00000	0.00008
Beryllium	0.00000	0.00000	0.00001	0.00000	0.00002
Cadmium	0.00001	0.00017	0.00049	0.00002	0.00068
Chromium	0.00000	0.00005	0.00024	0.00001	0.00030
Chromium III	0.00005	0.00094	0.00263	0.00008	0.00370
Chromium VI	0.00002	0.00048	0.00135	0.00004	0.00190
Chrysene	0.00001	0.00001	0.00003	0.00000	0.00005
Cobalt	0.00000	0.00102	0.00295	0.00009	0.00407
Copper	0.00247	0.00726	0.01713	0.00054	0.02740
Dibenzo[a,h]Anthracene	0.00000	0.00000	0.00000	0.00000	0.00000
Dioxin	0.00000	0.00000	0.00000	0.00000	0.00000
Ethylbenzene	0.00106	0.00212	0.00448	0.00014	0.00780

Pollutant Name	Stamford	Bridegport	New Haven	New London	State Total
Fluoranthene	0.00002	0.00004	0.00008	0.00000	0.00015
Fluorene	0.00004	0.00009	0.00019	0.00001	0.00032
Formaldehyde	0.07933	0.17957	0.72420	0.01746	1.00056
HCB	0.00000	0.00000	0.00000	0.00000	0.00000
Indeno[1,2,3-c,d]Pyrene	0.00001	0.00004	0.00009	0.00000	0.00015
Lead	0.00021	0.00060	0.00150	0.00005	0.00237
Manganese	0.00000	0.00039	0.00131	0.00004	0.00174
Mercury	0.00000	0.00000	0.00001	0.00000	0.00001
Naphthalene	0.00119	0.00250	0.00539	0.00017	0.00926
n-Hexane	0.00292	0.00582	0.01232	0.00039	0.02145
Nickel	0.00141	0.04232	0.12483	0.00388	0.17244
PCB	0.00000	0.00000	0.00000	0.00000	0.00001
Phenanthrene	0.00005	0.00010	0.00022	0.00001	0.00037
Phosphorous	0.00000	0.03820	0.11009	0.00350	0.15179
POM as 16-PAH	0.00000	0.00016	0.00052	0.00002	0.00069
POM as 7-PAH	0.00000	0.00000	0.00001	0.00000	0.00001
Propionaldehyde	0.00323	0.00646	0.01366	0.00043	0.02379
Pyrene	0.00003	0.00007	0.00015	0.00000	0.00026
Selenium	0.00000	0.00003	0.00011	0.00000	0.00014
Styrene	0.00111	0.00222	0.00470	0.00015	0.00819
Toluene	0.00170	0.00339	0.00717	0.00023	0.01248
Xylene	0.00255	0.00508	0.01075	0.00034	0.01872
Zinc	0.00141	0.00457	0.01101	0.00035	0.01734

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Appendix B.1

EPA 2008 National Emission Inventory

Locomotive Hazardous Air Pollutant Speciation Profiles

Table B.1-1. Locomotive HAP Profiles

Pollutant Name	Fraction	Speciation Base
1,3 Butadiene	0.0047735	PM10
2-2-4 Trimethylpentane	0.0022425	VOC
Acenaphthene	0.0000306	PM10
Acenaphthylene	0.0004275	PM10
Acetaldehyde	0.0276274	PM10
Acrolein	0.0045943	PM10
Anthracene	0.0001009	PM10
Arsenic	0.0000004	PM10
Benzene	0.0038020	PM10
Benzo(a)anthracene	0.0000160	PM10
Benzo(a)pyrene	0.0000027	PM10
Benzo(b)fluoranthene	0.0000064	PM10
Benzo(ghi)perylene	0.0000031	PM10
Benzo(k)fluoranthene	0.0000052	PM10
Beryllium	0.0000280	PM10
Cadmium	0.0000280	PM10
Chromium (III)	0.0000040	PM10
Chromium (VI)	0.0000021	PM10
Chrysene	0.0000119	PM10
Dibenz(a,h)anthracene	0.0000000	PM10
Ethylbenzene	0.0020000	VOC
Fluoranthene	0.0000746	PM10
Fluorene	0.0001407	PM10
Formaldehyde	0.0636582	PM10
Indeno(1,2,3-cd)pyrene	0.0000027	PM10
Lead	0.0000840	PM10
Manganese	0.0000020	PM10
Mercury	0.0000280	PM10
Napthalene	0.0025756	PM10
n-Hexane	0.0055000	VOC
Nickel	0.0000066	PM10
Phenanthrene	0.0005671	PM10
Propionaldehyde	0.0061000	VOC
Pyrene	0.0001054	PM10
Styrene	0.0021000	VOC
Toluene	0.0032000	VOC
Xylene	0.0048000	VOC

Appendix B.2

EPA 2008 National Emission Inventory

Marine Vessel Hazardous Air Pollutant Speciation Profiles

Table B.2-1. Marine Vessel HAP Profiles - Diesel

Pollutant Name	Category 1&2		Category 3	
	Fraction	Speciation Base	Fraction	Speciation Base
2,2,4-trimethylpentane	0.00025	VOC		
Acenaphthene	0.000015	PM2.5	3.4E-07	PM2.5
Acenaphthylene	2.3125E-05	PM2.5	5.25E-07	PM2.5
Acetaldehyde	0.04643625	VOC	0.000229	VOC
Acrolein	0.0021875	VOC		
Ammonia	0.02	PM10	0.00477	PM10
Anthracene	2.3125E-05	PM2.5	5.25E-07	PM2.5
Arsenic	0.00003	PM10	0.0001748	PM10
Benz[a]Anthracene	0.000025	PM2.5	5.67E-07	PM2.5
Benzene	0.012715	VOC	0.0000098	VOC
Benzo[a]Pyrene	0.000005	PM10	8.741E-07	PM10
Benzo[b]Fluoranthene	0.00001	PM10	1.748E-06	PM10
Benzo[g,h,I,]Perylene	5.625E-06	PM2.5	1.28E-07	PM2.5
Benzo[k]Fluoranthene	0.000005	PM10	8.741E-07	PM10
Beryllium			5.46E-07	PM10
Cadmium	0.00000515	PM10	0.0000226	PM10
Chromium III	0.000033	PM10	0.0001267	PM10
Chromium VI	0.000017	PM10	6.528E-05	PM10
Chrysene	4.375E-06	PM2.5	9.93E-08	PM2.5
Cobalt			0.0001538	PM10
Copper	0.00175	PM10	0.0003477	PM10
Dioxin	5E-09	PM10	8.741E-10	PM10
Ethylbenzene	0.00125	VOC		
Fluoranthene	0.00001375	PM2.5	3.12E-07	PM2.5
Fluorene	3.0625E-05	PM2.5	6.95E-07	PM2.5
Formaldehyde	0.0935	VOC	0.00157	VOC
HCB	0.00000004	PM10	6.993E-09	PM10
Indeno[1,2,3-c,d]Pyrene	0.00001	PM10	1.748E-06	PM10
Lead	0.00015	PM10	0.0000262	PM10
Manganese	1.275E-06	PM10	0.0000573	PM10
Mercury	0.00000005	PM10	5.245E-07	PM10
Naphthalene	0.00087563	PM2.5	0.0000199	PM2.5
n-Hexane	0.0034375	VOC		
Nickel	0.001	PM10	0.00589	PM10
PCB	0.0000005	PM10	8.741E-08	PM10
Phenanthrene	0.000035	PM2.5	7.94E-07	PM2.5
Phosphorous			0.0057343	PM10
POM as 16-PAH			0.0000249	PM2.5

Table B.2-1. Marine Vessel HAP Profiles - Diesel

Pollutant Name	**Category 1&2**		**Category 3**	
	Fraction	**Speciation Base**	**Fraction**	**Speciation Base**
POM as 7-PAH			2.658E-07	PM10
Propionaldehyde	0.0038125	VOC		
Pyrene	2.4375E-05	PM2.5	5.53E-07	PM2.5
Selenium	5.15E-08	PM10	3.48E-06	PM10
Styrene	0.0013125	VOC		
Toluene	0.002	VOC		
Xylene	0.003	VOC		
Zinc	0.001	PM10	0.0002622	PM10

Table B.2-2. Marine Vessel HAP profiles - Boilers

Pollutant	Fraction	Speciation Base
Acetaldehyde	3.86E-03	VOC
Benzene	1.65E-04	VOC
Formaldehyde	2.65E-02	VOC
POM as 7-PAH	4.50E-07	PM
POM as 16-PAH	4.56E-05	PM
Beryllium	1.09E-06	PM
Cadmium	1.52E-05	PM
Chromium	3.26E-05	PM
Lead	5.97E-05	PM
Manganese	1.14E-04	PM
Nickel	3.26E-03	PM
Selenium	2.66E-05	PM

APPENDIX C: FINDINGS OF INTERVIEWS WITH MOTOR CARRIERS, SHIPPERS, INDUSTRY ASSOCIATIONS, AND OTHER COMPANIES INVOLVED IN TRANSPORTING GOODS

Cambridge Systematics

This appendix summarizes the findings of our interviews with motor carriers, shippers, industry associations, the railroads, and other companies involved in transporting goods into and out of the State of Connecticut. The majority of the interviews were conducted during a visit to the state on February 22 and 23, 2012, with follow-up discussions conducted by phone over the following two weeks. The primary purpose of the interviews was to better understand current logistics patterns in the state, discuss strategies for reducing the environmental impacts associated with freight movement, and explore anticipated future trends. A total of 16 organizations were interviewed – seven shippers (including household, petroleum, waste and recycling, and food/juice products), one stevedore, one trucking association, one truck manufacturer, three motor carriers/distributors, and two short-line railroads. The list of interviewees is presented in Appendix C.1.

Key findings are discussed on the following topics:

- Mode choice and modal shift potential;
- Operations and backhaul;
- Shipper efforts to mitigate environmental impacts from freight;
- System constraints;
- Future trends; and
- Public policy opportunities.

Mode Choice and Modal Shift Potential

Current modal use and the reasons for modal choices were explored, along with consideration of alternative mode use (in particular, shifting from truck to rail), and motivations and constraints for such shifting.

- Shippers interviewed utilized both the truck and rail modes (where available); however, rail use has been declining across the board due largely to several cost issues and institutional constraints. These issues including the following (the number of interview subjects that reported the issue are included in parentheses):
    - **Fuel surcharges** that increase the cost of shipping on both the truck and rail modes. Certain carriers apply the surcharge more judiciously than others, prompting some shippers to explore alternatives. (6)
    - **263,000 lb. weight limits on the railroads** which leads to some shippers having to light load rail cars and reducing competitiveness with truck. (4)
    - **Siding access**. Some shippers might be interested in using rail because of the nature types of commodities they ship (heavy or bulk product), the distance of their suppliers or customers, or the profit margin of their product but do not have appropriate access to the rail network, either because of a deficient or non-existent siding or internal operations that preclude efficient connections to the siding. (3)
    - **Lack of an intermodal terminal in Connecticut**, which necessitates collecting long distance cargo at facilities out of state and draying the cargo by truck to the final destination. (5)

    - **Interchanges between multiple railroads and/or complicated negotiations with multiple carriers.** These can drive up cost, add time to the cargo delivery, and make arranging logistics very difficult, discouraging potential shippers from using rail and making arrangements to utilize truck for their needs. (3)
    - **Lack of rail boxcars**. One shipper, whose business (distributing heavy, bulky commodities, with relatively low margins moving long distances) who would otherwise benefit from using rail is prompted to use trucks for nearly all shipments because of a shortage of boxcars. (1)
- For many users, rail hit a peak right before the recession, sometimes when rail teaser rates were offered, making this option more competitive with trucking. There is generally a lack of competition in the railroad industry which was cited by many shippers (both current and potential users of rail) as contributing to higher rates and deteriorating service. Some rail customers own and maintain railcars, but this was reported as adding expense to an already expensive service.
- Cost is by far the biggest influence on the choice of mode, followed by reliability in the delivery schedule, and contract arrangements with carriers. Shipper relationships with carriers are often based on contracts and history and many have regular and consistent deliveries to customers. There may be a growing use of the spot freight market, but relationships still rule the day.
- Most shippers interviewed reported deliveries arriving at the terminal or warehouse having already been consolidated into 53' trailers. Several shippers noted this transloading occurring out of state at the intermodal yards in Massachusetts, New York, or New Jersey. Because there are no truck to rail intermodal facilities in Connecticut, product sent by rail to shippers in the state from very long distances has to be trucked to final destinations in Connecticut, likely causing long truck trips from the intermodal facility.

Operations and Backhaul

The interviews explored the extent to which shippers were improving fuel and load efficiency through more efficient operations, including reducing empty backhaul, focusing their efforts on shorter and intra-regional quicker turns, performing multiple deliveries during the day, more overall efficient routing, local sourcing, and other strategies. The potential for doing so further was also explored.

- For outbound shipments, truck drivers are generally dispatched by the local companies themselves or by a central office. For inbound shipments, customers or vendors typically make the arrangements with either a broker or the carriers. Trucks are both owned by the companies themselves or by a leasing company (such as Ryder). For businesses with seasonal delivery schedules, they may supplement their own fleet with owner-operators. There are benefits to both models: businesses with their own fleets have greater flexibility in using their own dispatching to maximize efficiency and/or explore alternatives/upgrades to the fleet; and leasing companies may have a greater economy of scale to make wholesale changes to their fleets to take advantage of the newest and most efficient technologies or maintenance techniques.
- Shippers are generally making efforts to pick the "low-hanging fruit" in maximizing efficiency in operations, for example, by reducing delivery schedules, conducting early or late dispatching to

avoid congestion, and consolidating larger less-than-truckload deliveries (i.e. by waiting an extra day for a fuller load).

- To the extent possible, shippers appear to be working to minimize empty backhauls, either by arranging backhauls themselves, or by working through a broker. However, imbalances in flows, logistical challenges, and incompatibility issues all hinder further efforts to fill empty trucks. For example, tankers cannot usually carry backhauls. Also, Connecticut is not a major manufacturer or natural resource producer, but has a large population. Therefore, most goods are shipped into the state rather than outbound, and waste is the primary export. (One result of this is that it is more expensive to ship goods into the state than out, because of the difficulty of finding a backhaul.) Some carriers develop relationships with multiple shippers and route their deliveries to capture a backhaul (e.g., delivering sand from Eastern to Western Connecticut and picking up a contaminated soil load for delivery in Western Massachusetts). Waste shippers act as the backhaul for many carriers delivering other commodities (e.g., consumer products), especially to urban areas. However, opportunities for additional backhauls appear limited.
- There was some interest by shippers to source more materials locally (such as animal feed), but it is difficult in many of these industries that have specialized needs (such as petroleum products, or specific type of stone). One interviewee noted that they would need to purchase new or upgraded equipment (in this case, a corn dryer) in order to be able to make use of locally sourced materials.
- Most shippers and carriers reported using global positioning systems (GPS) and/or other technological systems such as Computerized Fleet Analysis (CFA) to improve efficiency and manage their fleet. Many, but not all, have identified some savings in fuel use from the use of GPS. Some shippers and carriers report that they trust their drivers to know the most efficient routes and do not see a benefit to GPS systems.
- Some interviewees have worked to identify vendors closer in to reduce travel time and cost of fuel (e.g., smaller catchment area for terminals, customers arrange pick-up rather than product being distributed).

Shipper Efforts to Mitigate Environmental Impacts from Freight

The interviews explored the extent to which shippers had undertaken or considered other actions to mitigate their environmental impacts, including conversion to alternative fuels, purchase of newer or cleaner equipment, and pricing strategies.

- There is almost universal application of fuel surcharges for both truck and rail carriers. The primary objective of these is to recover transportation costs imposed by higher diesel prices. Surcharges may affect both truck and rail as they were cited by different interviewees both as making rail less competitive, and making it more difficult to competitively run a trucking operation. The rising costs of using diesel fuel (with the associated surcharges) for shippers have raised the profile of newer conventional trucks and/or alternative fuels. Shippers are starting to look more closely at the economics of converting or utilizing more efficient conventional vehicles (i.e. newer model year trucks).

- Some shippers have considered alternative fuels, primarily compressed natural gas (CNG) or liquid natural gas (LNG). This was especially considered by waste haulers and larger fleets who can afford to install refueling facilities and convert or purchase vehicles. Pilot programs are underway for some to evaluate the costs and other issues (maintenance, performance). Smaller shippers see some value in these types of vehicles (due to cheaper natural gas), but the capital costs associated with changeover (fueling facilities, new trucks) generally make it cost prohibitive at this point, and a lack of publicly-accessible fueling stations makes it most practical for centralized fleets that do not travel far. Although it was generally recognized by interviewees that CNG/LNG fuel itself currently costs less than diesel and the domestic supplies might contribute to lower long term costs for the fuels, many interviewees noted that the economics are not currently there when conversion costs are considered. However, some thought it a potentially good long-term investment to convert. Many already use natural gas for heating and other uses and would be able to connect into the pipeline grid.
- Fuel efficiency standards have risen on newer trucks and are more attractive in an environment of higher prices. Companies have also invested in new, fuel-efficient technology (both truck and rail) to save costs. However, recent emissions control regulations have raised the price of equipment and fuels, although they have also resulted in cleaner vehicles.
- Interviewees reported the use of auxiliary power units (APUs) to reduce idling, but according to a truck manufacturer, APUs are in use on only a small percentage of trucks (less than 5 percent). Similarly, usage of electrified hook-ups at truck stops is only about 5 percent or less.
- Interviewees claim that they keep their vehicles in very good shape and usually perform their own maintenance or utilize a preferred vendor for maintenance services. One large scale shipper indicated using computerized fleet analysis to perform maintenance tasks.

System Constraints

Infrastructure constraints to more efficient freight movement were discussed. These may include highway traffic congestion, lack of connections requiring more circuitous routing, and rail infrastructure limitations that hinder competitiveness.

- I-95 and the Merritt Parkway were cited by many users as major bottlenecks in the state that have congestion issues, with few routing alternatives. Low bridges throughout the state requiring some circuitous routing for local shipments were reported, although no specific bridges were identified.
- To avoid congestion, shippers and carriers employ a variety of strategies, including alternative routing (only on rare occasions), avoiding peak-period traffic through an earlier start to the day, and consolidation of shipments. Due to congestion, lack of rest areas, and high fuel taxes, Connecticut was characterized as "not a truck-friendly state."
- Inland petroleum terminals have been closing throughout the region, causing distributors to have to travel further for product. Another issue is the lack of redundancy in the network. For example, when facilities are shut down for emergencies, like a major hurricane, there are few, if any alternatives.

- Weight issues on many railroads continue to be a major constraint. Many of the railroads allow only 263,000 lb. cars on their networks, requiring light loading to connect to the Class I and making rail less competitive with truck on a cost basis. Example cited include the Connecticut River Bridge as well as the Pan Am Southern (PAS), Providence & Worcester (P&W), and New England Central Railroad (NECR) systems.
- Overweight permits and weight limits are an issue for Connecticut shippers. They have trouble competing with neighboring states with higher limits (i.e. 80,000 lbs. maximum versus 100,000 lbs. maximum in Massachusetts and Rhode Island) and require light loading for distribution to other states. This also applies to tanker trucks, which are subject to more restrictive weight limits in Connecticut. These lower maximum weights can potentially contribute to increased VMT (and associated diesel fuel/emissions) by requiring additional trips to ship the same volume of cargo.

Future Trends

Interviewees were asked to discuss future trends that they expected to affect the volume, types, or mode of commodity movement.

- Growth in freight is expected across the board. Continued growth is expected in inbound consumer products and outbound waste. There was some expectation of industry consolidation and less frequent/larger deliveries to customers.
- Some of the interviewees are bullish on expansion of the existing commodity mix in Connecticut (e.g., sand and stone outbound) while others are focused on relatively new markets (e.g., distribution of ethanol).
- Partnerships between the railroads are increasing (e.g., NECR and P&W) and they expressed an increasing interest in intermodal shipping, despite the lack of an intermodal terminal in the state.
- Growing use of cleaner and newer vehicles for truck and rail will include expanded use of APUs and more fuel-efficient vehicles.

Public Policy Opportunities

Interviewees were asked about state provided programs or incentives that might encourage them to adopt emissions-reducing practices such as shifting to rail, purchasing cleaner equipment, or making their operations more efficient.

- A number of interviewees noted that they had considered rail but there are existing barriers. There is strong interest in funding programs or support for the following:
    - Improved rail short line weight limits upgrades to 286,000 lbs. and higher weight limits for trucks on highways. (There has been some movement on this in the state legislature towards exempting APUs from weight limits.)
    - Industrial access funding for shippers, including support to reconfigure operations for use of rail. This might include not only support for rail access (e.g., maintenance of spurs and track) but also support for business to reconfigure internal operations to

provide efficient access to the rail spur. Most of the spurs are very old and many are legacy from other firms or previous operations that might not make operational sense to use any longer. An example from the interview was to assist the conversion of lumber properties on an existing railroad.

  - Newer vehicles and alternative fuel capital support, including fueling stations and fleet turnover support, which would particularly help smaller operators make the conversion; as well as publicly-accessible fueling stations. Cost assistance (up-front costs) to set up facilities provide the most value, rather than tax breaks. The break-even point should come in five to seven years or less.

- A strong current incentive in Connecticut for upgrading the carrier fleet is the five-year property tax exemption for new vehicles, although the state recently eliminated the payment in lieu of taxes (PILOT) reimbursement to municipalities for lost property taxes. The state also offers sales tax exemptions for new or used vehicles; however, few take advantage of this program.[1]
- The technology associated with "greener" trucks and locomotives is improving and conversion to newer vehicles is accelerating. For example, newer trucks (2007 or newer) are much more fuel efficient than previous model years and most also include emissions reduction components. Alternative fuel vehicles are also becoming more readily available; however, fuel cost savings are currently offset by a very high initial cost and long savings/recovery period. Due to this greater acceptance of these newer vehicles and market incentives to converting to more fuel efficient vehicles, policy makers have an opportunity to implement and expand programs to promote upgrading the fleet.

[1] This information is being further researched as it may have changed recently.

Appendix C.1 Interviewees

Table C.1-1 Interviewees

Interview Company	Industry Type	Location
Viking Kitchen Cabinets	Shipper	New Britain
USA Recycling	Shipper	Enfield
Central Connecticut Food Co-op	Shipper	Manchester
New England Silica Inc	Shipper	South Windsor
Country Pure Foods (specialty juice manufacturer)	Shipper	Ellington
Willimantic Waste Paper Company	Shipper	Willimantic
Yale New Haven Hospital[2]	Shipper	New Haven
Allen S Goodman (wholesale beer and liquor)	Shipper	East Hartford
Hess	Shipper	Groton
Logistec USA	Carrier/Terminal Operator	New London
CB White and Sons (tank truck operator)	Carrier/Terminal Operator	Rocky Hill
A.P Marquardt Inc (tank truck operator)	Carrier/Terminal Operator	Groton
Motor Transport Association of Connecticut	Carrier/Terminal Operator	Hartford
Housatonic Railroad	Railroads and Other	Canaan
Rail America -- holding company for both the Connecticut Southern Railroad (CSO) and the New England Central Railroad (NECR)	Railroads and Other	St. Albans, VT
Volvo Group North America	Railroads and Other	Greensboro, NC

[2] The Hospital does not have a dedicated shipping fleet, but does manage hundreds of deliveries a day at its campus.

APPENDIX D: ASSESSMENT OF TECHNOLOGY STRATEGIES

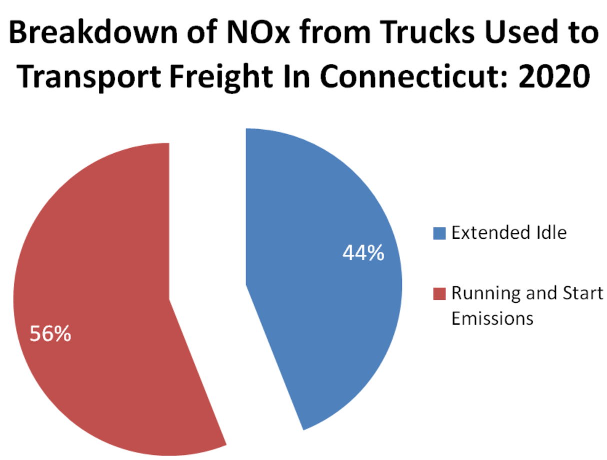
Overview of Technology Strategies

Technology Strategies reduce emissions per ton-mile. The analysis in this appendix focuses primarily on trucks since they account almost all the emissions associated from freight movement. The following strategies were evaluated:

1. Reduce or eliminate extended idling.
2. Implement a remote OBD inspection/maintenance (I/M) program.
3. Replacement with Natural Gas Vehicles.
4. Accelerated vehicle retirement for drayage fleets.
5. SmartWay retrofits.
6. Rail/Port strategies

1. Reduce or Eliminate Extended Idling

a. Strategy Overview
    i. 80% of freight-related NOx emissions come from long-haul tractor trailers:
        1. These vehicles often idle for long periods while the driver is resting.
        2. By 2020, about half of the NOx from long-haul tractor trailers is due to extended idling.
        3. Truck stop electrification, auxiliary power units (APUs), and other devices can be used to eliminate extended idling operation.



    ii. Truck-stops in Connecticut have limited parking spaces available, so truck stop electrification, although cost effective (~$2,000/ton NOx), will not be able to eliminate extended idling.
        1. Existing parking demand exceeds supply by 1,400 spaces
        2. Deficit increase to 2,000 spaces by 2025
    iii. Options to reduce extended idling include:

1. Auxiliary Power Units (APUs), diesel power assumed, covers all accessories, heating, cooling
2. Direct Fired Heaters (DFH), diesel power assumed, heating only (32% of idle time assumed – national average)
3. Battery A/C, can be charged from engine or charged using shorepower; cooling only (40% of idle time assumed – national average)

iv. Key drivers include:
1. significant fuel cost savings
2. emission reduction benefits
3. reduced engine wear
4. relatively low cost (<$10K); low weight (~ 400 lbs for an APU)
5. known costs and demonstrated performance – low risk

b. Equipment Costs

Equipment and O&M costs from literature:

	Equipment	O&M
APU	$9,000	$180/yr
DFH	$888	$200
Battery A/C	$4,300	$110

c. Emission Reduction Potential

i. Calculated for all scenarios with payback in < 10 yrs.
ii. Assumes full market penetration (upper bound).

	TPY Reduction		
	CO2	NOx	PM2.5
APUs TPY	49,670	1,798	2.28
% of EI	4.6%	45.0%	3.8%
DFH TPY	24,219	717	1.63
% of EI	2.3%	17.9%	2.7%
Batt A/C TPY	23,659	750	1.02
% of EI	2.2%	18.7%	1.7%

2. Remote OBD I/M Programs

a. Strategy Overview

i. I/M programs inspect vehicles for evidence of their emissions output. High emitting vehicles must be repaired until they meet standards.
ii. Connecticut's I/M program for light-duty vehicles is a key part of the State's attainment plan.

iii. Recently, there's been considerable interest in I/M programs for heavy-duty vehicles.
iv. Engines used in heavy-duty trucks built since 2010 emit less than 5% of the NOx and PM emitted from a 2006 or earlier model engine.
    1. 2010 and later models are equipped with catalytic NOx controls and diesel particulate filters that greatly reduce emissions.
    2. However, these devices must be maintained to keep emissions low. Often this requires refilling a reagent tank.
    3. 2013 and later model trucks will be equipped with OBDII systems that will identify trucks needing maintenance.
    4. Remotely monitoring OBDII systems (Remote OBD) by equipping trucks with wireless transponders will help assure continued low emission operation.
v. With remote OBD, trucks will be equipped with transponders that are plugged into the vehicle's OBD port. These transponders will transmit OBD status to receivers along the highway, e.g., at weigh stations.
    1. Remote OBD avoids the inconvenience of having to stop and test each truck.
    2. Remote OBD inspections can be tied into other electronic initiatives.
    3. Transponders are estimated to cost ~ $275.
    4. Annual costs are ~ $125.

b. Emission Reductions
    i. Remote OBDII inspections will help Connecticut realize the full benefits of the stringent Federal Emissions Standards and OBDII systems.
        1. In 2020, remote OBD inspections are estimated to reduce NOx emissions by 1 to 2 ton/day.
        2. In 2040, remote OBD inspections are estimated to reduce NOx emissions by 2 to 4 ton/day.
        3. Remote OBD inspections are estimated to cost $1,700 to $3,500 per ton of NOx removed, assuming they are tied into other electronic initiatives such as CVISN.

3. Replacement with Natural Gas Vehicles

a. Strategy Overview
    i. Running on Natural Gas has potential to significantly reduce CO2 emissions.
    ii. At present CNG and diesel prices, Natural Gas has potential to save fleet owners considerable fuel expense.
    iii. Replace conventional diesel/gasoline freight trucks with comparable natural gas vehicles in 2020.
    iv. Assume CNG for light commercial and single unit trucks; LNG for combination trucks
        1. Light Commercial => large pickups; small delivery vans
        2. Single units => panel vans up to large class 7 trucks

3. Combination units => tractor-trailer rigs

v. Key drivers include:

1. significant fuel cost savings on an equivalent-gallon basis:
   a. Cost estimates include refueling infra-structure, which can be more than $1,000,000 per natural gas refueling station.
2. substantial CO2 reduction
3. potential maintenance savings relative to gasoline engines

b. Fuel Cost

i. $/gal estimates from Alternative Fuel Data Center seasonal survey for New England, January 2012 (retail public access)

Fuel costs	$/equiv gal
Diesel	$4.08
Gasoline	$3.51
CNG (gasoline gallon equivalent)	$2.43*
LNG (diesel gallon equivalent)	$1.89*

*Cost includes infrastructure. Fuel cost alone is les than $1/gallon equivalent.

c. Scenario 1 – End of Life Replacement

i. Replace conventional diesel/gasoline trucks at end of useful life with comparable natural gas vehicle (NGV); CNG for light commercial / single units, LNG for combination trucks. Incremental cost for NGV:
   1. Single use trucks: $9,000 over diesel, $15,000 over gasoline.
   2. Combination short haul trucks: $40,000 over diesel.
   3. Combination long haul trucks: $80,000 over diesel.

ii. No cost associated with early vehicle retirement.

iii. Incremental costs include fuel, vehicle, and O&M.

iv. Incremental emission impacts based on MOVES for conventional vehicles; literature search for NGVs.

v. Payback in less than 5 years is possible for replacing all diesel powered truck categories with NGVs.

vi. Gasoline powered trucks have much longer payback periods, primarily because they are driven less, so there's less projected fuel savings.

d. Scenario 2 – Existing Vehicle Replacement

i. Investigates further market penetration potential for NGVs

ii. Start by replacing oldest model year still in service first (1990 assumed), in 2020.

iii. Maximum model year replacement in 2020 providing net savings over 10 years:

Vehicle/Fuel	Max Model Year Group
Light Commercial - Diesel	1990 – 1998
Single Unit Short Haul - Diesel	1990 – 1994
Single Unit Long Haul - Diesel	1990 – 1994
Combo Short Haul - Diesel	1990 – 2002
Combo Long Haul - Diesel	1990 – 2003

iv. Replacement of gasoline powered vehicles has payback > 10 years.

e. Maximum Emission Reductions (TPY)

Vehicle/Fuel Type	NOx	PM2.5	CO2
Lt Com - Diesel	50.8	1.8	8,930
Combo Short - Diesel	60.5	2.6	7,321
SU Short - Diesel	100	4.4	11,688
SU Long - Diesel	91	3.0	10,056
Combo Long - Diesel	858	32	122,245

f. Drayage Trucks
   i. Drayage trucks are a subset of short haul combination trucks.
   ii. Typically older/higher emitting than average.
   iii. Central access point and standard routes are favorable to alternative fuel application.

g. Drayage Trucks – NGV Payback and Emission Reduction Potential
   i. Assume same system required as for long-haul units (~$80,000 incremental price).
   ii. End of Life replacements can obtain payback in 6 - 7 years.
   iii. Emission reduction potential is very high for dray vehicles, due to their age: *replacing entire fleet would decrease dray CO2 emissions by 27%, NOx by 83%, and PM2.5 by 93% in first year of operation.*
   iv. Recommend survey of dray fleet VMT/age distribution for further characterization.

4. Accelerated Drayage Truck Retirement

a. Strategy Overview
   i. Early retirement for drayage trucks with new diesel trucks in 2020.
   ii. PM and NOx reduction is primary driver.
   iii. Some fuel savings through efficiency improvements.
   iv. Costs include:
      1. Cost of early purchase (cost of capital, i.e. discount rate)
      2. Resale (residual) value of retired trucks assumes straight line depreciation over useful life.

b. Payback and Emissions Benefits
   i. Payback:

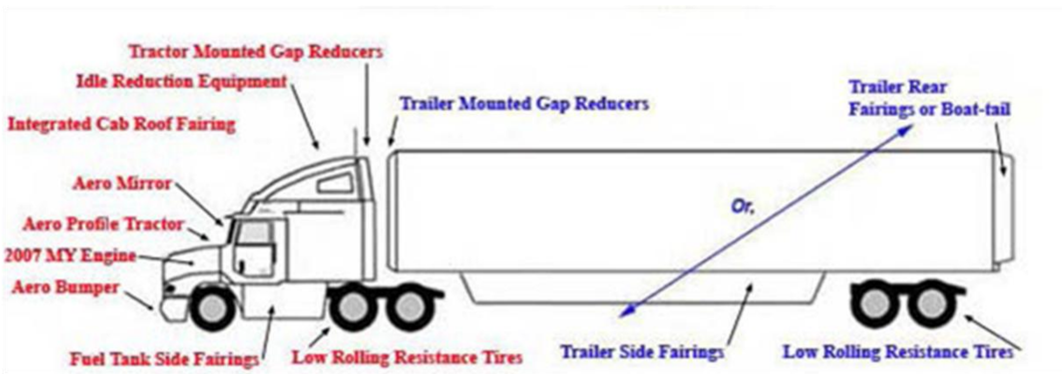
1. Fuel economy improvement by 2020 is significant (17% vs. dray fleet average) allowing payback for replacing all vehicles > 10 yrs old.

ii. Emissions Benefits:

1. Calculated for all scenarios with payback in < 10 yrs
2. Assumes full market penetration (upper bound)

Scenario	TPY Reduction		
	CO_2	NOx	PM2.5
Dray Fleet	9,018	254	12.62
% of Dray Fleet Emissions	10.4%	79.9%	91.7%

5. SmartWay Retrofit



a. Strategy Overview

i. Retrofit in-use trucks in 2020 with SmartWay-certified products.

ii. Aerodynamic treatments – long-haul combination trucks (front, side, rear trailer fairings); front fairings for single-unit trucks

iii. Low rolling resistance (LRR) tires, aluminum wheels for all but light commercial trucks

iv. Fuel savings is primary driver, some NOx reduction through reduced engine loads.

b. Estimated Costs and Emission Reductions

Truck Type	Cost	CO_2 Reduction**	NOx Reduction**
Long haul combination trucks	$10,495 / $23,840*	11.3%	15.6%
Short haul combination trucks	$5,500	9.2%	5.9%
Single Unit trucks	$3,255	7.5%	15.6%

*1 trailer per tractor / 2.5 trailers per tractor

** Full Market Penetration

c. Payback Evaluation
    i. Cash flow developed for each model year.
    ii. Payback for diesel powered trucks in 2 to 8 years; lowest for newest model year trucks.
    iii. No payback for gasoline trucks.

Strategies for Rail and Ports

Cost- effective strategies have been identified for rail and ports, but the overall impact on the emission inventory will be small.

Possible strategies:

- Prohibit extended idling for trucks at ports. Use same technologies previously described: APUs, DFH, etc.
- Require low emission gensets in yards.
- Re-engine and change propellers in tugs.
- Operational changes such as reduced speed zones.

Cold Ironing (Use of shore power at ports) does not appear to be cost effective.

1. **Rail Emission Control Options:**
    a. Yard Engines - Gen-sets
        i. Upgrade yard engines to comply with Tier III non-road engine standards, as well as the EPA's Tier III and IV locomotive standards, including idle reduction requirements:
            1. NOx reduction from 60% to 90 %.
            2. PM reductions around 80 %.
            3. Fuel savings from 20 to 50%.
            4. Purchased as a new locomotive - $1.5 to 2 million or as a repower option - $1 million
            5. Drastically reduces idling and associated emissions.
            6. $3,800 per ton of NOx removed
2. **Marine Emission Control Options**
    a. Cold Ironing
        i. Cold ironing = use of electricity from the grid to power electrical engines aboard vessels while Dockside.
            1. Costly option: $15,000 - $30,000 per ton of NOx
            2. $1.5 to 3 million for the landside infrastructure.
            3. $500,000 - $750,000 per vessel to retrofit vessels to use a cold ironing system

Detailed Analysis of Technology Strategies

1. **NGV Replacement Strategy**
    a. Strategy Overview
        i. Replace conventional diesel/gasoline freight trucks with comparable natural gas vehicles in 2020
        ii. Assume CNG for light commercial and single unit trucks; LNG for combination trucks
            1. Light Commercial => large pickups; small delivery vans
            2. Single units => panel vans up to large class 7 trucks
            3. Combination units => tractor-trailer rigs
        iii. Evaluation at the vehicle type level – not fleet-specific
        iv. Key drivers include:
            1. significant fuel cost savings on an equivalent-gallon basis
            2. substantial CO2 reduction benefits
            3. potential maintenance savings relative to gasoline engines
    b. Baseline Activity
        i. *Consider effects of fleet turnover and decreasing mileage with age, for both baseline (BAU) and replacement scenarios*
        ii. *Evaluate over 10 year operation period*
            1. *Example vehicle population – diesel combination short hauls*

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
1990	7	0	0	0	0	0	0	0	0	0
1991	5	5	0	0	0	0	0	0	0	0
1992	84	5	5	0	0	0	0	0	0	0
1993	98	84	5	5	0	0	0	0	0	0
1994	111	98	84	5	5	0	0	0	0	0
1995	125	111	98	84	5	5	0	0	0	0
1996	138	125	111	98	84	5	5	0	0	0
1997	152	138	125	111	98	84	5	5	0	0
1998	166	152	138	125	111	98	84	5	5	0
1999	179	166	152	138	125	111	98	84	5	5
2000	193	179	166	152	138	125	111	98	84	5
2001	207	193	179	166	152	138	125	111	98	84
2002	220	207	193	179	166	152	138	125	111	98
2003	234	220	207	193	179	166	152	138	125	111
2004	248	234	220	207	193	179	166	152	138	125
2005	261	248	234	220	207	193	179	166	152	138
2006	275	261	248	234	220	207	193	179	166	152
2007	288	275	261	248	234	220	207	193	179	166
2008	302	288	275	261	248	234	220	207	193	179
2009	316	302	288	275	261	248	234	220	207	193
2010	329	316	302	288	275	261	248	234	220	207
2011	343	329	316	302	288	275	261	248	234	220
2012	357	343	329	316	302	288	275	261	248	234
2013	370	357	343	329	316	302	288	275	261	248
2014	384	370	357	343	329	316	302	288	275	261
2015	531	384	370	357	343	329	316	302	288	275
2016	559	531	384	370	357	343	329	316	302	288
2017	587	559	531	384	370	357	343	329	316	302
2018	615	587	559	531	384	370	357	343	329	316
2019	643	615	587	559	531	384	370	357	343	329
2020	671	643	615	587	559	531	384	370	357	343
Total	**8,995**	**8,323**	**7,680**	**7,065**	**6,479**	**5,920**	**5,390**	**5,006**	**4,636**	**4,279**

c. Vehicle Activity/Performance
    i. MOVES provides conventional vehicle g/mi and MPG
    ii. Adjust fuel consumption to reflect impact of proposed National HD program (not in MOVES – from AEO, ~ 20%)
    iii. NGV emission rates
        1. Fuel consumption/CO2 from AEO and literature
        2. NOx and PM assumed to equal 2020 gasoline truck for light commercial and single units, 2020 diesel for combination trucks
    iv. Combine rates with TRANSEARCH VMT (allocated by model year) to obtain tons per year and fuel consumption impacts, by model year and calendar year

d. Cost Analysis
    i. $/gal for gasoline, diesel, CNG, LNG (CNG / LNG $ in equivalent gallons)
    ii. Non-fuel O&M costs include tires, oil changes, diesel exhaust fluid, scheduled maintenance; expressed in $/mi.
    iii. Incremental vehicle replacement costs from literature search – comparable to 2020 base vehicle in hp and emission standards
    iv. Cost of early purchase (cost of capital, i.e. discount rate)
    v. Resale (residual) value of retired trucks, assumes straight line depreciation over useful life
    vi. Real discount rate – 4.8% (2011 average rate for small business borrowing)

e. Scenario 1 – End of Life Replacement
    i. Replace conventional diesel/gasoline trucks at end of useful life with comparable natural gas vehicle; CNG for light commercial / single units, LNG for combination trucks
    ii. No cost associated with early vehicle retirement
    iii. Incremental costs include fuel, vehicle, and O&M; 10 year analysis period
    iv. Incremental emission impacts based on MOVES for conventional vehicles; literature search for NGVs

f. Calculation Inputs - # Vehicles & Mileage
    i. # Vehicles and Estimated Mi/Yr
        1. Statewide, 2020 Calendar Year

Vehicle/Fuel Type	**2020 Model Year Population**	**New Vehicle Miles/Yr***
Light Commercial - dsl	276	13,945
Light Commercial - gas	805	10,754
Single Unit Short Haul - dsl	386	47,027
Single Unit Short Haul - gas	170	23,285
Single Unit Long Haul - dsl	614	34,971
Single Unit Long Haul - gas	496	22,259
Combination Unit Short Haul - dsl	63	100,274
Combination Unit Long Haul - dsl	746	121,181
Total	**3,556**	

**Miles/yr decreases with each year of operation*

g. Calculation Inputs – Emissions/Fuel
   i. MOVES g/mi
      1. Includes start, running, extended idle emissions

Vehicle/Fuel Type	CO2	NOx	PM10
Light Commercial – dsl	612	0.81	0.006
Light Commercial - gas	356	0.31	0.009
Light Commercial - CNG	270	0.31	0.009
Single Unit Short Haul - dsl	878	0.65	0.010
Single Unit Short Haul - gas	861	0.59	0.009
Single Unit Short Haul - CNG	712	0.59	0.009
Single Unit Long Haul - dsl	785	0.59	0.009
Single Unit Long Haul - gas	794	1.17	0.021
Single Unit Long Haul - CNG	657	1.17	0.021
Combination Unit Short Haul - dsl	1,610	1.17	0.021
Combination Unit Short Haul - LNG	1,414	1.17	0.021
Combination Unit Long Haul - dsl	1,771	5.45	0.029
Combination Unit Long Haul - LNG	1,556	5.45	0.029

   ii. Fuel consumption
      1. From CO2 g/mi and g/physical gal factors (EPA)

Fuel	CO2 g/gal
Diesel	10,180
Gasoline	8,887
CNG (GGE)	7,030
LNG	4,394

h. Calculation Inputs - Fuel Cost
   i. $/gal estimates from Alternative Fuel Data Center seasonal survey for New England, January 2012 (retail public access)

Fuel costs	$/equiv gal
Diesel	$4.08
Gasoline	$3.51
CNG (gge)	$2.43
LNG (dge)	$1.89

i. Calculation Inputs – Vehicle / O&M Cost
   i. New vehicle purchase and O&M costs from EPA MARKAL model, PNNL, TIAX, RFF, MARBEK
   ii. O&M assumed to equal diesel truck $/mi

Vehicle/Fuel	Vehicle Cost	O&M ($/mi)
Lt Commercial - Dsl	$39,300	$0.029
Lt Commercial - Gas	$31,400	$0.053
Lt Commercial - CNG	$43,300	$0.029
Single Unit - Dsl	$74,200	$0.150
Single Unit - Gas	$68,800	$0.273
Single Unit - CNG	$83,300	$0.150
Combo Short - Dsl	$128,800	$0.156
Combo Short - LNG	$168,800	$0.156
Combo Long - Dsl	$129,900	$0.140
Combo Long - LNG	$213,500	$0.140

j. Payback for New Vehicle Purchase
   i. Payback obtainable for all diesel truck categories, but not gasoline trucks

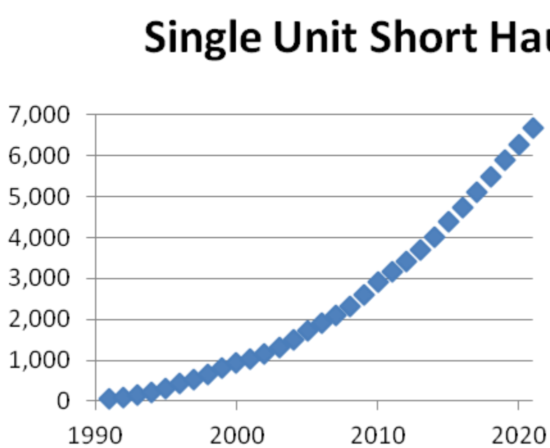
Vehicle/Fuel	Years to Payback
Lt Com - Diesel	3 – 4
SU Short - Diesel	3 – 4
SU Long - Diesel	4 – 5
Combo Short - Diesel	2 – 3
Combo Long - Diesel	3 - 4
Lt Com - Gas	> 10
SU Short - Gas	> 10
SU Long - Gas	> 10

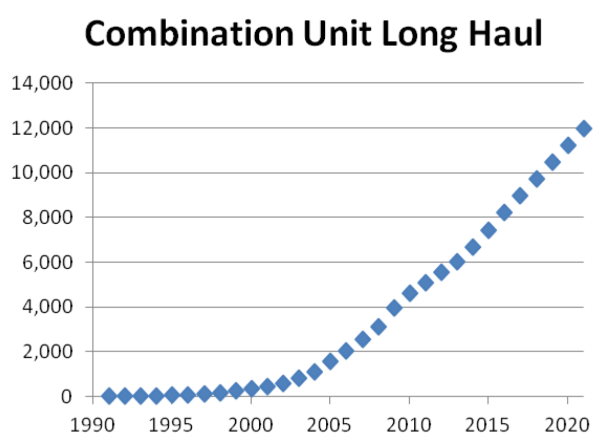
k. Scenario 2 – Existing Vehicle Replacement
   i. Investigates further market penetration potential for NGVs
   ii. Start by replacing oldest model year still in service first (1990 assumed), in 2020. This vehicle's VMT/yr will be very low by 2020, and will be retired the next year.
   iii. Assume *new* NGV travels same VMT in 2020 as *new* conventional vehicle. High mileage slowly decreases in subsequent years, as in Scenario 1.
   iv. Adjust VMT for remaining conventional vehicles to keep total fleet VMT constant
   v. Repeat process, replacing broader model year groups stepwise (1990–1991, 1990–1992, etc.)

l. Calculation Inputs - # Vehicles & Mileage
   i. # Vehicles and Average Mi/Yr – statewide 2020
      1. Mi/yr from VIUS, specific to CT freight vehicles

Vehicle/Fuel Type	2020 Population	Average Mi/Yr/Veh
Light Commercial - dsl	6,127	10,958
Light Commercial - gas	17,572	8,504
Single Unit Short Haul - dsl	6,661	21,633
Single Unit Short Haul - gas	3,063	10,328
Single Unit Long Haul - dsl	8,607	21,194
Single Unit Long Haul - gas	7,014	13,397
Combination Unit Short Haul - dsl	1,202	40,305
Combination Unit Long Haul - dsl	11,972	62,471
Total	**62,217**	

m. Calculation Inputs - # Vehicles by Model Yr
    i. Statewide population in 2020
        1. Cumulative Distribution Examples: Single Unit Short Haul & Combination Long Haul Diesels
        2. SU Short units last longer; potentially better targets for replacement





n. Calculation Inputs – VMT
    i. VMT by vehicle/fuel type – statewide 2020
        1. TRANSEARCH basis

Vehicle/Fuel Type		Miles/Yr	% VMT
Light Commercial - dsl		67,134,712	5%
Light Commercial - gas		149,428,874	10%
Single Unit Short Haul - dsl		144,089,710	10%
Single Unit Short Haul - gas		31,629,449	2%
Single Unit Long Haul - dsl		182,421,946	12%
Single Unit Long Haul - gas		93,974,942	6%
Combination Unit Short Haul - dsl		48,464,513	3%
Combination Unit Long Haul - dsl		747,891,542	51%
	Total	**1,465,035,668**	

o. Cost/Benefit Calculations

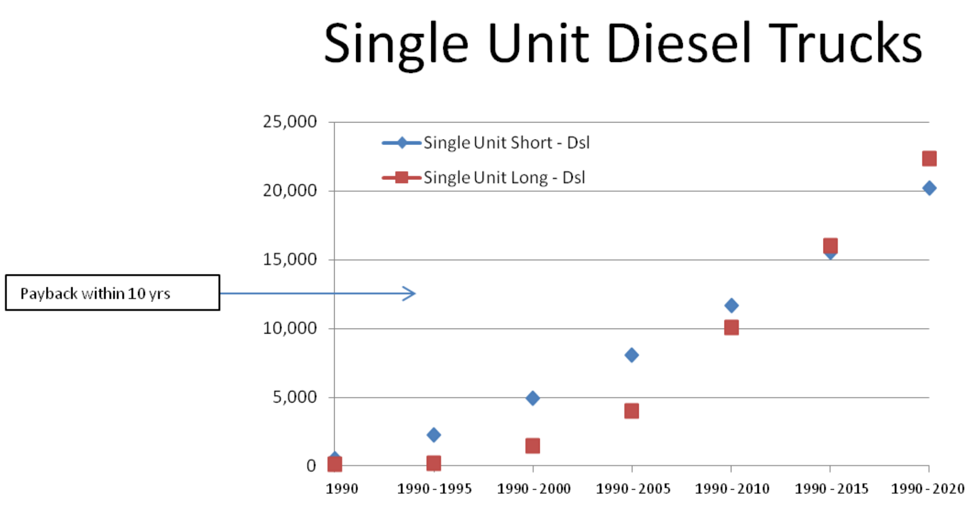
i. Approach - Calculate costs/savings and emission reduction for replacement of base vehicles

1. Develop 10 year cash flows for each model year replacement group, up to and including replacement of all model years.
2. Calculate NPV and amortized payment for each scenario to determine payback period
3. Cash flows by vehicle/fuel type: 240 scenarios
4. Calculate average emission reduction over 10 years for each scenario

p. Upper Bound CO2 Emission Reductions

i. Annual Average reduction – full fleet replacement

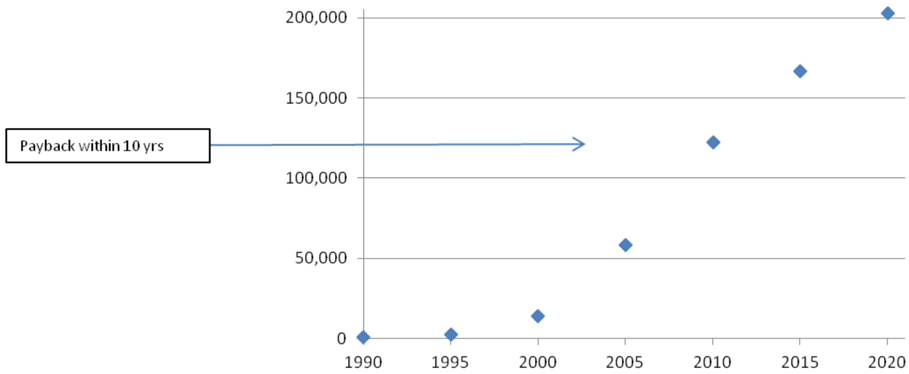
ii. TPY CO2 vs Model Year group replaced



iii. Average Baseline Single Unit Diesel Trucks ~ 214,000 TPY CO2

iv. *Maximum Emissions Reduction with Payback ~ 9,500 TPY (4% of single unit total)*

Long Haul Combination Diesel Trucks



v. Average Baseline Long Haul Combination Trucks ~ 1,070,000 TPY CO_2

vi. *Maximum Emissions Reduction with Payback (model years 1990 – 2010) ~ 120,000 TPY (11% of long haul combo total)*

	Model Years Replaced						
Vehicle/Fuel Type	**1990**	**1990 - 1995**	**1990 - 2000**	**1990 - 2005**	**1990 - 2010**	**1990 - 2015**	**1990 - 2020**
Lt Com - Diesel	146	311	988	4,030	8,930	16,353	22,068
Single Unit Short - Dsl	497	2,264	4,935	8,079	11,688	15,555	20,174
Single Unit Long - Dsl	122	192	1,441	3,980	10,056	16,013	22,330
Combo Short - Diesel	241	1,346	3,152	5,010	7,321	9,120	10,712
Lt Com - Gas	106	178	842	3,038	8,290	13,701	16,816
SU Short - Gas	160	683	1,337	1,994	2,747	3,562	4,532
SU Long - Gas	83	149	1,073	2,629	6,291	9,879	13,663
Combo Long - Diesel	764	2,499	14,145	58,524	122,245	166,896	202,762
Total	**2,119**	**7,622**	**27,915**	**87,284**	**177,568**	**251,079**	**313,057**
% Total Inventory*	**0.1%**	**0.5%**	**1.8%**	**5.7%**	**11.7%**	**16.5%**	**20.6%**

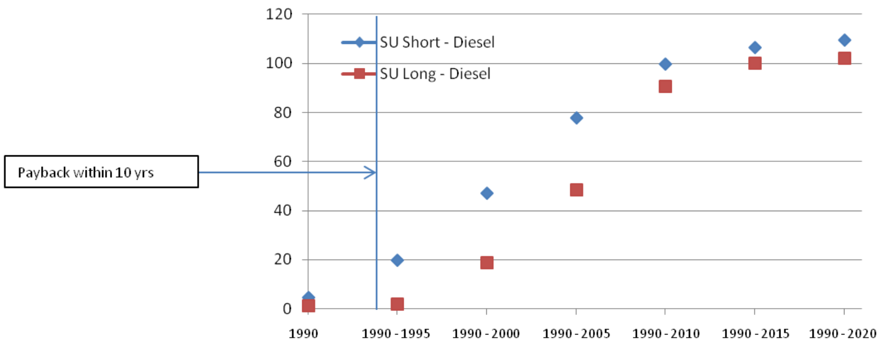
*Annual Average over 10 year analysis period

q. Upper Bound NOx Emission Reductions

i. Annual Average reduction – full fleet replacement

ii. TPY NOx vs Model Year group replaced

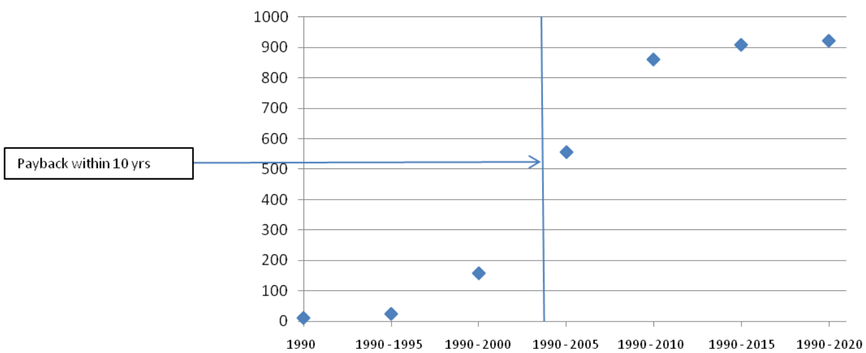
Single Unit Diesel Trucks



iii. Average Baseline Single Unit Diesel Trucks ~ 360 TPY NOx

iv. *Maximum Emissions Reduction with Payback ~ 100 TPY (28% of single unit total)*

Long Haul Combination Diesel Trucks



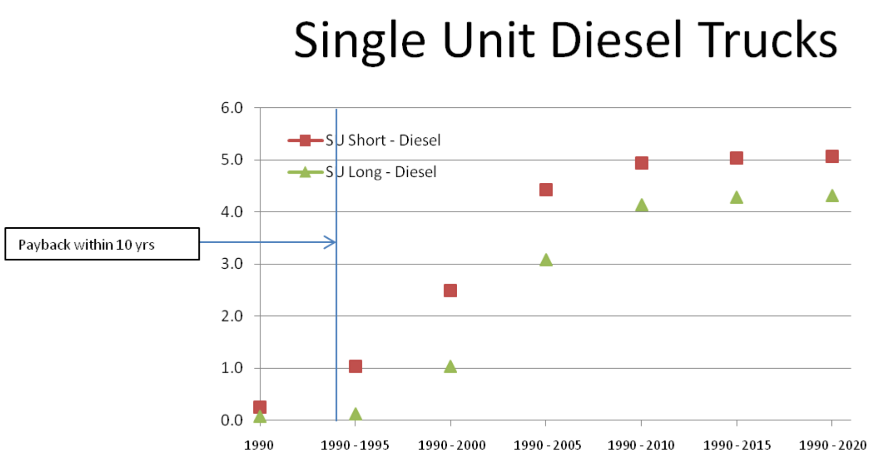
v. Average Baseline Long Haul Combination Trucks ~ 4,000 TPY NOx

vi. *Maximum Emissions Reduction with Payback (model years 1990 – 2010) ~ 850 TPY (21% of long haul combo total)*

	Model Years Replaced						
Vehicle/Fuel Type	**1990**	**1990 - 1995**	**1990 - 2000**	**1990 - 2005**	**1990 - 2010**	**1990 - 2015**	**1990 - 2020**
Lt Com - Diesel	1.3	2.7	8.5	32.0	50.8	67.7	77.1
Combo Short - Diesel	2.6	12.3	31.7	48.8	60.5	62.8	63.4
Lt Com - Gas	1.9	4.2	9.7	19.1	26.3	32.5	32.6
SU Short - Gas	1.1	4.6	9.4	14.7	19.9	20.9	21.1
SU Long - Gas	0.5	0.9	7.5	19.7	44.0	52.6	54.5
SU Short - Diesel	5	20	47	78	100	107	109
SU Long - Diesel	1	2	19	49	91	100	102
Combo Long - Diesel	9.6	24.7	155.9	553.6	858.3	907.8	919.7
Total	**22.8**	**71.3**	**288.8**	**814.5**	**1,250.4**	**1,351.1**	**1,380.2**
% Total Inventory*	**0.5%**	**1.5%**	**6.1%**	**17.2%**	**26.4%**	**28.6%**	**29.2%**

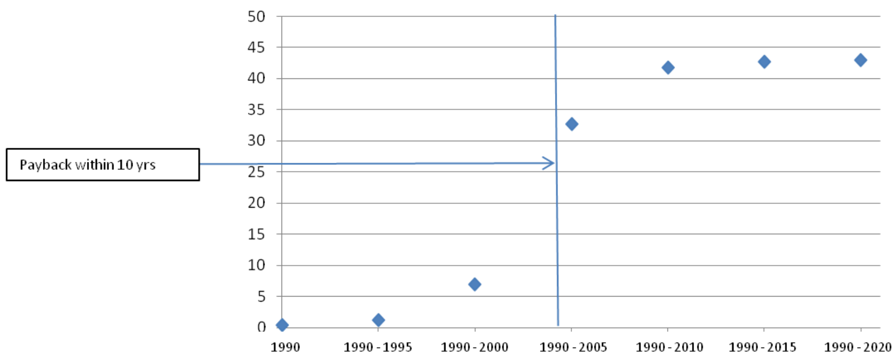
*Annual Average over 10 year analysis period

r. Upper Bound PM10 Emission Reductions
    i. Annual Average reduction – full fleet replacement
    ii. TPY PM10 vs Model Year group replaced



    iii. Average Baseline Single Unit Diesel Trucks ~ 12 TPY PM10
    iv. *Maximum Emissions Reduction with Payback ~ 5.4 TPY (45% of single unit total)*

Long Haul Combination Diesel Trucks



v. Average Baseline Long Haul Combination Trucks ~ 60 TPY PM10

vi. *Maximum Emissions Reduction with Payback (model years 1990 – 2010) ~ 42 TPY (70% of long haul combo total)*

	Model Years Replaced						
Vehicle/Fuel Type	**1990**	**1990 - 1995**	**1990 - 2000**	**1990 - 2005**	**1990 - 2010**	**1990 - 2015**	**1990 - 2020**
Lt Com - Diesel	0.09	0.18	0.55	1.62	1.85	1.85	1.81
SU Short - Diesel	0.25	1.04	2.50	4.44	4.94	5.04	5.08
SU Long - Diesel	0.07	0.12	1.04	3.09	4.14	4.29	4.33
Combo Short - Diesel	0.11	0.55	1.38	2.38	2.69	2.73	2.74
Lt Com - Gas	0.04	0.08	0.23	0.44	0.85	1.20	1.24
SU Short - Gas	0.01	0.05	0.10	0.13	0.15	0.17	0.17
SU Long - Gas	0.01	0.01	0.06	0.10	0.16	0.31	0.35
Combo Long - Diesel	0.37	1.13	6.97	32.72	41.72	42.68	42.90
Total	**1.0**	**3.2**	**12.8**	**44.9**	**56.5**	**58.3**	**58.6**
% Total Inventory*	**1.2%**	**3.9%**	**16.0%**	**55.9%**	**70.3%**	**72.5%**	**72.9%**

*Annual Average over 10 year analysis period

s. Payback Analysis

i. Number of years to cost recovery

1. Dependant on vehicle/fuel type, # model yrs replaced

Vehicle/Fuel	**1990**	**1990 – 91**	**1990 – 92**	**1990 - 93**	**1990 - 94**	**1990 - 95**	**1990 - 96**	**1990 - 97**	**1990 - 98**	**1990 - 99**	**1990 - 00**
Lt Com - Diesel	4	4	4	5	5	6	7	9	9	>10 yrs	>10 yrs
SU Short - Diesel	3	4	5	6	8	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
SU Long - Diesel	4	6	8	9	10	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
Combo Short - Diesel	2	2	2	3	3	4	4	5	6	6	7
Combo Long - Diesel	3	3	3	3	4	4	4	5	5	6	6
Lt Com - Gas	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
SU Short - Gas	5	6	8	9	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
SU Long - Gas	4	6	7	8	9	10	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs

Vehicle/Fuel	1990 – 01	1990 - 02	1990 - 03	1990 - 04	1990 - 05	1990 - 06	1990 - 07	1990 - 08	1990 - 09	1990 - 10
Lt Com - Diesel	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
SU Short - Diesel	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
SU Long - Diesel	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
Combo Short - Diesel	8	10	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
Combo Long – Diesel	7	8	10	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
Lt Com – Gas	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
SU Short – Gas	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs
SU Long – Gas	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs	>10 yrs

t. Net Present Value
   i. Maximum model year replacement providing net savings over 10 years

Vehicle/Fuel	Max Model Year Group
Light Commercial - Diesel	1990 – 1998
Single Unit Short Haul - Diesel	1990 – 1994
Single Unit Long Haul - Diesel	1990 – 1994
Combo Short Haul - Diesel	1990 – 2002
Combo Long Haul - Diesel	1990 – 2003

u. Sensitivity Analyses
   i. Conducted to address uncertainty in key input parameters
      1. Vary fuel cost increment
      2. Single Unit vehicle cost variation (for higher hp requirements)
      3. Dray Scenario – alter model year distribution and mileage for short haul combination trucks

v. Fuel Cost Variation
   i. Most significant risk associated with NGV investment is falling diesel/gasoline prices
   ii. Sensitivity case assumptions:
      1. NG prices stay flat due to high shale oil production
      2. Gas/diesel prices fall from AEO's "Reference" scenario to "Low Oil Price Scenario" for the New England region in 2020
      3. $/gal differential = $1.08 for gasoline, $1.19 for diesel

w. Lower Gas/Diesel Prices – Change in Payback
   i. For end of life replacements, only light commercial and combination short haul diesel trucks obtain payback during analysis period (5 and 6 yrs, respectively)
   ii. Maximum model year group replacement providing net savings over 10 yrs –

Vehicle/Fuel	Max Model Years
Lt Com - Diesel	1990 – 1994
SU Short - Diesel	None
SU Long - Diesel	1990 – 1991
Combo Short - Diesel	1990 – 1993
Combo Long - Diesel	1990 – 1993
Lt Com - Gas	None
SU Short - Gas	None
SU Long - Gas	1990 – 1991

iii. *Therefore significantly less market penetration is anticipated if diesel/gasoline prices fall substantially*

x. Single Unit Truck Cost Variation
   i. Single units have largest variation in GVW, payload, and hp requirements of all HD trucks
   ii. Vehicle cost differential between diesel and natural gas single unit trucks is ~$9,100 in the base case, e.g., representative of smaller delivery trucks
   iii. Sensitivity case evaluates scenario for much larger trucks (e.g., similar in size and power requirements to refuse trucks)
   iv. Cost differential = $50,000

y. Larger Single Unit Trucks – Change in Payback
   i. At the high end cost differential, short haul single unit trucks do no obtain payback during the analysis period, for either end of life replacements or in-use vehicle replacements
   ii. Long haul single unit trucks do obtain payback during the analysis period for in-use vehicle replacements, but only for the oldest model years – 1990 – 91 models, with payback at 10 years
   iii. Therefore we anticipate a range of payback periods and market penetration among single unit trucks, largely depending upon engine size/power requirements

z. Drayage Truck Cost Evaluation
   i. Drayage trucks are a subset of short haul combination trucks
   ii. Typically older/higher emitting than average
   iii. Central access point and standard routes are favorable to alternative fuel application

aa. Drayage Fleet Assumptions
   i. Truck age distribution modified using defaults from EPA's SmartWay Dray FLEET model
   ii. Use TRANSEARCH inbound/outbound annual port tonnage estimates for 2020, an average payload of 18 tons, and assumed operating time of 10 hours/truck/weekday to calculate dray fleet size – estimate 627 trucks statewide
   iii. Assume minimal/no on-dock rail (all truck)

iv. Use FLEET model default trip length of 25 miles to estimate total fleet VMT
v. Analysis assumes constant mileage accumulation, regardless of age (65,000)

bb. Drayage Trucks – Payback and Emission Reduction Potential

i. Assume same LNG/HPDI system required as for long-haul units (~$80,000 incremental price)
ii. End of Life replacements can obtain payback in 6 - 7 years
iii. Emission reduction potential is very high for dray vehicles, due to their age: *replacing entire fleet would decrease dray CO2 emissions by 27%, NOx by 83%, and PM10 by 93% in first year of operation*
iv. Recommend survey of dray fleet VMT/age distribution for further characterization

cc. Conclusions

i. Fuel cost differential is a significant driver, allowing moderate penetration into the fleet, even without fuel and vehicle tax incentives
ii. Additional fuel savings possible with slow-fill, on-site refueling (centrally operated fleets only)
iii. Only gasoline light commercial trucks don't provide payback (due to lower miles, less favorable vehicle cost increment, O&M penalty)
iv. Analysis does not consider fueling infrastructure or financing constraints – ultimate market penetration highly uncertain, especially for combination trucks requiring LNG
v. CO2, NOx and especially PM10 emission reductions possible for all vehicle fuel type replacements

2. On-Board Idle Reduction Strategies

a. Strategy Overview

i. Retrofit in-use long-haul combination trucks in 2020
ii. Extended idle significant portion of long-haul emissions inventory
    1. 9% CO2
    2. *64% NOx*
    3. 13% PM10
iii. Evaluation at the fleet level
iv. Options include
    1. Auxiliary Power Units (APUs), diesel power assumed, covers all accessories, heating, cooling
    2. Direct Fired Heaters (DFH), diesel power assumed, heating only (32% of idle time assumed – national average)
    3. Battery A/C, can be charged from engine or charged using shorepower; cooling only (40% of idle time assumed – national average)
v. Key drivers include:
    1. significant fuel cost savings
    2. emission reduction benefits
    3. reduced engine wear

4. relatively low cost (<$10K); low weight (~ 400 lbs for an APU)
5. known costs and demonstrated performance – low risk

b. Baseline Activity
    i. Evaluate over 10 year operation period
    ii. Consider effects of fleet turnover and decreasing idle hours with age, for baseline (BAU) and retrofit scenarios

Model Yr	Hrs/yr/truck	Model Yr	Hrs/yr/truck
1990	135	2006	586
1991	149	2007	610
1992	165	2008	681
1993	181	2009	831
1994	199	2010	913
1995	218	2011	1,006
1996	130	2012	1,107
1997	417	2013	1,216
1998	410	2014	1,338
1999	361	2015	1,473
2000	309	2016	1,619
2001	365	2017	1,781
2002	521	2018	1,959
2003	580	2019	2,156
2004	760	2020	2,371
2005	652		

c. Idle Activity/Emissions
    i. MOVES provides extended idle g/hr and gal/hr by model year
    ii. Adjust idle fuel consumption to reflect impact of proposed National HD program (not accounted for in MOVES – ~30% reduction by 2030, from DOE)
    iii. APU emission and fuel consumption rates from literature
    iv. Apply vehicle population estimates derived from TRANSEARCH VMT and VIUS miles/truck (allocated by model year) to obtain tons per year and fuel consumption impacts, by model year and calendar year

d. Cost Analysis
    i. $/gal diesel
    ii. Equipment purchase cost
    iii. Equipment maintenance costs in $/yr

e. Fuel Consumption Inputs
    i. Base case 0.75 - 1.0 gal/hr, depending on age
    ii. APUs 0.22 gal/hr
    iii. DFH 0.06 gal/hr
    iv. Battery A/C 0.1 gal/hr

f. Emission Rates
    i. Base case emission rates are age-dependant

	CO_2 g/hr	NOx g/hr	PM10 g/hr
Base case	7,717 - 10,682	232 - 266	0.37 - 7.85
APU	2,189	9.6	0.09
DFH	560	0.2	0.06
Battery A/C*	1,018	0.1	0.05

* Assumes national average electricity grid basis

g. Equipment Cost
   i. Equipment and O&M costs from literature

	Equipment	O&M
APU	$9,000	$180/yr
DFH	$888	$200
Battery A/C	$4,300	$110

h. Payback Evaluation
   i. Cash flow developed for each model year

Payback (yrs)			
Model Yr	APUs	DFH	Battery A/C
1990 - 97	>10 Yrs	>10 Yrs	>10 Yrs
1998	>10 Yrs	6	>10 Yrs
1999	>10 Yrs	6	>10 Yrs
2000	>10 Yrs	6	>10 Yrs
2001	>10 Yrs	5	>10 Yrs
2002	>10 Yrs	4	>10 Yrs
2003	>10 Yrs	2	>10 Yrs
2004	>10 Yrs	2	>10 Yrs
2005	>10 Yrs	2	>10 Yrs
2006	>10 Yrs	2	>10 Yrs
2007	>10 Yrs	2	>10 Yrs
2008	>10 Yrs	2	>10 Yrs
2009	>10 Yrs	2	>10 Yrs
2010	>10 Yrs	2	>10 Yrs
2011	6	1	9
2012	5	1	6
2013	4	1	5
2014	4	1	4
2015	3	1	4
2016	3	1	4
2017	3	1	3
2018	3	1	3
2019	3	1	3
2020	2	1	3

i. Emission Reduction Potential
   i. Calculated for all scenarios with payback in < 10 yrs
   ii. Assumes full market penetration (upper bound)

	TPY Reduction		
	CO2	**NOx**	**PM10**
APUs TPY	49,670	1,798	2.28
% of EI	4.6%	45.0%	3.8%
DFH TPY	24,219	717	1.63
% of EI	2.3%	17.9%	2.7%
Batt A/C TPY	23,659	750	1.02
% of EI	2.2%	18.7%	1.7%

j. Sensitivity Analysis – Fuel Cost Variation
   i. Lower Diesel by $1.19/gallon, as with NGVs

Payback (yrs)			
Model Yr	APUs	DFH	Battery A/C
1990 - 97	>10 Yrs	>10 Yrs	>10 Yrs
1998	>10 Yrs	>10 Yrs	>10 Yrs
1999	>10 Yrs	>10 Yrs	>10 Yrs
2000	>10 Yrs	>10 Yrs	>10 Yrs
2001	>10 Yrs	>10 Yrs	>10 Yrs
2002	>10 Yrs	>10 Yrs	>10 Yrs
2003	>10 Yrs	7	>10 Yrs
2004	>10 Yrs	3	>10 Yrs
2005	>10 Yrs	3	>10 Yrs
2006	>10 Yrs	3	>10 Yrs
2007	>10 Yrs	3	>10 Yrs
2008	>10 Yrs	3	>10 Yrs
2009	>10 Yrs	3	>10 Yrs
2010	>10 Yrs	2	>10 Yrs
2011	>10 Yrs	2	>10 Yrs
2012	>10 Yrs	2	>10 Yrs
2013	7	2	>10 Yrs
2014	6	2	8
2015	5	1	7
2016	5	1	6
2017	5	1	5
2018	4	1	5
2019	4	1	4
2020	4	1	4

	TPY Reduction		
	CO2	NOx	PM10
APUs TPY	45,715	1,670	2.12
% of EI	4.3%	41.8%	3.5%
DFH TPY	23,892	707	1.47
% of EI	2.2%	17.7%	2.5%
Batt A/C TPY	20,155	649	0.89
% of EI	1.9%	16.2%	1.5%

k. Sensitivity Analysis – Revised Market Penetration
   i. Penetration of technologies into base fleet highly uncertain (currently very low)
   ii. Optimistic base fleet penetration scenario from ATRI survey of truck company plans for idle use technologies, starting with 2010 model year

Idle reduction market penetration adjustments

Assumed MYr start	2010
APUs	28% per MY
Battery A/C	40% per MY
DFH	28% per MY

l. Conclusions
   i. Application of on-board idle reduction strategies very promising from an economic and technical standpoint
   ii. Key potential NOx reduction strategy
   iii. Main uncertainties include fuel cost differential and identification of policy levers to encourage retrofits
   iv. *Economics more robust than for NGVs – less sensitive to fuel price fluctuations*

3. SmartWay Retrofit Strategies

a. Strategy Overview
   i. Retrofit in-use trucks in 2020 with SmartWay-certified products
   ii. Aerodynamic treatments - long haul combination trucks (front, side, rear trailer fairings); front fairings for single unit trucks
   iii. Low rolling resistance (LRR) tires, aluminum wheels for all but light commercial trucks
   iv. Fuel savings is primary driver, some NOx reduction through reduced engine loads

b. Calculation Inputs
   i. Same calculation methodology as idle retrofits
   ii. Cost and benefits by "packages" described above, from CARB, TIAX

Truck Type	**Cost**	**CO2 Reduction**	**NOx Reduction**
Long haul combination trucks	$10,495 / $23,840*	11.3%	15.6%
Short haul combination trucks	$5,500	9.2%	5.9%
Single Unit trucks	$3,255	7.5%	15.6%

c. Payback Evaluation
   i. Cash flow developed for each model year
   ii. No payback for gasoline trucks (not shown)

	Payback (yrs)				
Model Yr	**Long Haul Combo***		**Short Haul Combo**	**Long Haul SU - Dsl**	**Short Haul SU - Dsl**
1990 - 2007	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2008	8	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2009	7	>10 Yrs	8	>10 Yrs	>10 Yrs
2010	5	>10 Yrs	7	>10 Yrs	>10 Yrs
2011	4	>10 Yrs	6	>10 Yrs	>10 Yrs
2012	3	>10 Yrs	6	>10 Yrs	>10 Yrs
2013	3	>10 Yrs	5	>10 Yrs	10
2014	3	>10 Yrs	5	>10 Yrs	9
2015	3	>10 Yrs	4	>10 Yrs	8
2016	3	9	3	>10 Yrs	7
2017	2	7	3	10	5
2018	2	6	3	9	5
2019	2	5	2	7	4
2020	2	5	2	7	4

*1 trailer per tractor / 2.5 trailers per tractor

d. Emission Reduction Potential
   i. Calculated for all scenarios with payback in < 10 yrs
   ii. Assumes full market penetration (upper bound)

	TPY Reduction		
	CO_2	**NO_x**	**PM_{10}**
Long Haul Combo*	66,692	285	0.00
% of Long Haul EI	4.0%	5.0%	0.0%
Short Haul Combo	4,109	2	0.00
% of Short Haul EI	4.1%	1.4%	0.0%
Long Haul SU	3,223	5	0.00
% of Dsl Long Haul SU EI	2.0%	2.0%	0.0%
Short Haul SU	4,466	8	0.00
% of Dsl Short Haul SU EI	3.0%	2.8%	0.0%

* 1 trailer per tractor

e. Sensitivity Analysis – Fuel Cost Variation
   i. Lower Diesel by $1.19/gallon

		Payback (yrs)			
Model Yr		Long Haul Combo*	Short Haul Combo	Long Haul SU - Dsl	Short Haul SU - Dsl
1990 - 2007	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2008	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2009	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2010	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2011	8	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2012	6	>10 Yrs	>10 Yrs	>10 Yrs	>10 Yrs
2013	5	>10 Yrs	8	>10 Yrs	>10 Yrs
2014	5	>10 Yrs	9	>10 Yrs	>10 Yrs
2015	5	>10 Yrs	7	>10 Yrs	>10 Yrs
2016	4	>10 Yrs	5	>10 Yrs	>10 Yrs
2017	4	>10 Yrs	4	>10 Yrs	>10 Yrs
2018	3	>10 Yrs	4	>10 Yrs	8
2019	3	10	3	>10 Yrs	6
2020	3	9	3	>10 Yrs	6

	TPY Reduction		
	CO_2	NOx	PM10
Long Haul Combo*	59,504	247	0.00
% of Long Haul EI	3.6%	4.3%	0.0%
Short Haul Combo	3,333	2	0.00
% of Short Haul EI	3.3%	1.0%	0.0%
Long Haul SU	0	0	0.00
% of Dsl Long Haul SU EI	0.0%	0.0%	0.0%
Short Haul SU	2,251	3	0.00
% of Dsl Short Haul SU EI	1.5%	1.2%	0.0%

* 1 trailer per tractor

f. Conclusions
   i. Proven technology
   ii. Payback relatively robust against fuel cost variance
   iii. Future penetration into baseline fleet uncertain

4. Accelerated Drayage Truck Retirement

a. Strategy Overview
   i. Early retirement for drayage trucks with new diesel trucks in 2020
   ii. PM and NOx reduction is primary driver
   iii. Some fuel savings through efficiency improvements
   iv. Costs include
      1. Cost of early purchase (cost of capital, i.e. discount rate)

2. Resale (residual) value of retired trucks, assumes straight line depreciation over useful life

b. Payback Evaluation

i. Fuel economy improvement by 2020 is significant (17% vs dray fleet average) allowing payback deep into the fleet

Model Yr Group	Payback (Yrs)
1996	1
1996 - 1997	1
1996 - 1998	2
1996 - 1999	2
1996 - 2000	3
1996 - 2001	4
1996 - 2002	5
1996 - 2003	6
1996 - 2004	6
1996 - 2005	7
1996 - 2006	7
1996 - 2007	8
1996 - 2008	9
1996 - 2009	10
1996 - 2010+	>10 yrs

c. Emission Reduction Potential

i. Calculated for all scenarios with payback in < 10 yrs

ii. Assumes full market penetration (upper bound)

	TPY Reduction		
	CO2	NOx	PM10
Dray Fleet	9,018	254	12.62
% of Dray Fleet Emissions	10.4%	79.9%	91.7%

d. Sensitivity Analyses

i. Lower Diesel by $1.19/gallon, as with NGVs

1. *Payback only obtained for replacement of 1996 – 1998 model years*
2. Similar sensitivity to annual mileage assumptions for dray vehicles (65,000 mi/yr)

e. Conclusions

i. Given continued high diesel prices and significant fuel economy improvements in base fleet by 2020, anticipate market-driven accelerated turnover in older diesel trucks

ii. Uncertain how new vehicle and resale vehicle markets will change in response to increased supply/demand

iii. This holds true for alternative fuel vehicle markets as well

5. **Strategies for Rail and Port**
    a. Strategy Overview
        i. Rail Emission Control Options
        ii. Marine Emission Control Options
        iii. Cost- effective strategies have been identified, but the overall impact on the emission inventory will be small.
    b. Rail Emission Control Options
        i. Overview

Strategy	**% Fuel Savings**	**% emission reduction**		
		CO2	**NOX**	**PM**
Repower Yard with Tier 2	10 to 30	10 to 30	18 to 60	67
Repower Line-haul with Tier 2	10 to 30	10 to 30	60	67
Genset Yard Locomotives	20 to 50	35	60 to 88	80
Hybrid Line Haul Locomotives	10 to 15	15	50	10

        ii. Yard Engines – Gensets
            1. These engines comply with Tier III non-road engine standards, as well as the EPA's Tier III and IV locomotive standards, including idle reduction requirements:
            2. NOx reduction from 60% to 90 % and
            3. PM reductions around 80 %.
            4. Fuel savings from 20 to 50%.
            5. Purchased as a new locomotive - $1.5 to 2 million or as a repower option - $1 million
            6. Facilitates Idle Reduction
            7. $3,800 per ton of NOx removed
    c. Marine Emission Control Options
        i. Engine retrofits (Tier 3 was phased in in 2009 and Tier 4 will be phased in starting in 2014)
        ii. Improved propeller design
        iii. Port Operational Changes
            1. Reduced speed zones: 20% in speed = 40% reduction in emissions
        iv. Auxiliary engine fuel requirements
        v. Subsidizing replacement of older auxiliary engines
        vi. Use of ultra low sulfur fuel
        vii. Cold Ironing: Cold ironing = use of electricity from the grid to power electrical engines aboard vessels while Dockside.
            1. Costly option: $15,000 - $30,000 per ton of NOx
            2. $1.5 to 3 million for the landside infrastructure.
            3. $500,000 - $750,000 per vessel to retrofit vessels to use a cold ironing system

APPENDIX E: SUMMARY OF VMT REDUCTION STRATEGIES

Cambridge Systematics

Rail Infrastructure Improvements

Overview

- Track & bridge upgrades
  - –Weight limits, vertical and horizontal clearances, running speed
- Possible Hudson River bridge or barge crossing

Affected Market

- ~120,000 trucks potentially divertible to rail carload (0.7% of total trucks)
- ~400,000 trucks potentially divertible to intermodal rail

Benefits

- Basic upgrades needed just to maintain existing rail share
- More extensive improvements to shift goods from truck to rail – reduce truck VMT by ~1-2%
- Emissions impacts mixed – most benefits occur out of state

Costs

- State rail plan identifies $400-500 million in rail investment needs through 2031
- Hudson River crossing >$1-2 billion

New Intermodal Terminal in South-Central CT

Overview

- In-state intermodal terminal as alternative to MA, NJ
- Need other improvements to take full advantage
  - Track & bridge clearances
  - Hudson River bridge or barge crossing?

Affected Market

- ~1% of total truck tonnage divertible to rail
  - Long-distance (>400 mi), lower-value commodities

Benefits

- Potential truck VMT reduction of up to 4-6%
- Up to 4% reduction in CT pollutants
- Up to 2 mmt global CO2 reductions

Costs

- $150-200 million for intermodal terminal
- Possible additional rail infrastructure costs of ~$400 million - $2 billion over 20-30 years

Rail Access Improvements

Overview

•Site users next to rail
 –Freight villages/rail-oriented development
 –Waste transfer facilities
•Need track & bridge upgrades to take full advantage of market

Benefits

•Make rail more competitive by reducing or eliminating truck drayage costs
•Support/increase truck VMT and emission reductions from rail infrastructure improvements

Affected Market

•~120,000 long-distance truck units potentially divertible to rail carload (0.7% of total trucks)
•3.2 million tons of solid waste – 97% carried by truck (180,000 truck trips)

Costs

•Land use/facility siting strategies may be implemented for low or zero net cost
•Infrastructure improvements may be needed (e.g., spur tracks)

Truck Tolls or VMT Fees

Overview

•Place tolls on major highways, or:
•Implement weight-based VMT fees for trucks

Benefits

•Encourage mode-shifting through price incentives
•Divert traffic from congested roadways in CT
•Generate revenue to fund infrastructure improvements that support air quality

Affected Market

•52% of truck VMT is passing through CT

Costs

•Increases costs for shippers/ carriers
•Impacts on surrounding states from changes in traffic routing

Increase Tanker Truck Weight Limits

Overview

- Increase from 9,000 to 10,000 gallon limit consistent with neighboring states
- Would reduce number of petroleum tanker trucks

Affected Market

- 300,000 tanker truck trips per year

Benefits

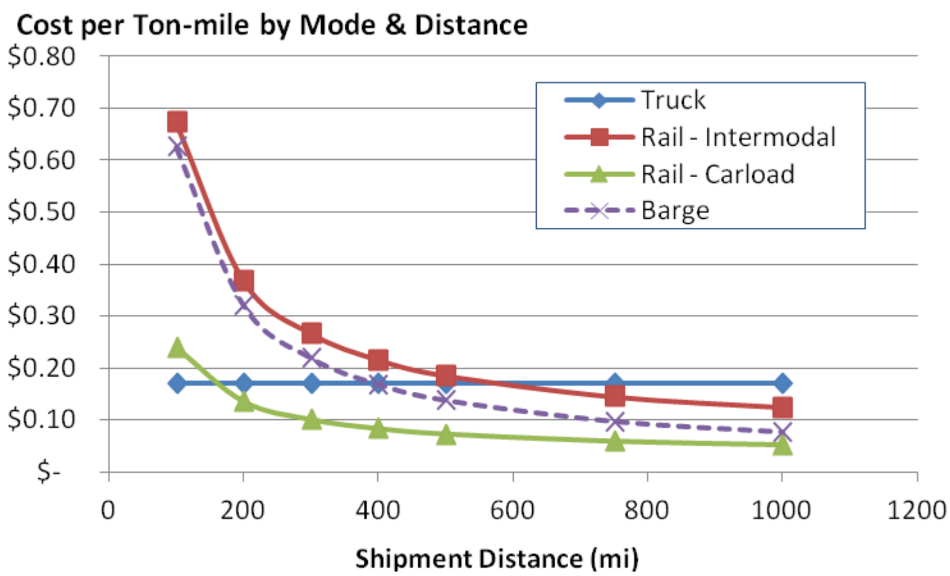
- Could reduce ~3 million VMT per year
- Emission reductions of ~0.3% of statewide inventory

Costs

- Possible increase in road maintenance costs
- Reduces costs to shippers due to greater efficiency + harmonization with neighboring states
- Risk management

Factors Affecting Truck-Rail Mode Shift Potential

- Limited market of "contestable commodities"
  - Most suitable for high freight volumes moving longer distances
  - Carload most competitive for heavy, low-value commodities
  - Intermodal requires volume density
  - No intermodal container terminal in CT
- Substandard rail infrastructure
- Circuitous routing – no Hudson crossing south of Albany
- Cost per ton-mile



- See Appendix G for discussion

Reducing Empty Backhauls (See Appendix F for discussion)

Truck Backhaul Truck Units (Total)

Year	Direction	Empty Trucks[1]	Loaded Trucks
2009	Inbound	1,189,874	3,138,001
2009	Intrastate	1,298,122	791,189
2009	Outbound	2,260,668	1,706,154
2009	Through	1,183,763	4,953,298
2020	Inbound	1,572,431	3,889,838
2020	Intrastate	1,704,198	1,011,859
2020	Outbound	2,882,126	2,283,242
2020	Through	1,636,979	6,655,661
2040	Inbound	2,090,427	5,195,334
2040	Intrastate	2,270,111	1,422,127
2040	Outbound	4,089,893	2,988,705
2040	Through	2,354,827	9,681,437

Source: IHS Global Insight Transearch 2009

[1]STCC 4221 "Semi-trailers Returned Empty"

Backhaul Ratios – Truck Units	2009	2020	2040
Loaded Outbound	70%	69%	70%
Loaded Inbound	72%	74%	79%

Truck Backhaul VMT (Within CT)

Year	Direction	Empty VMT[1]	Loaded VMT
2009	Inbound	55,386,456	184,243,772
2009	Intrastate	45,886,691	41,573,164
2009	Outbound	104,448,557	109,147,635
2009	Through	116,008,744	531,645,106
2020	Inbound	72,813,256	230,280,006
2020	Intrastate	60,184,787	54,499,885
2020	Outbound	134,000,786	144,260,777
2020	Through	160,423,946	710,103,776
2040	Inbound	96,120,304	306,016,428
2040	Intrastate	79,931,813	77,505,588
2040	Outbound	191,256,035	184,865,314
2040	Through	230,773,092	1,014,265,950

Backhaul Ratios – VMT (Within CT)	2009	2020	2040
Loaded Outbound	51%	50%	52%
Loaded Inbound	57%	58%	62%

Truck Backhaul VMT (Total)

Year	Direction	Empty VMT[1]	Loaded VMT
2009	Inbound	107,432,756	1,223,579,118
2009	Intrastate	45,886,691	41,573,164
2009	Outbound	272,780,769	594,396,528
2009	Through	206,514,548	4,054,739,420
2020	Inbound	141,705,717	1,543,781,758
2020	Intrastate	60,184,787	54,499,885
2020	Outbound	345,802,586	788,645,833
2020	Through	286,153,217	5,227,663,117
2040	Inbound	188,285,384	2,178,489,134
2040	Intrastate	79,931,813	77,505,588
2040	Outbound	488,630,803	1,087,198,923
2040	Through	421,746,758	7,273,618,654

Backhaul Ratios – VMT (Total)	2009	2020	2040
Loaded Outbound	18%	18%	17%
Loaded Inbound	22%	22%	22%

Other Measures

- Short sea shipping: See Appendix H for discussion.
  - Feasibility to be determined.
- Electronic screening/check-through at inspection stations (See Appendix I for discussion)
  - Small emissions benefit (<0.01%), although cost-effective
  - Most benefits already achieved through CVISN
- Traffic and parking information for truckers (See Appendix I for discussion)
  - Benefits unknown but likely to be small

APPENDIX F: PROFILE ON THE TRANSPORTATION USES ASSOCIATED WITH THE SOLID WASTE AND PETROLEUM SECTORS WITHIN THE STATE, AND AN EVALUATION OF BACKHAUL CHALLENGES

Cambridge Systematics

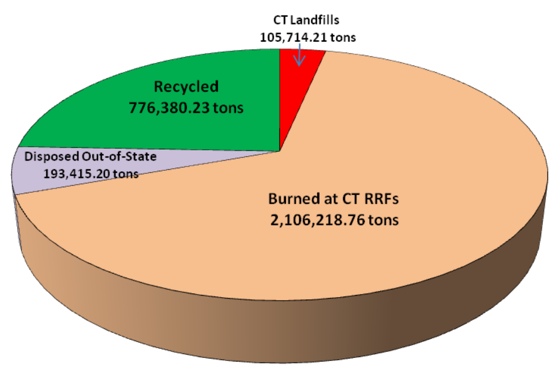
This Appendix presents a brief profile of two major truck-dependent industries in the State of Connecticut: the Municipal Solid Waste (MSW) Industry and the Petroleum Products distribution industry. Both profiles are based on data from Transearch, a commodity flow dataset prepared by IHS Global Insight and analyzed by Cambridge Systematics, the Freight Analysis Framework from the Federal Highway Administration, data from the Connecticut Department of Energy and Environmental Protection, and interviews with two major waste haulers and recycling processors in the State, and two firms involved in petroleum distribution activities. The primary purpose of the analysis is to better understand current logistics patterns for MSW and petroleum products, explore trends, and identify opportunities for mitigating the transportation effects from these important regional industries. This appendix provides a brief discussion of the backhaul trucking issues in the State (of which many local industries in Connecticut, especially MSW can play a major role in mitigating).

Solid Waste in Connecticut

In 2009, the State of Connecticut generated nearly 3.2 million tons of municipal solid waste (MSW), including both waste for disposal and recyclables. Over 2.1 million tons (about two thirds) was processed at the one of the State's seven resource recovery facilities (RRF), approximately 0.1 million tons (3 percent) disposed directly into Connecticut landfills (i.e. without processing), 0.2 million tons disposed at landfills out of State (6 percent) and 0.8 million tons (24 percent) recycled. Figure F.1 displays the distribution of the disposed and recycled tonnage in the State.

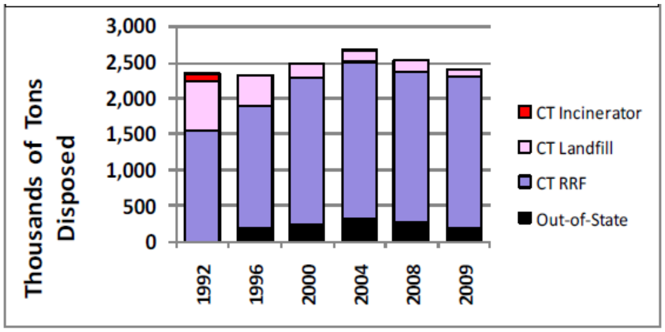
Overall, according to the Federal Highway Administration's Freight Analysis Framework (FAF), about 97% of the total waste in the State is carried by truck, with a small remaining proportion of total tonnage associated with outbound rail tonnage (3%) to locations in the Upper Midwest such as Ohio and Pennsylvania. About 78% of total tonnage in Connecticut is associated with intrastate (i.e. within Connecticut) flows and includes municipal solid waste pick-up, consolidation, and distribution to onward terminals such as RRF facilities, landfills, or recycling processing plants.

Figure F.1 Tons CT MSW Reported Disposed and Recycled FY 2009



Source: Connecticut DEEP

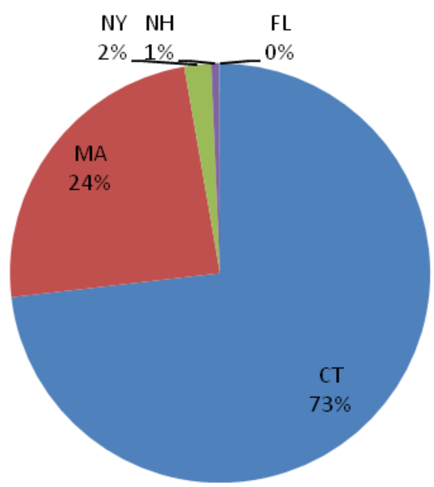
Figure F.2 Destination of CT MSW Disposed in FY 1992/2009



Source: Connecticut DEEP

Following the processing of MSW at RRF facilities (dark purple bars in Figure F.2), about 3/4 of the total waste tonnage is "burned off." In 2009, the remaining 0.7 million tons (largely ash residue or metals recovered from RRF ash) was either recycled or disposed of in a landfill. Figure F.3 shows the distribution of tonnage from RRF facilities that goes to either in or out of State landfills or recycling facilities. Nearly 3/4 of the processed RRF tonnage is disposed in Connecticut, with an additional 1/4 disposed in Massachusetts. Ash residue accounts for about 75 percent of the RRF tonnage.

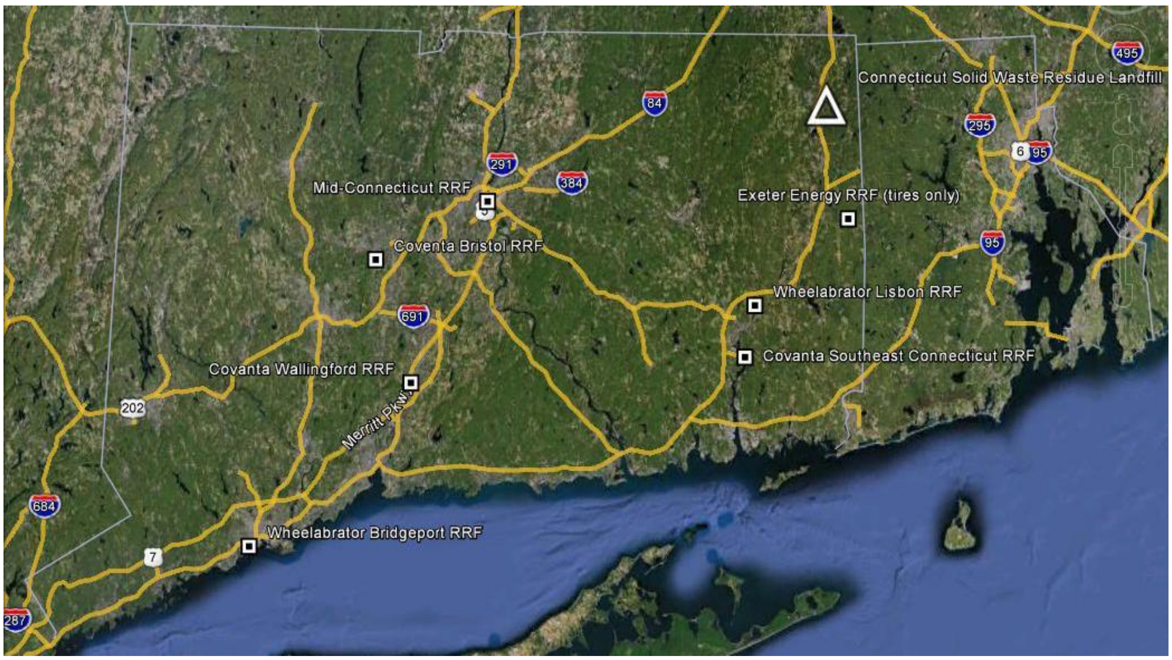
Figure F.3 Destination of Solid Waste Tonnage sent out from RRF Facilities in FY 2009



Source: Connecticut DEEP

There are currently six RRF facilities in the State, with a seventh dedicated to the disposal of tires.[1] Currently, The Wheelabrator Putnam Ash Residue Landfill in northeastern Connecticut is the only facility in the State that can accommodate ash from Connecticut's waste-to-energy facilities. The facility currently provides over 400,000 tons per year of ash disposal for four of Connecticut's six waste-to-energy plants (Bridgeport, Lisbon, Mid-Connecticut, and Wallingford).[2] The RRF plants in Bristol and Preston (Southeast Connecticut RRF) dispose of their ash in New York and Massachusetts, respectively. Figure F.4 shows the locations of Connecticut RRF facilities and the States' only disposal site.

Figure F.4 Current Locations of Connecticut RRF facilities and RRF Residue Landfill



Source: Google Earth and Connecticut DEEP

[1] http://www.ct.gov/dep/cwp/view.asp?A=2718&Q=332074
[2] Company website: http://www.wheelabratortechnologies.com/plants/ash-landfills/wheelabrator-putnam-inc/

Truck Flows of Solid Waste

Based on the total raw tonnage of MSW in Connecticut, and using a truck payload factor of 18 tons (an average volume for each truck hauling MSW and recyclables)[3], there are between 170,000 and 180,000 total annual trucks[4] distributing waste and recyclables on Connecticut's roadways. About 125,000 trucks (70 percent) are moving exclusively within the State and transferring waste directly from customers to Connecticut landfills and RRF facilities. As described above, about 6 percent of total MSW is disposed out of State (accounting for about 10,000 trucks) with a portion of the trip occurring within Connecticut. MSW tonnage that is recycled accounts for about 25 percent of the total tonnage (43,000 trucks) and also uses Connecticut roadways for at least a portion of the trip. For RRF facilities in the State, the volume of total waste produced from all the State's facilities accounts for about 700,000 tons of waste or over 40,000 annual trucks, with over 30,000 of these hauling ash residue from RRF facilities to landfills. Over 80 percent of these trucks (25,000) are hauling the ash for disposal at a Connecticut ash residue landfill. There is only one such facility actually located in the State (in Putnam, eastern Connecticut) and so trucks serving RRF facilities in the State are required to truck ash residue long distances (i.e. greater than 50 miles one-way) for disposal. For example, the disposal landfill for the Wheelabrator Bridgeport facility in Bridgeport, Connecticut is the Connecticut Solid Waste residue landfill in Putnam, over 100 miles away, one way.

Interviews

Two major solid waste disposal organizations were interviewed with about 600 employees between the two of them. Waste transfer stations (for inbound tonnage) in the State have catchment areas of between 20-50 miles, with an outside range of about 100 miles. Both solid waste companies interviewed dispatch trucks out of major hubs and focus on both solid waste collection, especially Municipal Solid Waste (MSW), Construction and demolition (C&D), waste processing (including recycling), and disposal. Developing new locations for hubs or terminals is determined by the level of local demand. One of the firms interviewed collected about 650,000 tons in waste (about 20 percent of the statewide total) in a recent year. The other firm handles a smaller, but still substantial, amount (their DEEP Permit allows for 15,000 tons/day in inbound waste). For outbound shipments, both firms sort and pack recycled materials and waste product and can reduce volumes over 50% by packing.[5]

Both large waste collection operations utilize both truck and rail, with truck used principally for waste collection and both truck and rail used for outbound distribution. For outbound traffic, the waste is shipped by either truck or rail to landfills in the State of Connecticut or other States in the Northeast/Midwest/Canada (major destinations include: Ohio, Pennsylvania, Virginia, and Massachusetts). One of the interviewees also identified outbound international shipments for high value recyclables in containers via the Port of New York/New Jersey.

Mode Shift/Local Sourcing and Major Constraints

- For some waste products handled, (such as high grade paper products) the transportation cost is pretty marginal. For MSW, however, transportation can be the biggest cost, challenging the product margins.

[3] Based on interviews with waste haulers from previous CS work
[4] 3.2 million tons divided by 18 tons/truck
[5] Source: Willimantic Waste

- At the peak of rail use for both interview subjects (several years ago) one company utilized rail for handling for about 35% of their tonnage (outbound), and truck for 65%. Since then, there is a much smaller percentage for rail. The other company utilizes rail for about 10% of their total traffic.

- The short lines railroads can be very difficult to deal with directly. Multiple interchanges with the rail and high costs are discouraging shippers to utilize rail. There are also issues with switching charges and other surcharges (including fuel surcharges on each rail car) for using rail. Shippers currently have little alternative or leverage in rate negotiation (beyond switching to truck). For many commodities it is currently more cost effective to use truck.

- There is a major issue with light-loading rail cars on most of the Statewide short line rail network (including PAS, P&W[6], and CSO) that can only carry cars less than 263,000 lbs (263K).

- Waste shipping acts as the backhaul for a lot of drivers (outbound) who make deliveries to local shippers (such as Home Depot). Dispatchers utilize 3PLs to source the waste as a backhaul. This can be encouraged by linking brokers with waste haulers and somehow incentivizing the backhaul. This will be described later in this appendix.

- Waste companies are very focused on local sourcing and are able to identify efficiencies when taking over another company (both shippers interviewed had done so multiple times over the past 10 years).

Future Trends and Opportunities

- Both companies interviewed feel that as long as the economy keeps growing, there will be a demand for waste handling. Since the data available from the DEEP is from 2009, it is difficult to determine the effect of the economic recovery on regional waste demand, although the recession seems to have influenced the decline in overall waste between 2008 and 2009 (Figure F.2). Recycling growth is expected to continue, as waste processors improve their techniques and technology and are able to identify new markets (both domestic and international) for recycled products.

- Further declines in rail share are expected for outbound waste, in part because of difficulties in negotiating with the railroad and high costs. Rail rates are fast increasing (including fuel surcharges) and outbound customers are showing a preference for truck because of the speed and greater efficiency.

- Opportunities for mode shifts (from truck to rail) in Connecticut may include greater use of rail for long distance outbound shipments of recycled materials or greater volumes of materials bound for out-of state landfills. Longer distances do increase the cost for municipalities to dispose of their waste; however, it has been a challenge in recent years for the State to permit new landfill facilities. The rail share decline is substantiated by both the interviews and the FAF data and directing attention to institutional and cost structure issues on the railroad may help arrest the decline.

- Although there is currently no rail access to RRF facilities, there may be future opportunities to reduce emissions by sending processed waste (i.e. ash and other residue) out of state (further distances such as New York, New Hampshire, and Massachusetts) using rail. Providing a rail siding to these facilities may be an expensive proposition however, another option would be utilization of

[6] There is a reported risk that P&W service will be curtailed for rails to trails conversion.

truck to rail bulk transfer facility for MSW or RRF residue waste to transport the waste to out of State facilities. With growing demand for waste and limited disposal options in the State, this may become a more attractive option over time.

- There is only one landfill in the State that can receive ash residue from RRF facilities. If there was another RRF waste disposal landfill in the State of Connecticut, there might be opportunities to reduce *long distance* (i.e. greater than 50 miles) truck traffic (and associated VMT) in the State by between 12-15,000 annual trucks. Finding a new location to dispose of RRF ash residue near activity centers could likely reduce truck traffic and associated emissions as several of the highest volume RRF facilities are located in the central part of the State. Previously, there was an ash landfill in Hartford, publically owned, which reached capacity in the late 2000's, necessitating the transferring of the Hartford area RRF waste to Putnam, increasing costs for municipalities and requiring longer transportation trips. The State has explored options to replace this facility but has not yet approved a new site.[7]

- It is recognized that an additional ash landfill in the State would help reduce costs of waste disposal for municipalities.[8] As described previously, over 25,000 trucks annually are hauling ash for disposal at a Connecticut ash residue landfill. Of these, about 20,000 (80 percent) are hauling ash from three RRF facilities—Bristol, Mid-Connecticut (Hartford), and Wallingford. The annual VMT generated by these moves is about 1.8 million VMT (not including backhaul. Since the trucks hauling ash residue carry somewhat specialized cargo, a backhaul for those trucks on the trip is unlikely. This adds about 1.8 million VMT to the State's highways, totaling about 3.6 million VMT generated by the trucks hauling ash from central Connecticut's three RRF facilities.

- By siting a new ash landfill somewhere in the Hartford region (to mitigate the transportation effects from the closing of the original Hartford-area landfill in 2008), VMT could be reduced to about 1.2 million miles, 2.4 million miles less (two thirds) than current distribution patterns

- Allowing for heavier truck loads to and from waste transfer facilities would also likely reduce VMT. Trucks hauling waste generally exceed the limits for weight before the filling the trailers' volume meaning that greater volumes of waste could fit in each trailer and reduce overall trips.

- Working with brokers to link waste haulers with inbound shippers and/or incentivizing the backhaul could help reduce empty backhauls.

Petroleum Distribution

Petroleum distribution activities play a large role in the transportation system in the State of Connecticut, involving several different modes, including pipeline, barge, and most prominently, truck. In 2009, tanker trucks on Connecticut roadways hauled nearly 7 million tons of fuel product, accounting for about 300,000 trucks. According to Transearch data, nearly 50 percent of the refined petroleum product tonnage carried by tanker truck is inbound to the State of Connecticut, with another 36 percent outbound, and 17 percent traveling through the State.

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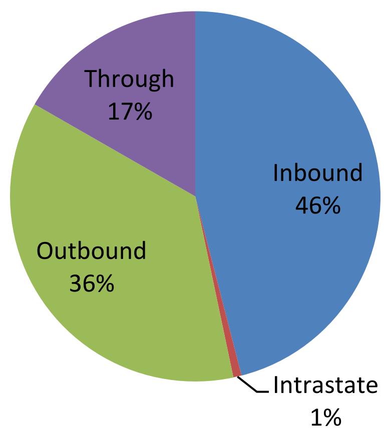
[7] In 2008 and 2009, the Connecticut Resources Recovery Authority (CRRA) conducted a 16 month, $1.5 million study of potential sites to replace the closed Hartford landfill and identified one site in Franklin, CT that met the State's criteria for an ash landfill. However, the CRRA decided to pursue other alternatives as of August, 2009. http://www.crra.org/documents/press/2009/CRRA_suspends_ash_landfill_initiative_8-27-2009.pdf

[8] Ibid

About 75 percent of the through tonnage is traveling between New York and Massachusetts on Connecticut's roadways. Outbound tonnage (i.e. originating in Connecticut and terminating in another State) is predominantly traveling to New York and New Jersey, the two States accounting for about 95 percent of the total. A very large proportion of the inbound tonnage to Connecticut originates in Massachusetts (about 82 percent). Figure F.5 shows the distribution of tanker truck tonnage in the State, by direction of flow.

Figure F.5 Direction of Tanker Truck Freight Flows in Connecticut, 2009



According to information reported by interview subjects, the industry is relatively stable, although the increasing price of crude oil, constrained Northeast petroleum refining capacity, and other regulatory and institutional challenges (such as air quality regulations of both refineries and trucks) have contributed to rising distribution costs. Other challenges that the region has faced in recent years and will likely continue to experience in the absence of stable petroleum pricing includes the closing and consolidation of refined petroleum product terminals, congestion, and lack of redundancy in the distribution network.

Interviews

For this project, two petroleum product distributors were interviewed, with about 150 employees between them and accounting for tens of thousands of annual tanker truck trips, as well as a bulk petroleum storage facility terminal for a major international oil producer. According to the interviewees, terminal locations for fuel/heating oil and gasoline are located throughout the State, with concentrations in places like New Haven, Bridgeport, Groton, and Wethersfield. In February 2012, there were 25 such terminals located throughout the State. This number has declined by about 10% during the last decade.[9] The interviewees reported a range of transportation modes for sourcing and distributing petroleum products including barge and pipeline, rail, and truck (although in Connecticut, rail is generally not used for petroleum product delivery).

[9] Source: IRS TCN Terminals (2003-2012)

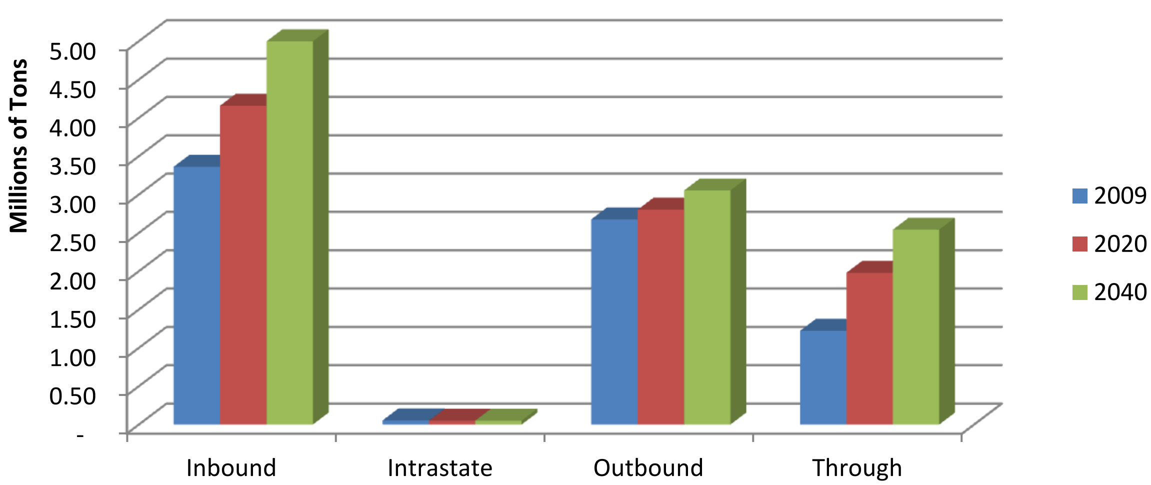
For "inbound" product, (i.e. refinery to the terminal) barges, tanker ships, and pipelines are used to transfer product. One distributer noted that a major source of product for loading terminals on the Connecticut coast (New Haven) or near Hartford arrives from refineries in St. Johns (Canada). These deliveries are made by barge. If any additives are required for the petroleum product, they are brought to the terminals by truck. Customers for the terminal operators are carriers or fuel transporters. Most customers arrange shipments (using tanker trucks) to collect fuel for onward distribution.

For "outbound" distribution (i.e. collection from the terminal for delivery to gasoline filling stations or other fuel/heating oil customers throughout the region), trucks are the exclusive mode. Outbound product from the terminals can also be sent out by barge or ship to locations up river. Depending largely on the distance from their own storage yards to the petroleum terminals, tanker truck operators can make multiple trips in a single day. Product carriers generally do not operate long distances over the road, rather concentrating on local distribution. Some customers are 3rd party carriers but many are companies sourcing product for further distribution or their own use. The petroleum business is market based and extremely time sensitive (i.e. customers monitor the price of fuel on a day to day basis) and expect delivery immediately. Tanker trucks are very specialized vehicles making backhauls difficult. Fuel hauling trucks are generally optimized for weight limits and specifications for highways on regions where they operate. There is little to no use of rail in Connecticut for distributing petroleum products.

Future Trends

Figure F.6 shows the anticipated growth in tanker trucks flows of refined petroleum products between 2009 and 2040 from the Transearch data. By 2040, total tonnage will increase by about 50 percent, with through freight growing by the fastest rate (over 100 percent), with inbound and outbound flows increasing by 49 and 14 percent, respectively. Intrastate flows will experience marginal declines over the next 30 years, accounting for less than 1 percent of the tonnage in 2040.

Figure F.6 Growth in Tanker Truck Freight Flows in Connecticut, by Direction



The local Connecticut petroleum distribution business has experienced challenges over the past several years, including declining numbers of terminals (especially inland), contributing to remaining terminals sometimes having difficulty accommodating demand, and likely contributing to increased sourcing of fuel from sources outside the State. Limited numbers of facilities can also cause problems when accidents or natural disasters restrict access at the terminals (i.e. New Haven terminal closed after the Hurricane, and the region had no alternative source of fuel). The closing of terminals is seemingly associated with declining demand for certain types of fuels as well as a tightening of supply for refined petroleum products throughout the Northeast region.

Other constraints identified by users include serious highway congestion on key distribution routes such as I-95 and the interchange between I-95 and I-91. For accessing these facilities, trucks are generally dispatched very early in the morning to avoid the congestion. Since fuel/heating oil and gasoline trucks distribute to filling stations and other facilities throughout the State, there are truck restrictions at certain network points because of weight limits on bridges. This can contribute to some circuitous routing to avoid the restricted areas. A specific example of circuitous routing was noted during the construction of the I -195/Fall River Bridge when trucks had to utilize bypasses, increasing the number of miles travelled. Finally, New England's disharmonious weight limit laws contribute to less than optimal use of tankers. Tankers are allowed 9,000 gallon tankers in Connecticut and 10,000 in Massachusetts, but Massachusetts requires 6 axles for those loads. This requires specialized trucks for deliveries to each State.

Another somewhat unique challenge in the State is the conversion of fuel from summer to winter blends. The distributors often run with short loads during the month-long transition period, which adds additional trips and miles to the network. This transition time is needed to allow for users to "run down their tanks." About 10% of trips in May are affected by this shift.

Opportunities

- Exploring strategies for converting portions of the tanker fleet to cleaner burning fuels. There is currently limited interest from haulers due to the high capital cost associated with the conversion.

- There are limited opportunities for reducing emissions by more local sourcing due to the proximity of distributors to terminal locations for companies offering tanker truck services.

- Exploration by the State of allowing heavier tanker trucks on State highways could allow for fewer overall deliveries and reduced VMT. Permitting 10,000 gallon tanker trucks would allow for about 11 percent additional capacity for each truck, theoretically leading to a corresponding reduction in the number of total tanker truck trips. According to Transearch data from IHS Global Insight, in 2009, there were about 300,000 trucks carrying refined petroleum products in tanker trucks on Connecticut roadways, with about 2/3 of them carrying product such as gasoline, kerosene, or fuel oils and another 1/3 carrying product such as liquefied gas. With the efficiency improvements from allowing 10,000 gallon tanker trucks, as opposed to 9,000 gallon trucks, the total annual trucks needed to haul the same volume of product could be reduced by nearly 33,000, including inbound, outbound, through, and intrastate trucks. This number increases to nearly 50,000 annual trucks by 2040.

- Tanker trucks use both roadways in Connecticut and outside the State, with VMT on Connecticut roadways accounting for about 36 percent of the total (including through trips). VMT associated with utilizing the 9,000 gallon tanker trucks is about 26 million miles on Connecticut roadways. Allowing the 10,000 gallon tanker trucks would reduce overall VMT to about 23 million miles, a savings of nearly 3 million VMT.

Opportunities for Reducing Backhaul Challenges in Connecticut

Backhaul issues in the State of Connecticut area are of concern, however, industry (including both shippers and carriers) works diligently to fill their backhauls to reduce the costs of providing truck service both within and to Connecticut. According to information collected in the interviews, carriers utilize a range of strategies to fill their backhauls when making deliveries within, to or from the State of Connecticut including:

- brokerages
- load matching services
- personal relationships with shippers

A major "export" for Connecticut is waste and according to interviews with waste haulers in the State, many carriers will make deliveries in the State to retail outlets, warehouses and distribution facilities, and other customers, and collect an outbound waste or recyclables load bound for neighboring states of New York, Massachusetts, Rhode Island, and New Jersey. Despite efforts to reduce backhauls, data from Transearch indicates that both inbound and outbound trucks in Connecticut have a backhaul ratio of about **70 percent**. This means that for every 10 trucks that make a delivery in the State, about 7 have an empty backhaul (i.e. no cargo). Transearch reports an even worse ratio for intrastate truck moves: for every 10 trucks carrying cargo with both an origin and destination within the State, there are 16 empty trucks. This could demonstrate carriers traveling to seek a shipment before delivery and an empty backhaul back to a terminal following delivery. Several interview subjects reported higher overall costs for making deliveries in the State, the result of the challenges in securing a backhaul. These proportions will remain similar through 2040, with the backhaul ratio associated with inbound cargo worsening to nearly 80 percent.

The VMT associated with backhauls in Connecticut accounts for about 206 million miles for inbound, outbound, and intrastate trucks in 2009. This number is expected to increase to over 367 million by 2040, an increase of over 80 percent. The proportion of VMT associated with backhauls is lower than the proportion of trucks (50 percent versus 70 percent), indicating that backhauls are generally much shorter than loaded trips (possibly trucks doing a backhaul to a centralized terminal). This is also substantiated by VMT for intrastate moves which have a backhaul ratio to 1:1.1 (i.e. every 10 loaded VMT for with both an origin and destination within the State, there is 11 empty VMT).

Opportunities

As described previously, many different strategies are available to help eliminate backhauls and have been employed by industry throughout the United States, however most come with additional cost and do not always fit with the operational plan of the carrier. The use of brokers adds additional fixed cost to a delivery and certain prominent backhaul products (such as waste) already have thin margins. Many companies elect to develop personal or business relationships with specific shippers located throughout the northeast, as opposed to using brokers, and incorporate the backhaul into typical operations (i.e. a carrier based at a terminal in Hartford regularly delivers a shipment of sand to a customer in New Haven, collect a shipment of waste in New Haven, and deliver that waste to a landfill or RRF facility in the Hartford area).

Other strategies rely on technology for load matching backhauls and have been applied most prominently at Ports around the Country for drayage truck drivers. Research indicates that currently, optimization of loads using technology is an almost exclusively managed by the private sector, and several private organizations (i.e. loadmatch.com, Transcore, VICS empty miles) have developed software to link carriers with empty backhauls to potential loads. Many of these programs are best optimized for carriers that serve shippers on a consistent basis and seem to be less effective for one-off loads. Subsequently, many of the adopters of these technologies are larger scale operators that have integrated the software into their cost structure and can maintain long term contacts. According to interviews, the truck carrier industry in Connecticut is dominated by smaller operations (between 5-10 trucks) that may not be able to take full advantage of these programs. Some load matching services charge an annual fee and others a monthly fee, which may be prohibitive to smaller carriers.[10] [11] Additionally, users may be able to achieve the same benefits by developing personal relationships.

Realizing the full benefits from these strategies (including brokerages, load matching tools, and professional relationships with multiple shippers) depend on the sharing and dissemination of information on routing and other operations. The research indicates that there is not much that can be done by policy makers to encourage backhauls that industry is not already doing to maximize its own efficiency. Policy makers could however, encourage the use of these services through tax incentives or other subsidies, although tracking the utilization of these load matching tools might prove a challenge. On a macro scale, the backhaul issue may be alleviated by supporting coordination between land use and freight transportation planning, which may over time allow for more consistent distribution of “producing” and “consuming” freight clusters around the State. Encouraging the location of truck terminals next to major shippers might help reduce the empty trip at the “beginning” of a medium or long haul move.

The Federal Government (FHWA), in cooperation with States and regional governments has been exploring strategies to identify and promote public benefits from improved truck load efficiency. FHWA is currently developing a Freight Advanced Traveler Information System (FRATIS) Concept of Operations focused on assessing the deployment of technologies to improve the efficiency of freight operations, including drayage programs. Another FHWA project designed to test opportunities for improved load matching in the Kansas City Region was the Cross-town Improvement Project (C-TIP)[12], which utilized a collaborative dispatch model to identify load matching opportunities, and included a smart phone application with traffic and routing information, and wireless communications platform for delivering work orders to drivers. Findings from a series of 2010-2011 tests indicated that the use and monitoring of the tools lead to an increase in time savings and a reduction in empty loads of between 8-21 percent.[13]

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[10] http://freightmatch.transcore.com/3sixtyexpress.aspx?referrer=www.google.com
[11] https://www.emptymiles.org/
[12] http://ops.fhwa.dot.gov/freight/technology/best_practice/index.htm
[13] C-TIP Project Evaluation Final Report, FHWA, February 2012

APPENDIX G: MODE SHIFT STRATEGY EVALUATION

Cambridge Systematics

Current Intermodal Traffic

Currently, there is no intermodal rail traffic originating, terminating or passing through Connecticut. The Transearch data were used to estimate the volume of rail dray traffic (i.e., STCC 5021 and 5022) moving into, out of, and through Connecticut via out-of-state intermodal rail terminals. TRANSEARCH inbound and outbound intermodal traffic data were compared to the Federal Highway Administration Freight Analysis Framework version 3.2 (FAF3.2) "multiple modes and mail" data and were scaled up to match the FHWA FAF3.2 data for the base year (2009). The TRANSEARCH forecasts were used to estimate future traffic volumes. The through traffic in TRANSEARCH was not adjusted because the FHWA FAF3.2 does not separately identify intermodal rail through traffic.

Subsequently, the FHWA FAF3.2 data were used to determine the origins or destinations of the out-of-state intermodal rail traffic associated with Connecticut. The resulting intermodal traffic is presented in Table G.1. The 2009 volumes total 5.8 million tons, a 2.6% share of all truck and rail traffic.

Table G.1 Current Out-Of-State Intermodal Market Share

Mode	Tons 2009	Tons 2020	Tons 2040
Rail Intermodal (Drayed to, from or through CT)	5,860,343	8,089,579	13,380,173
Rail Carload	3,591,509	4,615,196	6,331,990
Truck (Including Intermodal Dray)	216,206,166	279,818,425	383,230,781
Intermodal Share (with respect to Truck and Rail)	**2.6%**	**2.8%**	**3.3%**

Source: IHS GI 2009 TRANSEARCH (truck, rail carload and forecast) and FHWA FAF3.2 (intermodal rail base year)

Intermodal Diversion

The divertible intermodal market was defined as shipments of "contestable" commodities (e.g., general merchandise, building materials, specialty chemicals, food products, auto parts, etc.), moving on trips longer than 400 miles, by dry van, reefer, bulk, or tank trucks.

These truck shipments were extracted from TRANSEARCH, and the current rail intermodal market share for each lane was calculated using the rail intermodal flows estimated with FHWA FAF3.2. The rail intermodal shares were then compared to U.S. domestic regional market shares from FHWA FAF3 (see Step 1 below) and depending if the existing intermodal shares were greater or smaller than the regional intermodal market shares, truck traffic was then diverted to rail intermodal. The following steps explain this process in detail:

1. **Calculate U.S. regional intermodal market shares by distance.** Using truck and the "multiple modes and mail" categories in the FAF3, the average mode share using a total volume-weighted average (truck plus intermodal tonnage) was calculated for East-East, East-West, West-West markets, and National markets (see Table G.2 below). The Mississippi River was used as the dividing line, with gateway cities, e.g., Chicago, shared across the regions. Non-intermodal commodity groups, i.e., cereal grains, metallic ores, coal, crude petroleum, gasoline, and fuel oil, were excluded.

Table G.2 Intermodal Rail Average Regional Market Shares

Mileage Segment	East-East	East-West	West-West	National
<250	2.85%	4.56%	3.77%	3.09%
250-499	5.59%	8.39%	6.16%	5.70%
500-749	12.78%	16.04%	6.29%	10.97%
750-1,249	20.85%	24.75%	13.32%	19.84%
1,250-1,999	15.66%	17.34%	27.64%	21.08%
>2,000	26.62%	26.94%	31.76%	26.62%

Source: FHWA Freight Analysis Framework version 3.

2. Estimate intermodal diversion in lanes where there is no current intermodal service. In this situation, the market share that is appropriate for the geography was applied, i.e., if it is an East-East market such as Connecticut to Atlanta, the average for an East-East market was used; alternatively, when evaluating Connecticut to Minneapolis, the East-West market average was used for the relevant distance range. This share then was applied to the truck volumes available from the TRANSEARCH truck volume for the specified OD region pair.

3. Estimate intermodal diversion in lanes where there is current intermodal service. In this case, the existing rail intermodal share was compared with the average for the distance range from the FAF3 (calculated in Step 1 of this section). If the existing rail intermodal market share was below the typical share for this distance, then sufficient truck volume was diverted to rail intermodal to match the typical share by region. If the intermodal market share already exceeded the typical average, the highest calculated share irrespective of region was applied to the diversion potential.

Table G.3 presents the results of the intermodal diversion. The table shows the current and projected diverted truck tons, units and value to intermodal rail as well as the share of the diversion of the total truck traffic. About 7.6 million truck tons, a 3.5% share of the total truck tons, were estimated to be divertible to rail intermodal in the base year, and 73% of the diversion constitutes through traffic.

Table G.3 Truck Diversion to Rail Intermodal

Year	Tons (Millions)	Units (Millions)	Value (Billions)	% of Total Truck Tons	% of Total Truck Units	% of Total Truck Value
2009	7.60	0.40	14.26	3.5%	2.4%	3.7%
2020	9.35	0.49	25.18	3.3%	2.3%	4.3%
2040	12.83	0.69	64.41	3.3%	2.3%	5.8%

Intermodal Scenarios

Base Case

Current intermodal traffic is drayed to, from and through Connecticut via out-of-state intermodal terminals in Massachusetts, New Jersey and Pennsylvania. The Base Case consists of the rail ton-miles and truck VMT in the base year 2009 and projected years 2020 and 2040 if there is no intermodal diversion from truck to rail and no infrastructure improvements are made to allow rail intermodal access in the State. In the Base Case the rail ton-miles within the State are associated with rail carload only, and the truck VMT within Connecticut include the intermodal rail day via out-of-state terminals, which represent about 3.8% of the total truck VMT within the State.

Intermodal Scenario 1—Rail via New CT Rail Terminal

The first scenario shifts existing out-of-state rail intermodal traffic being drayed to/from Connecticut to a new intermodal terminal within Connecticut.

This scenario assumes:

- A new rail intermodal terminal in the New Haven area;
- Traffic being drayed to/from Connecticut via out-of-state terminals shifts to the new Connecticut terminal; and
- Traffic being drayed through Connecticut is not shifted to the new Connecticut terminal (remains as is in the Base Case).

The impacts are:

- Adds rail ton-miles of travel within Connecticut; and
- Reduces truck dray miles of travel within Connecticut.

Intermodal Scenario 2—Truck to Rail via Existing Rail Terminals

Scenario 2 diverts shipments from truck to intermodal rail via the existing out out-of-state rail terminals in New Jersey, Massachusetts and Pennsylvania.

This scenario assumes:

- Base Case intermodal rail and rail dray remains as is;
- Truck shipments originating or terminating in Connecticut are diverted to rail via existing out-of-state intermodal rail terminals;
- Diverted shipments are drayed to/from existing out-of-state intermodal rail terminals; and
- Through truck traffic is diverted to rail via existing out-of-state intermodal rail terminals.

The expected impacts are:

- Reduces truck-miles of travel within Connecticut; and
- No change to rail ton-miles of travel within Connecticut.

Intermodal Scenario 3—Truck to Rail via New CT Rail Terminal

Intermodal Scenario 3 diverts shipments from truck to rail via a new intermodal terminal within Connecticut.

It assumes:

- A new rail intermodal terminal in the New Haven area;

- Truck shipments originating or terminating in Connecticut are diverted to rail via new Connecticut terminal;
- Shipments are drayed to/from the new rail intermodal terminal;
- Existing traffic being drayed to/from Connecticut via out-of-state terminals shifts to the new Connecticut terminal (i.e., Scenario 1); and
- Through truck traffic diverted to rail continues to use out-of-state rail terminals.

The impacts are:

- Adds rail ton-miles of travel within Connecticut; and
- Reduces truck-miles of travel within Connecticut.

Intermodal Diversion Impacts

The impacts of the intermodal scenarios on truck VMT and rail ton-miles are presented in Tables G.4 through G.9. The impacts are quantified separately for the Connecticut network only (Tables G.4-G.7) and for the National network (Tables G.8-G.9). The impacts on the State network of traffic originating or terminating in the Connecticut are presented separately than the impacts of through traffic.

If there is diversion from truck to rail intermodal, and a new rail intermodal terminal is built in Connecticut along with the associated infrastructure improvements for intermodal rail access in the State (i.e., Scenario 3), inbound and outbound truck VMT within Connecticut are expected to be reduced 5% to 269 million VMT, rail ton-miles are expected to increase 279% to 573 million ton-miles, and through truck VMT within Connecticut are expected to decrease 8% to 339 million.

More than 18 times the volume of VMT reductions associated with intermodal diversion would occur beyond Connecticut borders. Truck VMT on the National network are expected to be reduced 18% to 5.1 billion and rail ton-miles increased 153% to 28.1 billion (Scenario 3 in Tables G.8-G.9).

Table G.4 Intermodal Diversion Impacts on Truck VMT
Inbound and Outbound Traffic, CT Network Only

	2009		2020		2040	
Scenario	**Truck VMT[1]**	**% Change**	**Truck VMT[1]**	**% Change**	**Truck VMT[1]**	**% Change**
Base	283	0%	363	0%	476	0%
Scenario 1	272	-4%	347	-4%	450	-6%
Scenario 2	282	-1%	361	-1%	474	-1%
Scenario 3	269	-5%	344	-5%	446	-6%

Notes: [1]Truck VMT in millions

Table G.5 Intermodal Diversion Impacts on Rail Ton-Miles

Inbound and Outbound Traffic, CT Network Only

Scenario	2009		2020		2040	
	Rail Ton-Miles[1]	% Change	Rail Ton-Miles[1]	% Change	Rail Ton-Miles[1]	% Change
Base	151	0%	168	0%	210	0%
Scenario 1	461	205%	595	255%	916	337%
Scenario 2	151	0%	168	0%	210	0%
Scenario 3	573	279%	735	338%	1,117	433%

Notes: [1]Rail ton-miles in millions

Table G.6 Intermodal Diversion Impacts on Truck VMT

Through Traffic, CT Network Only

Scenario	2009		2020		2040	
	Truck VMT[1]	% Change	Truck VMT[1]	% Change	Truck VMT[1]	% Change
Base	370	0%	506	0%	752	0%
Scenario 1	370	0%	506	0%	752	0%
Scenario 2	339	-8%	469	-7%	702	-7%
Scenario 3	339	-8%	469	-7%	702	-7%

Notes: [1]Truck VMT in millions

Table G.7 Intermodal Diversion Impacts on Rail Ton-Miles

Through Traffic, CT Network Only

Scenario	2009		2020		2040	
	Rail Ton-Miles[1]	% Change	Rail Ton-Miles[1]	% Change	Rail Ton-Miles[1]	% Change
All Scenarios	0	0%	0	0%	0	0%

Notes: [1]Rail ton-miles in millions

Table G.8 Intermodal Diversion Impacts on Truck VMT

All Traffic to/from/thru CT, National Network

	2009		2020		2040	
Scenario	**Truck VMT[1]**	**% Change**	**Truck VMT[1]**	**% Change**	**Truck VMT[1]**	**% Change**
Base	5,914	0%	7,615	0%	10,617	0%
Scenario 1	5,881	-1%	7,569	-1%	10,540	-1%
Scenario 2	5,131	-13%	6,652	-13%	9,268	-13%
Scenario 3	5,094	-14%	6,601	-13%	9,185	-13%

Notes: [1]Truck VMT in millions

Table G.9 Intermodal Diversion Impacts on Rail Ton-Miles

All Traffic to/from/thru CT, National Network

	2009		2020		2040	
Scenario	**Rail Ton-Miles[1]**	**% Change**	**Rail Ton-Miles[1]**	**% Change**	**Rail Ton-Miles[1]**	**% Change**
Base	11,118	0%	15,341	0%	25,361	0%
Scenario 1	12,220	10%	16,865	10%	27,896	10%
Scenario 2	26,742	141%	34,561	125%	52,331	106%
Scenario 3	28,106	153%	36,409	137%	55,327	118%

Notes: [1]Rail ton-miles in millions

Carload Diversion

The divertible carload market was defined as shipments of "contestable" commodities (e.g., farm products, chemical products, metal scraps, petroleum products, etc.), moving on trips longer than 250 miles, by bulk, or tank trucks.

These truck shipments were extracted from TRANSEARCH, and the current rail carload market share for each lane was calculated. The rail carload shares were then compared to U.S. domestic regional market shares from FHWA FAF3.2 (see Step 1 below) and depending if the existing carload shares were greater or smaller than the regional carload market shares, truck traffic was then diverted to rail carload. The following steps explain this process in detail:

1. **Calculate U.S. regional carload market shares by distance.** Using the truck and rail categories in the FAF3, the average mode share using a total volume-weighted average (truck plus rail carload tonnage) was calculated for Northeast-Northeast, Northeast-U.S. Remainder, U.S. Remainder-U.S. Remainder markets, and National markets (see Table G.10 below). The Northeast included the New England region and New York and the remaining states with the exception of Alaska and Hawaii were included in U.S. Remainder. Non-bulk commodity groups, e.g., live animals, pharmaceuticals, textiles, motorized vehicles, and transportation equipment, were excluded.

Table G.10 Carload Rail Average Regional Market Shares

Mileage Segment	Northeast-Northeast	Northeast-U.S. Rem.	U.S. Rem.-U.S. Rem.	National
<250	2.16%	4.80%	5.68%	5.39%
250-499	6.02%	11.48%	13.58%	13.23%
500-749	6.32%	18.89%	23.08%	22.81%
750-1,249	0%	20.40%	37.58%	36.00%
1,250-1,999	0%	13.43%	41.98%	37.29%
>2,000	0%	10.72%	22.74%	20.48%

Source: FHWA Freight Analysis Framework version 3.2.

2. **Estimate carload diversion in lanes where there is no current carload service.** In this situation, the market share that is appropriate for the geography was applied, i.e., if it is a Northeast-Northeast market such as Connecticut to Maine, the average for a Northeast-Northeast market was used; alternatively, when evaluating Connecticut to Minneapolis, the Northeast-U.S. Remainder market average was used for the relevant distance range. This share then was applied to the truck volumes available from the TRANSEARCH truck volume for the specified OD region pair.

3. **Estimate carload diversion in lanes where there is current carload service.** In this case, the existing rail carload share was compared with the average for the distance range from the FAF3 (calculated in Step 1 of this section). If the existing rail carload market share was below the typical share for this distance, then sufficient truck volume was diverted to rail carload to match the typical share by region. If the carload market share already exceeded the typical average, the highest calculated share irrespective of region was applied to the diversion potential.

Table G.11 presents the results of the carload diversion. The table shows the current and projected diverted truck tons, units and value to rail carload as well as the share of the diversion of the total truck traffic. About 2 million truck tons, a 0.9% share of the total truck tons, were estimated to be divertible to rail carload in the base year, and 74% of the diversion constitutes through traffic.

Table G.11 Truck Diversion to Rail Carload

Year	Tons (Millions)	Units (Millions)	Value (Billions)	% of Total Truck Tons	% of Total Truck Units	% of Total Truck Value
2009	2.03	0.12	934.62	0.9%	0.7%	0.2%
2020	2.37	0.14	1,139.48	0.8%	0.6%	0.2%
2040	2.58	0.15	1,455.84	0.7%	0.5%	0.1%

Carload Scenarios

Base Case

Currently, the rail traffic originating, terminating or passing through Connecticut is rail carload. The Base Case consists of the rail ton-miles and truck VMT in the base year 2009 and forecast years 2020 and 2040 if there is no diversion from truck to rail carload.

Carload Scenario 1—Truckload to Rail Carload

This scenario assumes truckload shipments to, from and through Connecticut are diverted to rail carload. The impacts are:

- Adds rail ton-miles of travel within Connecticut; and
- Reduces truck miles of travel within Connecticut.

Carload Diversion Impacts

Tables G.12 and G.13 show respectively the impacts of carload diversion on truck VMT and rail ton-miles within Connecticut. As a result of the carload diversion, rail ton-miles are expected to increase 100% to 354 million, and truck VMT decrease 1% to 687 million.

Table G.12 Carload Diversion Impacts on Truck VMT

All Traffic to/from/thru CT, CT Network Only

Scenario	2009 Truck VMT[1]	2009 % Change	2020 Truck VMT[1]	2020 % Change	2040 Truck VMT[1]	2040 % Change
Base	696	0%	926	0%	1,310	0%
Scenario 1	687	-1%	915	-1%	1,297	-1%

Notes: [1]Truck VMT in millions

Table G.13 Carload Diversion Impacts on Rail Ton-Miles

All Traffic to/from/thru CT, CT Network Only

Scenario	2009 Rail Ton-Miles[1]	2009 % Change	2020 Rail Ton-Miles[1]	2020 % Change	2040 Rail Ton-Miles[1]	2040 % Change
Base	177	0%	201	0%	261	0%
Scenario 1	354	100%	407	103%	485	85%

Notes: [1]Rail ton-miles in millions

APPENDIX H: M-95 CORRODOR COALITION’S WATERSIDE PROJECT

The I-95 Corridor Coalition’s waterside system was selected as a Marine Highway Corridor under the U.S. Department of Transportation’s (USDOT’s) America’s Marine Highway Program, a new initiative to move more cargo on the water rather than on crowded highways. As the sponsor of the M-95 Marine Highway Corridor, the I-95 Corridor Coalition will be assisted by the USDOT Maritime Administration in developing transportation services and with identifying potential freight and passenger markets.

In addition to the M-95 Marine Highway Corridor designation, several projects and initiatives in the I-95 Corridor were selected to be eligible for federal assistance under the Program. “These projects will help make better use of America’s Marine Highway by reducing gridlock, improving the environment, and putting skilled mariners and shipbuilders to work,” said David Matsuda, Maritime Administrator.

Projects and Initiatives selected in the I-95 Corridor include:

- Cross Sound Enhancements Project (Connecticut DOT)
- New England Marine Highway Expansion Project (Maine DOT)
- Cross Gulf Container Expansion Project (Ports of Manatee, FL, and Brownsville, TX)
- Gulf Atlantic Marine Highway Project (South Carolina State Ports Authority and Port of Galveston, TX)
- Trans-Hudson Rail Service Project (Port Authority of New York & New Jersey)
- James River Container Expansion Project (Virginia Port Authority)
- Hudson River Food Corridor Initiative (New York City Soil & Water Conservation District)
- New Jersey Marine Highway Initiative (New Jersey DOT)
- East Coast Marine Highway Initiative (Ports of New Bedford, MA, Baltimore, MD, and Canaveral, FL)

M-95 Marine Highway Corridor Attributes: The 1,925 mile-long I-95 Corridor is the major North-South landside freight corridor on the East Coast. The USDOT identified more than a dozen major freight truck bottlenecks along this route, along with significant critical rail congestion along the upper portions. Projections of future freight volumes indicate increasing freight congestion challenges, with limited opportunity to increase landside capacity.

The Corridor is home to 15 of the largest 50 marine ports in the United States (as ranked by total throughput). These ports handle approximately 582 million short tons of cargo, or 26 percent of the national total. Much of this freight begins or ends its journeys with an I-95 transit. Fortunately, the East coast also possesses a host of waterways, bays, rivers, and the Atlantic coast itself. The Corridor is also lined with less congested, smaller niche ports that could play a vital part in the developing marine highway service network. While several Marine Highway operations already serve this corridor, there is significant opportunity for expansion to help address growing congestion, reduce greenhouse gas emissions, conserve energy, and lower landside infrastructure maintenance costs.

APPENDIX I: SYSTEM EFFICIENCY IMPROVEMENTS

Cambridge Systematics

This appendix describes strategies that improve the efficiency of truck freight delivery system by improving the utilization of available information sources. The following strategies are evaluated:

- Electronic screening of commercial vehicles
- Smart roadside initiative

Electronic screening of commercial vehicles

Overview of Strategy and Expected Benefits

As part of the Commercial Vehicle Information Systems and Networks (CVISN) program, Connecticut has deployed electronic screening technology at its Union and Greenwich inspection facilities to target enforcement resources at non-compliant carriers and carriers with histories of non-compliance. CVISN is a cooperative effort among State and Federal agencies to organize information and communication systems related to commercial vehicle operations (CVO), and allow them to operate in an integrated manner.[1] Compliant carriers that opt to enroll in the State's program are allowed to bypass the inspection facility, which reduces the number of commercial vehicles idling while in queue to be weighed and/or be inspected. Any carrier may register with the State's CVO credentialing system via the state's website (https://www.cvisn.ct.gov/ct/).

Electronic pre-screening has been deployed in many other states and some evaluations of benefits have been conducted. Battelle and ATRI (2007) estimates the per-screening benefits to be $8.68 per bypass, assuming a 4 minute savings per bypass and a value of time of $2.16 per minute.[2] PrePass, which has coverage in over 30 states, also publishes per-vehicle benefits estimates for time savings, fuel savings, and operating costs, assuming that 5 minutes and 0.4 gallons of fuel are saved per bypass.[3]

Potential Benefits in Connecticut

The Connecticut Department of Public Safety (DPS) publishes a biannual weigh station summary report. We reviewed publications for July 1, 2008 – June 30, 2010 (the latest report available on-line). The six permanent weigh and inspection stations operating in Connecticut are included. Table I.1 summarizes operating statistics from these stations, including operational and open hours, vehicles checked through (during open hours – whether weighed or bypassed), total inspections (vehicles weighed), operating costs, and percent of checked vehicles that were weighed. These are shown by station for the first half of 2010, and for all stations for the entire period reviewed.

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[1] For more information on CVISN, see: Connecticut DMV, "The Connecticut CVISN/PRISM Project," http://www.ct.gov/dmv/cwp/view.asp?a=798&Q=289872&PM=1; and FHWA & FMCSA, "CVISN Safety Information Exchange for Commercial Vehicles in Connecticut: A Case Study," FHWA-JPO-04-030, http://cvisn.fmcsa.dot.gov/WhatsNew/Connecticut/Connecticut.htm.

[2] Battelle and American Transportation Research Institute (2007). "Economic Analysis and Business Case for Motor Carrier Industry Support of CVISN." Prepared for U.S. Department of Transportation. This study cites a savings of 3 to 5 minutes per truck based on a 2002 FHWA evaluation of the Oregon Green Light program.

[3] http://www.prepass.com/services/prepass/pages/calculateyoursavings.aspx

Table I.1 Weigh Station Operating Statistics

Weigh Station	Operational Hrs	Hrs Open Sign Activated	Vehicles Checked Through	Total Inspections (weighed)	Op Costs	% of checked vehicles weighed
By station - 2010 1/1 - 6/30						
Greenwich	1,414	881	106,469	12,599	$131,367	12%
Danbury	566	225	13,679	13,679	$52,390	100%
Middletown	268	55	9,580	9,580	$41,194	100%
Waterford SB	58	49	1,947	1,947	$8,549	100%
Waterford NB	169	138	8,146	8,146	$24,116	100%
Union	1,074	900	120,084	6,515	$94,463	5%
Total						
2008 7/1-12/31	3,292	2,211	282,048	63,012	$401,759	22%
2009 1/1-6/30	3,216	2,098	293,278	60,009	$375,363	20%
2009 7/1-12/31	3,370	2,067	277,660	37,445	$365,645	13%
2010 1/1-6/30	3,549	2,248	259,905	52,466	$352,080	20%
Annual Average	**6,714**	**4,312**	**556,446**	**106,466**	**$747,424**	**19%**

The following observations can be made:

- The "open" sign is activated for about one-half of the total hours (365 * 24 = 8,760 total hours per year). It is not known whether these are the busiest hours in terms of truck traffic.

- Greenwich and Union are by far the busiest stations, accounting for 87 percent of total vehicles checked through in first half of 2010.

- At these two stations, the vast majority of vehicles were checked through but not weighed (88 percent at Greenwich, 95 percent at Union). While these vehicles were likely pre-screened, it is not known whether this is entirely due to use of the pre-screening technology, or whether there were bypasses for other reasons as well.

- At the other remaining stations, all vehicles checked-through during open hours were weighed.

It is not known for certain how many more vehicles might be checked through and not weighed with comprehensive deployment of pre-screening technology at all stations and for all trucks. To estimate the potential benefits of comprehensive deployment, however, we assumed that 95 percent of all trucks at all facilities could be checked through (assuming the inspection stations are open for the same time periods as in the past). Out of the total of 556,000 annual check-throughs, 450,000 are currently bypassed without weighing. An additional 78,600 would bypass the weigh stations with 95 percent coverage for all stations.

It was further assumed that each bypass would save 5 minutes of idling time per truck, for a total savings of 6,550 hours in idling time annually (78,600 * 5 min / 60 min/hr). (To be checked through a facility, a truck would still need to slow to about 10 mph, so emissions from a full power merge would not be eliminated.) Idle emission factors in grams per hour were taken from the MOVES model using input data consistent with that used for the emissions inventory conducted for this project. Table I.2 shows emissions rates and the total savings per year, and compares this savings against the total statewide emissions from trucks.

Table I.2 Emission Rates and Potential Savings from Pre-Clearance (2009)

Emissions Component	Emissions Rate (g/hr)	Savings (tons per year)	Total statewide emissions (trucks)	% Savings
CO2	9,143	66.05	1,918,234	0.003%
NOx	248	1.79	15,829	0.011%
PM2.5	3.04	0.02	570	0.004%
VOC	46.2	0.33	3,354	0.010%
CO	88.7	0.64	29,226	0.002%

As Table I.2 shows, the total potential emissions savings is a small percentage of the statewide inventory –0.01 percent for NOx and VOC (about 1.8 and 0.3 tons per year respectively), and 0.002 to 0.004 percent for CO, CO2, and PM2.5. Some uncertainties in this assessment are noted, such as the actual percentage of trucks that could ultimately be cleared through pre-screening, and the extent to which bypasses are due to pre-screening. However, even a substantial variation in these parameters would be unlikely to increase the CO2 savings beyond 0.01 percent of the statewide inventory, or NOx and VOC beyond 0.02 to 0.03 percent. Looking ahead to strategy impacts in 2020, emission rates should be lower, but the percentage savings should be similar, since total emissions per truck will also be lower.

While the emissions benefits of pre-screening are small, the strategy does appear to be highly cost-effective, based on savings in vehicle operator time, fuel savings, and perhaps inspection station operation costs. In other words, pre-screening – if used effectively – results in net cost savings, with a short payback period, and therefore would make sense regardless of emissions benefits. Battelle and ATRI (2007) estimates the per-screening benefits to be $8.68 per bypass, noting a return on investment of 6:1 to 15:1, with a payback of less than one year. Fuel savings of 0.08 gallons per bypass add another $0.30, assuming the CO2 emissions rates as noted in Table I.2.[4] Further savings to the public sector could result from the need to weigh fewer trucks. The cost per vehicle weighed averages to about $7.00 based on the statistics reported by DPS.

[4] This is considerably lower than PrePass' estimate of 0.40 gallons per bypass – see http://www.prepass.com/services/prepass/SiteInformation/Pages/ServiceMap.aspx

Smart roadside initiative

The United States DOT and other public-sector entities (e.g., I-95 Corridor Coalition) currently are supporting the development and/or testing of a wide range of new Intelligent Transportation Systems for Commercial Vehicle Operations (ITS/CVO) applications that have the potential to improve air quality. These applications include:

- Smart Parking, which will provide real-time truck parking availability information to motor carriers, in order to reduce the amount of time spent driving in search of an available parking space;
- Dynamic Mobility, which will integrate real-time traveler information directly into motor carrier routing and dispatch decisions so that motor carriers can reduce the amount of time spent idling in congestion; and
- Cross-town Improvement Program, which will integrate Dynamic Mobility functionality with load matching to limit the number of empty/unproductive moves made by commercial vehicles.

1. Smart Parking

Overview of Strategy and Expected Benefits

Trucks frequently need to park overnight to rest during long-distance deliveries, or for a shorter period of time to wait for an appropriate pick-up or delivery window at their destination. Trucks may park at rest areas, public or privately owned service plazas, at other private establishments (such as fast food restaurants), or at other undesignated parking areas such as the shoulder of highway off-ramps. "Smart parking" systems to inform truck drivers where parking is available, and possibly allow them to make reservations, have been proposed primarily for safety reasons (to help avoid driver fatigue), but the potential for environmental benefits has also been identified. It is possible that having real-time information on parking availability could reduce fuel use and emissions by avoiding searching for parking. Such information might be provided by variable message signs on the highway, radio, mobile phone, or on-board computers.[5]

One of the major challenges to implementing smart parking is the technology to count trucks at rest areas/service plazas to determine when spaces are available. A 2001 statewide truck parking study undertaken by ConnDOT concluded that "using electronic display boards to provide real time information regarding parking space availability and/or direct drivers to other facilities does not appear to be beneficial." This conclusion was based on the inability to continuously update changes in parking availability.[6] Research has been undertaken since that time on new technologies to track parking availability, but these technologies are still clearly under development and widespread deployment has not yet been proven feasible or beneficial. A study led by the Volpe National Transportation Systems Center was the first known test of two technologies, video imaging and magnetometer, using sites in Massachusetts. The test found that counting trucks is more challenging than counting cars due to the wider variety of equipment.[7] A study led by Caltrans and UC-Berkeley is currently underway to examine

[5] "Smart Parking for Trucks." http://www.innovativemobility.org/trucks_parking/index.shtml
[6] Connecticut Department of Transportation (2001). *Truck Stop and Rest Area Parking Study.*
[7] Chachich, A., and S. Smith (no date). "Smart Park: Truck Parking Field Operation Test Results." Volpe National Transportation Systems Center.

smart truck parking along the I-5 corridor in California.[8] This study is evaluating smart parking technologies, deployment, and benefits using pilot sites along this corridor. The ability to make parking reservations is also being tested.

Assuming that technological hurdles could be overcome, the benefits of implementing such technology need to be determined. In the California study, a survey of 95 truckers found that nearly three-quarters said that the ability to look up the availability of parking at truck stops would "definitely" or "probably" be useful. However, the potential savings in terms of search time, fuel, and emissions have not yet been quantified.

Potential Benefits in Connecticut

To determine the extent to which lack of truck parking information might be contributing to excess emissions from truckers searching for available parking spots, discussions were held with Connecticut DOT staff to assess the current state of truck parking in Connecticut. A 2008 state study on rest areas and service plazas was also reviewed.[9] The 2008 report identified 31 state-owned roadside facilities, either rest areas or service areas, of which 21 have truck parking (the remainder are on parkways on which trucks are not permitted).

It became clear from these reviews that lack of truck parking is a problem in the state. DOT staff noted that all truck parking is full at night, and typically fills up by late afternoon or early evening. The 2008 report found truck parking deficits in many locations, particularly along I-95 in southwestern Connecticut, and along I-84 west of Hartford, with a current deficit of 700 spaces at rest areas/service plazas (demand 65 percent higher than supply – a deficit of 33 spaces per rest area/service plaza) and 745 spaces in other locations where parking is not provided. The projected deficit in 2025 under a "do-nothing" scenario is 2,000 spaces. Staff also noted that there are substantial barriers to expanding the supply of truck parking, either at public or private facilities. Efforts are underway to expand space at a few existing facilities, but opportunities for siting new facilities, or for significant expansion, are not readily available.

ConnDOT staff noted that they were not sure what value real-time information on parking availability would provide given that spaces fill up rapidly and that truckers know they will be full by a certain time. They were also unsure as to how parking availability would be monitored. It is also possible that some communication of parking availability already occurs among truckers via citizens band (CB) radio.

A calculation was performed assuming that a number of trucks each weekday equal to the current estimated rest area/service plaza parking deficit (700 spaces) could save 10 minutes of low-speed driving or idling time by knowing that spaces are available in advance. Table I.3 shows the corresponding emission reduction calculations. These savings represent about 0.04 to 0.05 percent of statewide NOx and VOC emissions from trucks, and 0.015 percent of statewide CO2 emissions.

[8] Caltrans, et al. (2011). "Smart Truck Parking Improving the Parking Experience." Presented at 18th ITS World Congress, October 2011.
[9] Earth Tech, et al (2008). "CT Statewide Rest Area and Service Plaza Study." Volume 1, prepared for Connecticut Department of Transportation.

Given uncertainties in the most appropriate technology, costs of deploying a smart parking system serving all rest areas and service plazas have not yet been documented. Therefore it is impossible to develop a cost-effectiveness estimate at this point.

Table I.3 Potential Savings from Truck Parking Information (2009)

Emissions Component	Emissions Rate (g/hr)	Savings (tons per year)	% of Statewide Truck Emissions
CO2	9,143	294	0.015%
NOx	248	7.97	0.050%
PM2.5	3.04	0.10	0.017%
VOC	46.2	1.49	0.044%
CO	88.7	2.85	0.010%

2. Dynamic Mobility

Freight route management information is in common use in the private sector. Carriers use GPS systems to track truck locations, provide weather and traffic information, and identify alternative routes. The state-of-the-art with GPS is to incorporate real-time traffic data into the routing algorithms. These are available on consumer GPS, both as original equipment manufacturer (OEM) installations on vehicles as well as aftermarket devices. In addition, most carriers use routing and dispatching programs that plot and optimize truck routes based on pickup and delivery points, refueling stations, etc. UPS and FedEx both have in-house proprietary systems that do dynamic routing.

Truck highway information systems also have been found to be beneficial; in an operational test of the FleetForward program by the I-95 Corridor Coalition, 75 percent of carriers believed it was a valuable tool to identify congestion and 33 percent believed that on-time delivery and/or estimated time of arrival improved."

However, the limited evaluation data on freight route management systems has not been able to quantify a VMT, fuel savings, or GHG benefit. In an operational test of the FleetForward program by the I-95 Corridor Coalition, carriers generally did not believe that the technology reduced operating costs (of which fuel consumption is one component) and the study was unable to identify any impact on congestion. "No reliable evidence yet exists on the potential cost-effectiveness of real-time transit, carpool, parking, or freight information systems in reducing GHG emissions."[10] Since this reference is somewhat dated, inquiries were made with various USDOT and FHWA offices responsible for ITS and freight operations research, and a search was made for additional literature. However, no more recent

[10] Cambridge Systematics and SAIC (2000). "FleetForward Evaluation: Final Report." Prepared for I-95 Corridor Coalition and U.S. DOT.

sources could be identified that have quantified an environmental benefit from dynamic routing systems for freight carriers. A 2010 USDOT Report to Congress that reviewed GHG reduction strategies also did not identify sources beyond the 2000 report referenced here.[11]

[11] U.S. Department of Transportation (2010). *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions.*