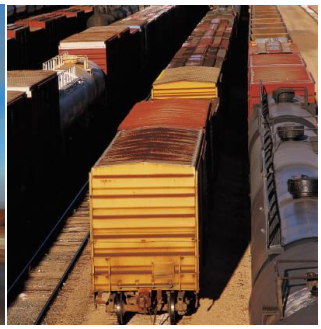
DEVELOPMENT OF A STRATEGIC PLAN FOR REDUCING EMISSIONS ASSOCIATED WITH FREIGHT MOVEMENT IN CONNECTICUT



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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

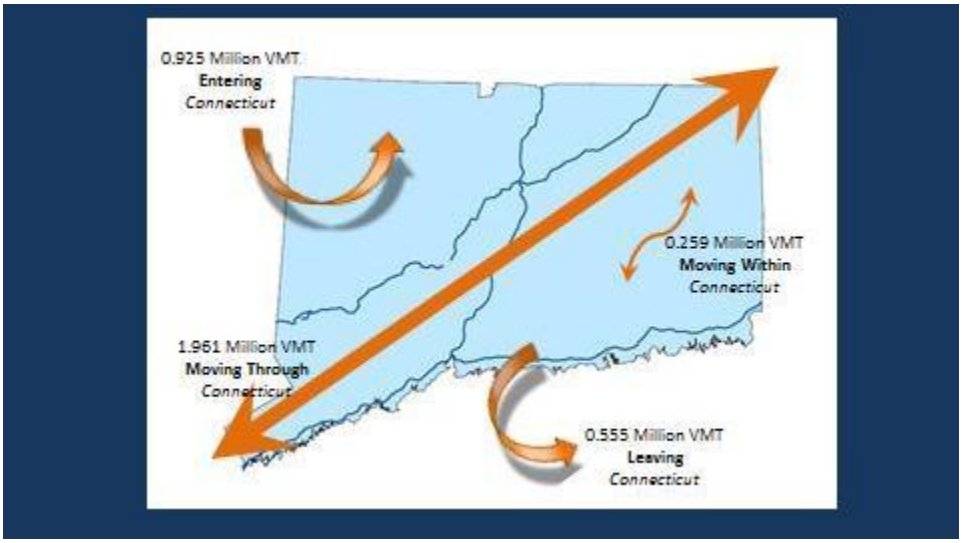
How Freight is Moved in Connecticut

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.

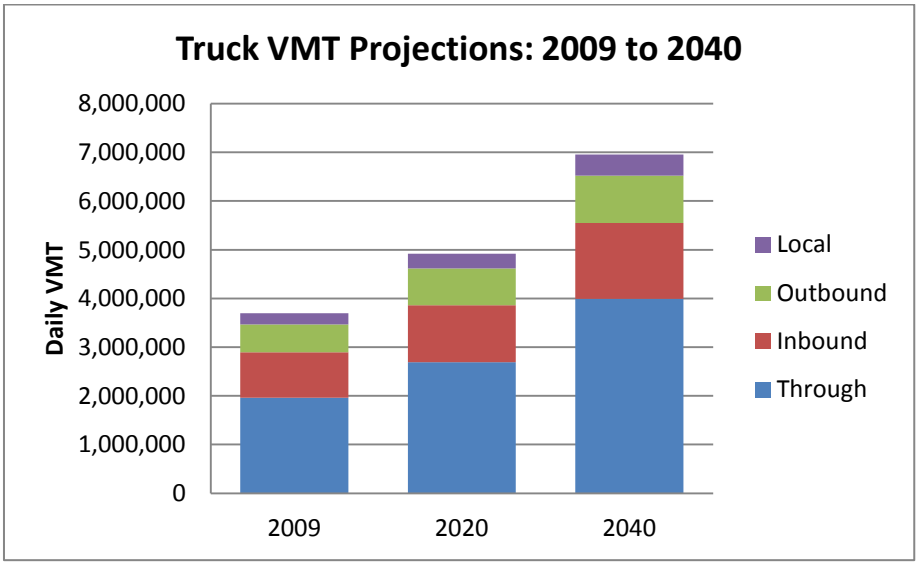
Figure 1 – Movement of Truck Freight in Connecticut



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

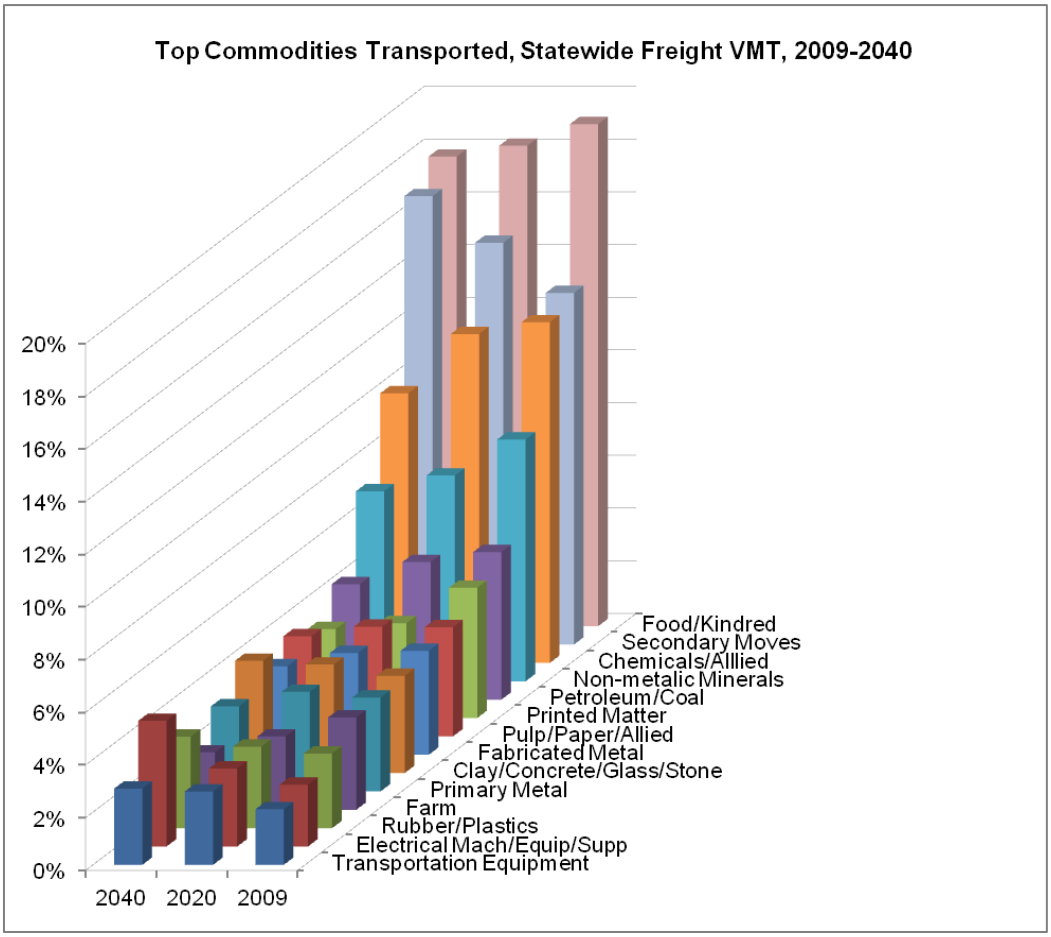


Source: dKC Analysis of Transearch

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.

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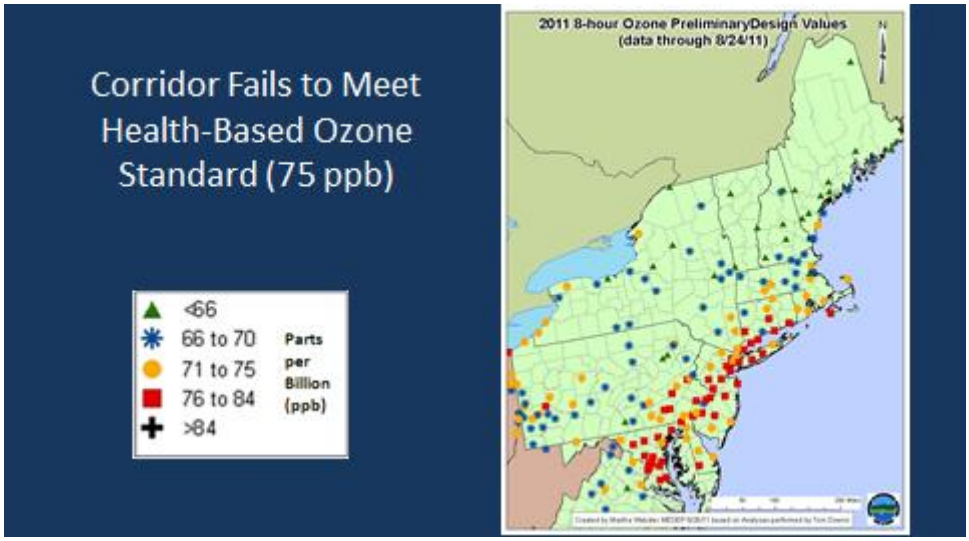
[5] 2011 Mobility Report, Texas Transportation Institute, (http://mobility.tamu.edu/ums/).

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.

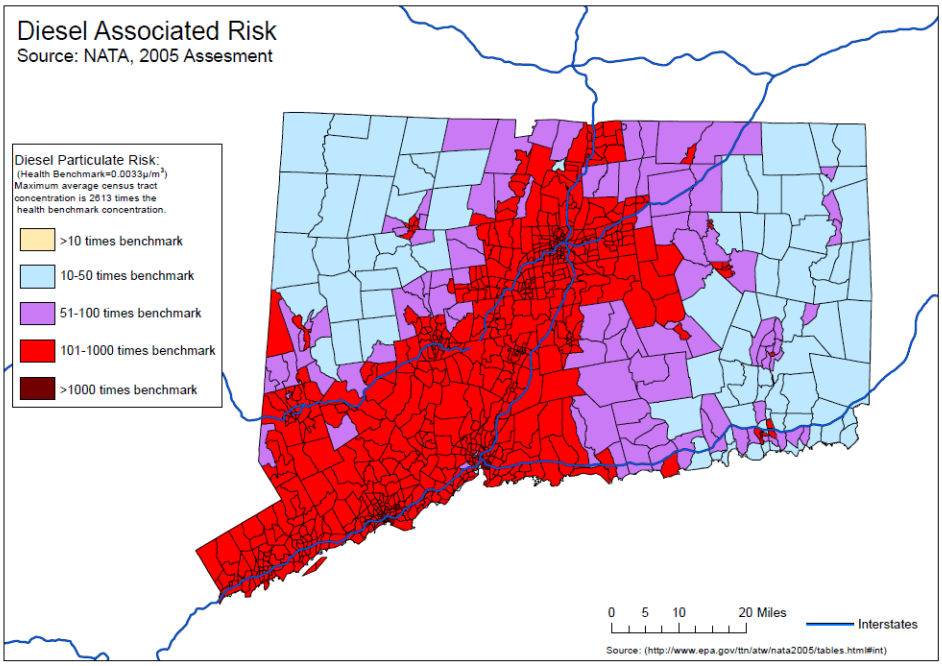
Figure 4 – Air Quality in CT and Throughout the I-95 Corridor



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)

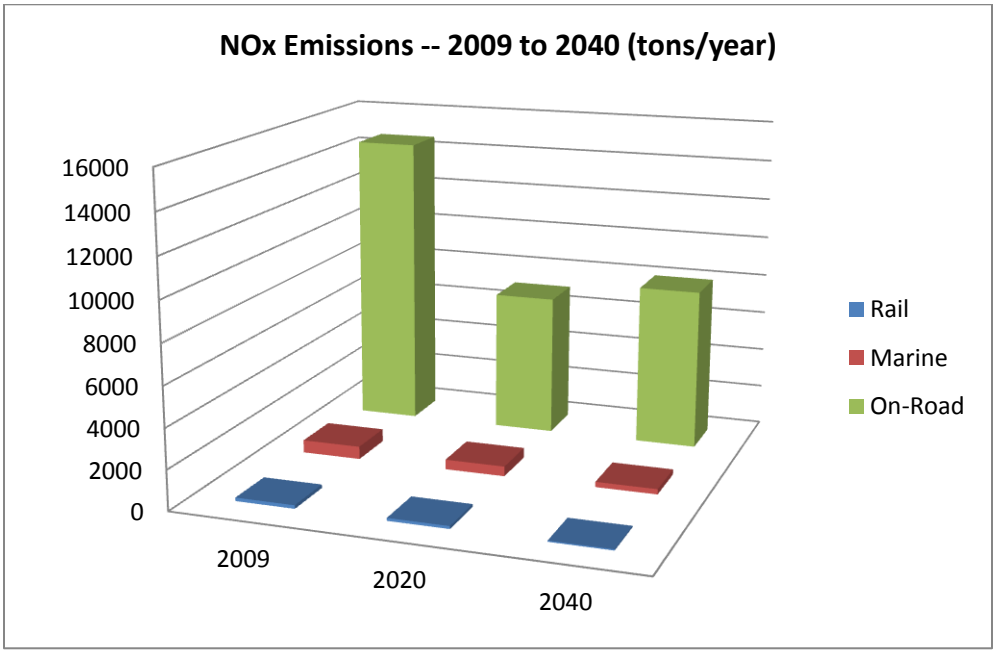
Pollutants by Freight Type – 2009-2040 (tons/year)			
2009			
Type	**NOx**	**PM**	**CO_2**
On-Road	**14,636**	**539**	**1,729,025**
Rail	**173**	**4**	**8,605**
Marine	**638**	**38**	**50,175**
Total	**15,447**	**581**	**1,787,805**
2020			
On-Road	**7,069**	**113**	**2,292,949**
Rail	**141**	**3**	**9,682**
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



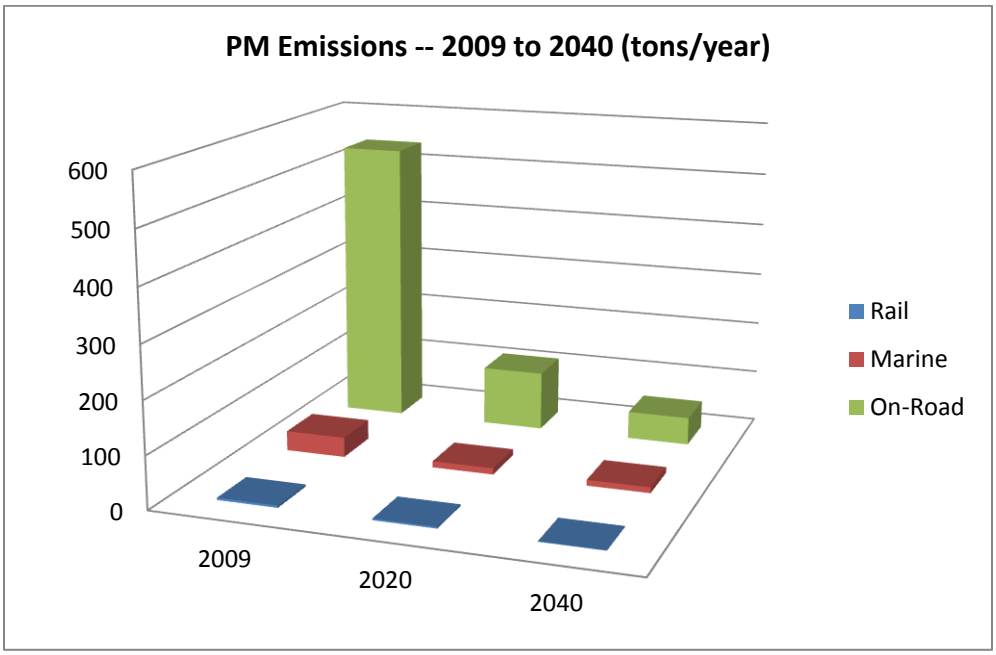
Source: ERG

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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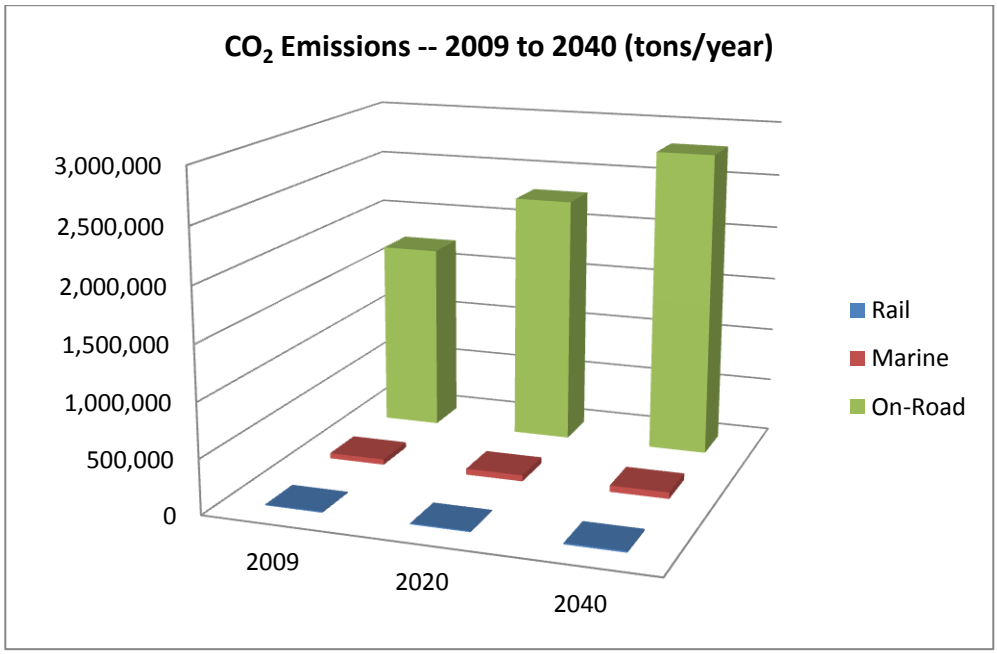
Figure 8 – CO_2 Emissions by Freight Movement Mode



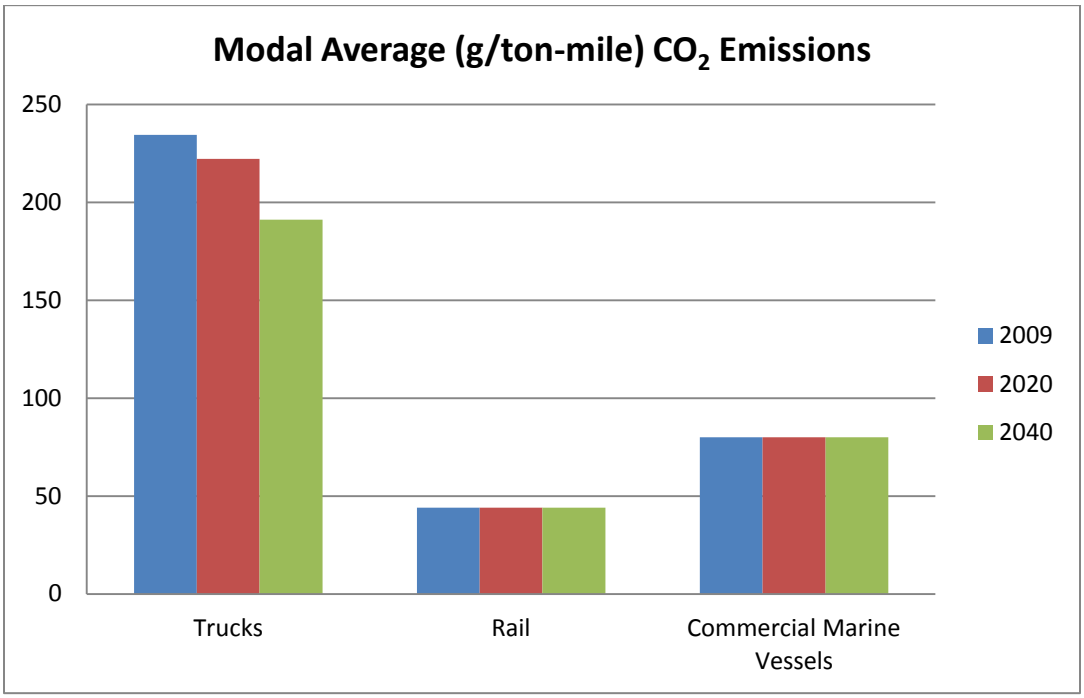
Source: ERG

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

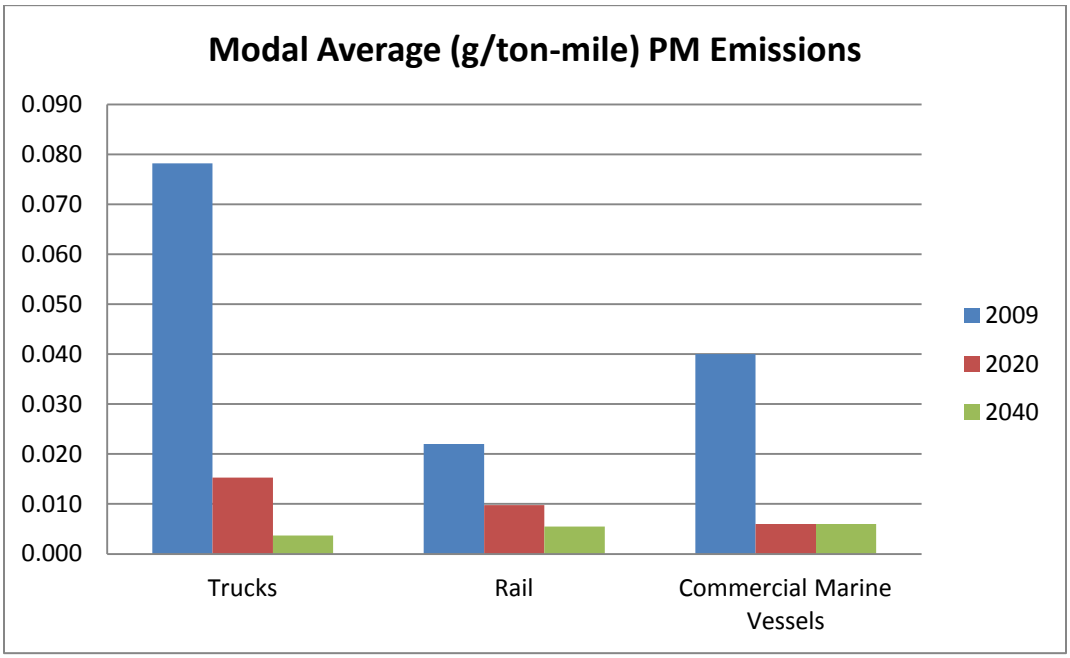


Source: ERG

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.

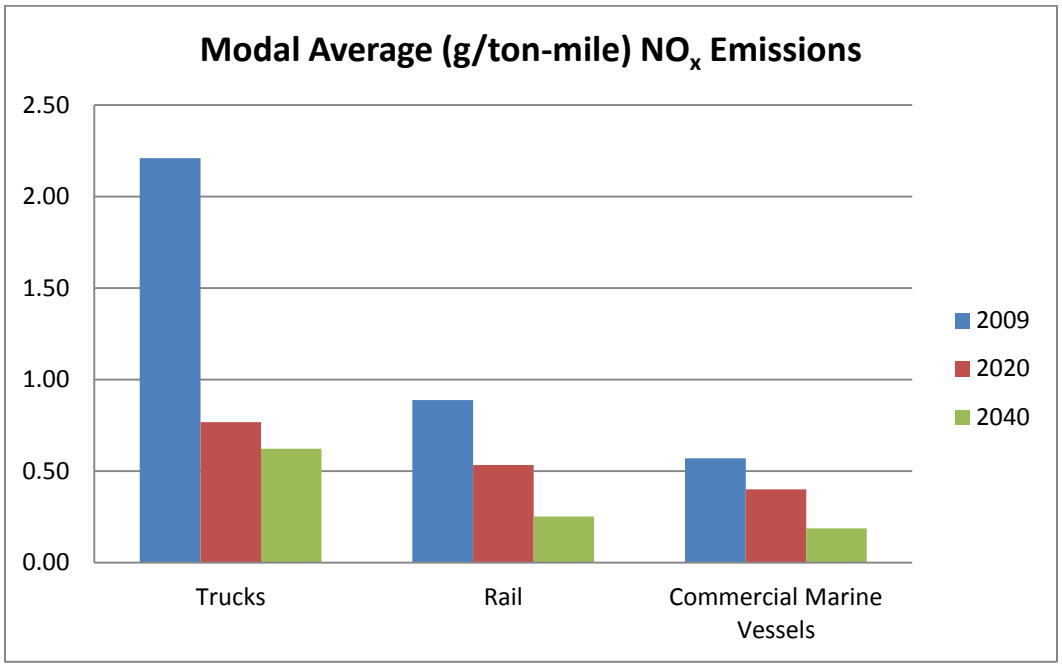
Currently, NOx emissions per ton-mile are significantly greater for trucks than for rail and marine, but in the future, truck emissions are closer to rail and marine levels. If extended idling by long-haul trucks were eliminated, these trucks would have about the same NOx emissions per ton-mile as rail 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



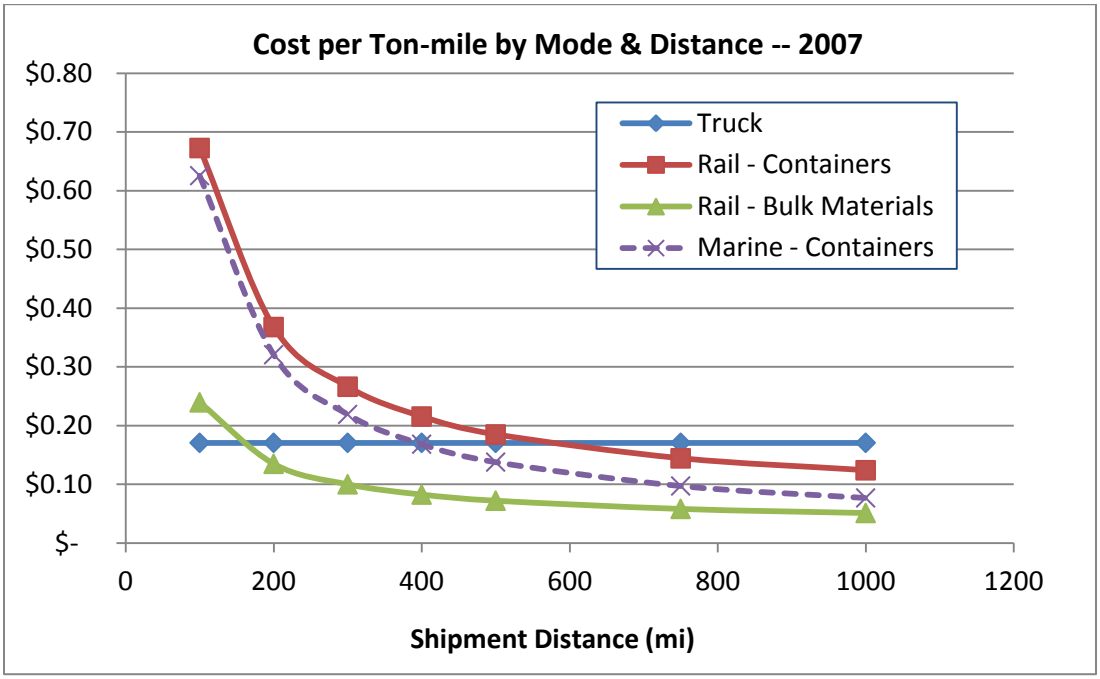
Source: ERG

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



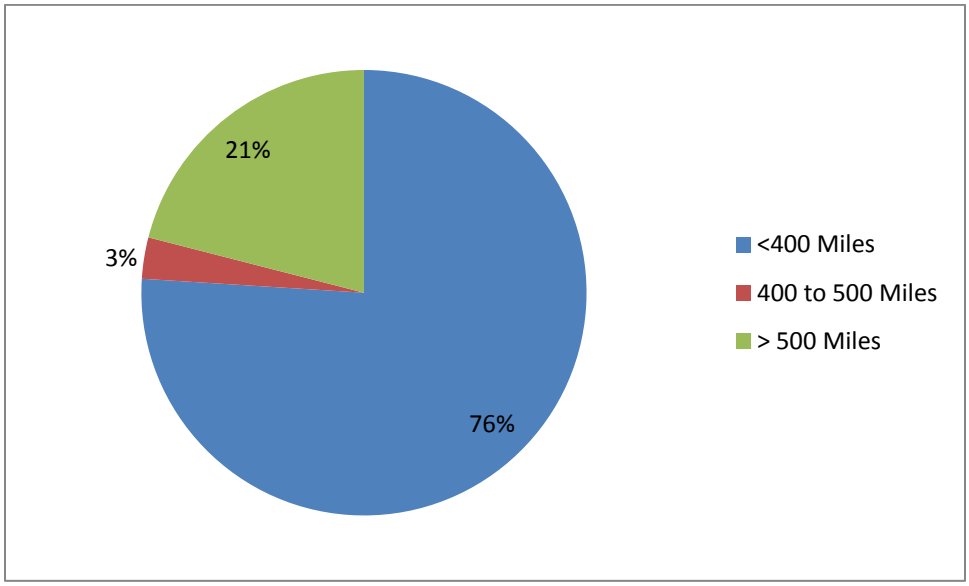
Source: Cambridge Systematics

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.

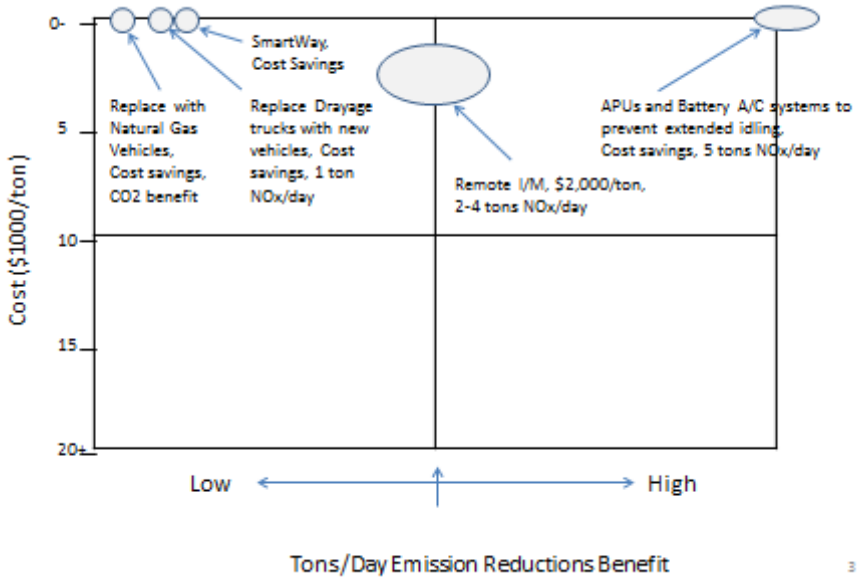
4.0 Conclusions and Recommendations to Address Environmental Impacts of Freight Movement

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.