Cutting Emissions from Freight Transportation

Summary:
This initiative presents an array of specific measures that can be adopted to decrease GHG emissions from thethat state's freight transportation sector, which is forecast for continued growth, despite the economic downturn and decreased transportation funding. Primarily, these measures aim to (1) improve the efficiency of vehicle trips, (2) reduce large diesel engine idling and emissions, and (3) shift freight from trucks to other modes. With regard to this last point, draft U.S. Senate legislation has a goal of increasing the proportion of national freight provided by means other than trucks by 10 percent by 2020.

Comment [L1]: Is the legislation final?

Other Agencies Involved:
PennDOT, American Trucking Association (ATA)/PA Motor Truck Association (PMTA), Keystone State Railroad Association/members, PennPORTS (Department of Community and Economic Development [DCED]), MPO/RPOs, local governments.

Possible New Measures:

I. Improve Trucking Efficiency

A. **Expand EPA SmartWay Truck Transport:** This option entails development of a technology option package modeled after the EPA's SmartWay Transport Partnership (EPA, 2009a). This voluntary partnership is designed to encourage shippers and fleets to reduce air pollution and GHG emissions through lower fuel consumption. By identifying and promoting fuel-saving retrofit technologies, the partnership enables truck fleets to better understand how to reduce fuel consumption via the most economical means available. In many cases, fuel-saving retrofits can result in net cost savings over the long run. The two technology options analyzed are listed below:

- **Aluminum Wheels With Single-Wide Tires:** Replacing the typical configuration of two wheels and tires at the end of each axle on heavy-duty trucks and commercial trailers with an aluminum wheel and a single-wide tire improves fuel economy by 4 percent by decreasing rolling resistance and weight (EPA, 2009b).
- **Trailer Fairings:** Adding front and side fairings (e.g., skirts) to trailers reduces aerodynamic drag and improves fuel economy by 5 percent (EPA, 2009b).

While the combined costs associated with installing both technology options (<$10,000) is modest compared to the cost of a tractor-trailer, such up-front costs may be prohibitive for some truck owners. While grants may help, a revolving loan program is a better financial assistance option (Bynum, 2009). With a payback of roughly 3 years, the money loaned from the initial fund is quickly returned and used for new loans. The SmartWay Transport Partnership is currently working with iBank, a company that provides businesses with access to its network of loan lenders (Bynum, 2009; iBank, 2009). The advantage is that these lenders will bid on the loan request, lowering the interest rate and simplifying the process of acquiring a loan. The process is similar to what LendingTree is doing for consumer loans (Bynum, 2009).

The following ATA recommendations target reduced fuel consumption by 86 billion gallons and the carbon footprint of commercial vehicles by nearly 1 billion tons over the next 10 years nationwide:

- **Increase Fuel Efficiency**: Under SmartWay, CO_2 reductions of 119 million tons expected nationwide by 2018 (24.95 and 25.02 lbs/gal gasoline and diesel, respectively).
- **Install Heavy Truck On-Board Emission Sensors***:* Devices alert a driver when the emissions system is malfunctioning. An EPA rule phases in beginning in 2010, with a

universal engine mandate by 2013. The rule is modeled after passenger vehicle systems and CARB. Emissions are reduced by up to 90 percent. However, current costs are high.

- **Outfit Trucks With Speed Governors:** Use the EPA calculator to estimate fuel savings. Obtain cost information on and set a goal for what percentage of PA trucks might have this technology installed within 10, 15, and 20 years, and the type of state policy/program needed to achieve these goals.
- **Install Idling Reduction Technologies:** See Work Plan T-3.

Approximately 30 (2 percent) of more than 1,600 PMTA members are enrolled in SmartWay. EPA and ATA could work more closely with state trucking associations (including possible customization and state-run SmartWay plans) to facilitate greater participation.

B. **More Productive Truck Combinations**: Advocated by the ATA, this option expands (geographic) operation of higher-productivity vehicles, including single tractor trailer maximum gross vehicle weight of 97,000 lbs, heavier double 33-foot trailers, and triples. Determine the relationships between truck weight, fuel consumption, and increased ability to move freight. Establish goals for how this initiative would lead to changes and improvements in PA at the same 10-, 15-, and 20-year intervals listed previously.

C. **Future Federal Requirements*:*** Current federal/EPA requirements mandate reductions in NO_x and PM, but not CO_2. Regulations are under congressional consideration and development, and the plan will be updated should legislation including significant emission reductions be passed.

II. Expand Rail Freight and Improve Efficiency

A. Switchyard Initiatives

Low-Emission Locomotive: This is Norfolk Southern's (NS's) preferred/approved terminology to allow flexibility regarding current and future technologies. The current focus on the new General Electric (GE) engine is due to a favorable cost-benefit ratio and a long history with GE;

"GenSet Switcher" Locomotive: GenSets use two small diesel engines instead of one large one, with one switched off during idle (see Section B) or when not hauling a heavy load or climbing grade. This is a good option for smaller class II/III railroads operating locomotives individually or not transporting a lot of freight cars at once; Class I (e.g., NS) can't cover costs with fuel savings to date. Over 60 PA railroads use hundreds of locomotives that would be candidates for GenSet conversion. This reduces emissions by 80 percent–90 percent, and uses up to 37 percent less fuel versus older models.

Electric Wide-Span Cranes: Operating from electric power, these cranes produce zero emissions on site. The wide-stance design eliminates up to six diesel trucks (hostlers) for shuttling containers. A hybrid model is also under development.

Battery Powered Locomotives: NS has received grants from the Federal Railroad Association and the U.S. Department of Energy to support research of electric locomotives powered by lead acid batteries. Successful project completion will enable diesel locomotive regenerative braking and reduce fuel consumption.

Mother/Slug Engine Re-Powers: Switcher/yard locomotives often operate in pairs to move large numbers of cars to other locations after long-haul delivery. A mother/slug is a locomotive pair configuration that consists of one four-axle locomotive (mother) powered by an engine approaching current EPA standards for controlling emissions of criteria pollutants, and one four-axle platform of four traction motors without an engine (slug). Typically, switchers are powered by pre-1973 engines not mandated to be rebuilt by existing federal law/regulations. A mother/slug realizes fuel benefits over existing pairs due to one engine instead of two, and the new replacement engine is more fuel efficient. Fuel savings for converting a switcher pair from traditional configuration to mother/slug are estimated at 25 percent–38 percent, with corresponding GHG emission reduction.

Because these projects reduce criteria pollutants in many cases, re-powering the mother/slug could be partly funded by CMAQ funding, with a match provided by the railroad. This yard locomotive configuration can be built at NS's Juniata Locomotive Shop, and the new engine can be built at the GE plants in Erie and Grove City. Currently, NS operates about 27 pair (54) of switcher locomotives in PA, and each locomotive uses approximately 82,000 gallons of fuel per year.[1]CSX also operates about 38 yard locomotives statewide.

B. *Reduce Locomotive Engine Idling (not included in PA Act 124)*

Auxiliary Power Units: Railroads use APUs to warm engines, allowing them to shut down in cold weather. CSX pioneered APUs, and hundreds are currently in use in PA. NS plans to ultimately phase out APUs, which still produce emissions, and future engine requirements will result in much greater idling reductions.

Automatic Engine Stop-Start Idling Reduction: This technology allows the main engines to shut down when ambient conditions are favorable. It is currently built and installed in Altoona (e.g., NS). Railroads are establishing and reinforcing shutdown requirements, including driver training/rewards.

"GenSet Switcher" Locomotives (see also Section A): Their smaller engines are the only ones that use antifreeze, allowing them to shut down in cold weather.

C. Long-Haul Initiatives

Expand/Upgrade Existing Rail: Each ton-mile of freight moved by rail versus road reduces GHG emissions by two-thirds or more. If 10 percent of nationwide long-haul truck freight converted to rail, annual GHG emissions would fall by more than 12 million tons (equivalent to taking 2 million cars off the road), and cumulative reductions through 2020 could be 200 million tons. Upgrading existing rail capacity to facilitate double-stacked trailers significantly enhances freight delivery, reduces fuel use, and minimizes freight reconfiguration during delivery. NS's impending Crescent Corridor expansion consists primarily of upgrading track to accommodate double-stacked containers the 6-state length of I-81 (Tennessee to upstate New York), as well as upgrading/installing some double track. (The Heartland Corridor will reduce 200 route miles from each shipment and transit time by one day.) However, the large majority of rail expansion is intermodal, which still involves truck transport to/from the facility. Finally, significant improvement in the NS-Amtrak relationship could expand rail capacity.

Expand EPA SmartWay Rail Transport*:* SmartWay members agree to improve their fuel efficiency, reduce their environmental footprint, reduce their energy consumption, and engage in corporate citizenship. Freight trains are three or more times more fuel-efficient than trucks. (See I, Trucking, for additional guidance).

Policy Issues: Class I rail expansion is contingent on significant public-sector cost sharing at the federal and state levels.

[1] Procedures for Emission Inventory Preparation Volume IV: Mobile Sources, Chapter 6, United States Environmental Protection Agency, 1992.

III. Expand Marine Freight and Improve Efficiency

There are two recommended PA initiatives for the commercial marine sector. One is to make the infrastructure improvements needed to allow the amount of freight shipped by vessel in PA to increase in situations where marine vessel transport is more energy efficient than truck or rail transport. Growth possibilities and issues differ for each of the three major PA port areas: the Philadelphia area, the Pittsburgh area, and the Erie area. The second initiative is to provide the financing and incentives (and regulations) needed to improve the energy efficiency and associated GHG emissions of the vessels and cargo handling equipment in use at the major PA port facilities. This second initiative is designed to make the PA port operations as GHG efficient as possible.

Superior Efficiency: Water transport is generally 40 percent more efficient than rail; rail is already three times more fuel efficient than trucks. For example, in the Port of Pittsburgh, one 15-barge tow replaces 1,000 trucks.

Philadelphia/South Jersey/Delaware River Ports: These ports have signed a Memorandum of Understanding (MOU, 2008) to reduce or neutralize the impacts of operations and expansion by reducing energy consumption, employing cleaner energy sources, and replacing and modernizing vehicles and equipment.

Marine Diesel Engine Retrofits: The Port of Pittsburgh's “gap financing” plan contains $20 million (including CMAQ funds)to repair and upgrade engines per EPA **r**equirements.

Diesel Engine Containerized Cranes: The Port of Philadelphians developed a plan to electrify all (20+) current cranes by the fall of 2009.

Intermodal Port/Rail*:* PennDOT Rail Freight Assistance Program has awarded $1million to the Port of Erie/Industrial Development Corporation to restore rail service to industrial parks, replace 12,000 trucks, and serve biodiesel manufacturers. GE Locomotive is seeking to partner on hybrid locomotive and tugboat prototypes.

America’s Marine Corridor/Ben Franklin Corridor*:* The Port of Philadelphia is applying for federal funds to glean business from Panama Canal widening (2014), which is expected to reroute significant volumes from the West Coast. The conversion of cross-country truck/rail freight to ships/barges will reduce regional emissions.

Policy Issues: Federal regulations (e.g., Jones Act) present roadblocks to short sea shipping and other marine conversion opportunities. Environmental concerns regarding waterway dredging (water quality, wildlife, etc.) must also be resolved/balanced.

Potential GHG Reductions and Economic Costs:

Table 1 summarizes the emission benefits and costs of the measures applied to truck freight and locomotives. Marine freight measures are not yet included in this table.

Table 1. Estimated GHG Emissions Reductions and Cost-Effectiveness

GHG emission savings (2020)	1.15	MMtCO_2e
Net Present Value (2013-2020)	-1370.38	$million
Cumulative Emissions Reductions (2013-2020)	5.89	MMtCO_2e
Cost-effectiveness (2013-2020)	-211	$/t$CO_2$e

GHG = greenhouse gas; MMtCO_2e = million metric tons of carbon dioxide equivalent; $/t$CO_2$e = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate cost savings.

Heavy-Duty Trucks

The two technology options considered in the heavy-duty truck analysis are based on EPA’s SmartWay Transport Partnership (EPA, 2009b). The first option is the installation of aluminum wheels for single-wide tires to reduce vehicle weight and rolling resistance. The second option is the installation of fairings (e.g., front and side skirts) to improve vehicle aerodynamics. The improved fuel economy and associated GHG emission reductions for each option are additive (Bynum, 2009).

GHG Reduction from Installing Aluminum Wheels

Replacing the typical heavy-duty truck configuration of two wheels and tires at the end of each axle with an aluminum wheel and a single-wide tire decreases rolling resistance and weight. This technology can be applied to all tractor and trailer tire positions, except for the steer tires. When applied to these tire positions, it can reduce fuel consumption by 4 percent (EPA, 2009b). Since half of the tires suitable for retrofitting are located on the tractor, and half are located on the trailer, the fuel savings is allocated equally between the tractor and the trailer (i.e., the fuel savings from retrofitting a tractor-truck is assumed to be 2 percent, and the fuel savings from retrofitting a trailer is assumed to be 2 percent). DOT reports the number of tractor-trucks registered in Pennsylvania in 2007 as 74,404 (DOT, 2008b) and the number of commercial trailers as 152,489 (DOT, 2008c). Table 6-2 shows the assigned penetration rate for retrofits and the total tractor-trucks and trailers retrofitted through 2020 under this policy option.

Table 2. Total Tractor-Trucks and Trailers Retrofitted With Aluminum Wheels

Year	Heavy-Duty Trucks Registered in PA	Penetration Rate for Tractor-Trucks	Trucks Retrofitted	Commercial Trailers Registered in PA	Penetration Rate for Trailers	Trailers Retrofitted
2013	74,404	12.5	9,301	152,489	6.9	10,522
2014	74,404	25	18,601	152,489	13.8	21,043
2015	74,404	37.5	27,566	152,489	20.7	34,565
2016	74,404	50	37,202	152,489	27.6	42,087
2017	74,404	62.5	46,502	152,489	34.5	52,609
2018	74,404	75	55,803	152,489	41.4	63,130
2019	74,404	87.5	65,103	152,489	48.3	73,652
2020	74,404	100	74,404	152,489	55.2	84,174

The estimated GHG emission reductions from replacing existing two-wheel, two-tire configurations with a single aluminum wheel are based on diesel fuel savings. To calculate these emissions, the total VMT in the state (108,699 million miles; DOT, 2008a) are multiplied by the fraction of miles traveled by heavy-duty trucks (0.07; PA DEP, 2007) to obtain total annual VMT by heavy-duty trucks in Pennsylvania in 2007. Total annual VMT is then divided by the average fuel economy of heavy-duty trucks (6.0 mpg; Bynum, 2009) to obtain total diesel fuel consumed (1,268 million gallons). Fuel savings are based on the total diesel fuel consumed, the percentage of fuel savings associated with the retrofits, and the penetration rate for tractor-trucks and trailers:

Total fuel savings = (1,268 million gallons)*(0.02)*((penetration rate for tractor trucks + penetration rate for trailers)/100)

Total fuel savings is multiplied by GHG emissions per million gallons of diesel fuel consumed (0.01125 MMt; DOE, 2008) to obtain the total annual GHG emission reduction.

Table 3. GHG Emission Reduction From Installing Aluminum Wheels

Year	Vehicle Miles Traveled by Heavy Trucks in PA (million miles)	Average Fuel Economy of Long-Haul Heavy Trucks (miles per gallon)	Diesel Fuel Savings (million gallons)	GHG Reduction ($MMtCO_2e$)
2013	7,609	6.00	4.92	0.06
2014	7,609	6.00	9.84	0.11
2015	7,609	6.00	14.76	0.17
2016	7,609	6.00	19.68	0.22
2017	7,609	6.00	24.60	0..28
2018	7,609	6.00	29.52	0.33
2019	7,609	6.00	34.44	0.39
2020	7,609	6.00	39.36	0.45
Total				**2.01**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Heavy-Duty Trucks: Costs Associated With Installing Aluminum Wheels

The cost of retrofitting a tractor-truck and trailer with aluminum wheels is approximately $5,600 (2007$; EPA, 2009b). Since half of the wheels suitable for retrofit are located on the tractor-truck and half are located on the trailer, the cost is assumed to be $2,800 for each. The total cost of retrofitting is calculated by multiplying the number of trucks and trailers being retrofitted in a given year by $2,800. The cost savings, shown in Table 6-4, are realized in the fuel savings from reduced vehicle weight and lower rolling resistance. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel. Net costs are the installation costs minus the fuel cost savings. Since two standard tires cost roughly the same as one single-wide tire and wear at a comparable rate, there is no additional tire cost imposed by retrofitting (EPA, 2004a). Trucks retrofitted with aluminum wheels and new-generation wide tires cause no more damage to roads than trucks with conventional tire configurations (EPA, 2004a).

Table 4. Costs of and Cost Savings From Installing Aluminum Wheels for Single-Wide Tires

Year	Installation Costs ($MM)	Diesel Fuel Saved (million gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2013	42.70	4.92	16.97	25.72
2014	42.70	9.84	36.01	6.68
2015	42.70	14.76	55.79	-13.09
2016	42.70	19.68	75.38	-32.68
2017	42.70	24.60	95.45	-52.75
2018	42.70	29.52	115.72	.73.03
2019	42.70	34.44	135.70	-93.01
2020	21.35	39.36	156.273	-134.92
Total				**-294.05**

$MM = million dollars. Negative net costs indicate costs savings.

Heavy-Duty Trucks: GHG Reduction From Installing Fairings

At highway speeds, aerodynamic drag accounts for the majority of truck energy losses (EPA, 2004b). Reducing drag improves fuel efficiency. Since the majority of long-haul tractor trucks on the road in 2009 (>75 percent) already contain aerodynamic features, such as air deflectors mounted on the top of the cab, drag-reduction options should focus on trailer aerodynamics (Bynum, 2009). The addition of front and side fairings (e.g., skirts) to a trailer can reduce fuel consumption by 5 percent (EPA, 2009b). These panels are attached to the side or bottom of the trailer and hang down to enclose the open space between the rear wheels of the tractor and the rear wheels of the trailer. Such enclosure reduces wind resistance.

The estimated GHG emissions reductions from installing front and side fairings on trailers are based on diesel fuel savings. To calculate these emissions, the total VMT in the state (108,699 million miles; DOT, 2008a) are multiplied by the fraction of miles traveled by heavy-duty trucks (0.07; PA DEP, 2007) to obtain total annual VMT by heavy-duty trucks in Pennsylvania in 2007. Total annual VMT is then divided by the average fuel economy of heavy-duty trucks (6.0 miles per gallon; Bynum, 2009) to obtain total diesel fuel consumed (1,268 million gallons). Fuel savings are based on the total diesel fuel consumed, the percent fuel savings associated with the retrofits, and the penetration rate for trailers. DOT reports the number of commercial trailers registered in Pennsylvania in 2007 as 152,489 (DOT, 2008c). Since there are more trailers than tractor-trucks, the probability of realizing the fuel savings associated with a trailer retrofit is the ratio of tractor-trucks to trailers.

Total fuel savings = (1,268 million gallons)*(0.05)*(penetration rate for trailers/100)*(# of heavy-duty trucks/# of commercial trailers)

Total fuel savings is multiplied by GHG emissions per million gallons of diesel fuel consumed (0.01125 MMt; DOE, 2008) to obtain the total annual GHG emissions reduction.

Table 5. GHG Emission Reductions From Installing Fairings

Year	Commercial Trailers Registered in PA	Penetration Rate	Trailers Retrofitted	Diesel Fuel Savings (million gallons)	GHG Reduction ($MMtCO_2e$)
2013	152,489	6.9	10,522	3.87	0.04
2014	152,489	13.8	21,044	7.73	0.09
2015	152,489	20.7	31,565	11.60	0.13
2016	152,489	27.6	42,087	15.47	0.18
2017	152,489	34.5	52,609	19.34	0.22
2018	152,489	41.4	63,130	23.20	0.26
2019	152,489	48.3	73,652	27.07	0.31
2020	152,489	55.2	84,174	30.94	0.35
Total					**1.58**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Heavy-Duty Trucks: Costs Associated with Installing Fairings

The cost of retrofitting a trailer with front and side fairings is approximately $2,400 (2007$; EPA, 2009b). The total cost of retrofitting is calculated by multiplying the number of trailers being retrofitted in a given year by $2,400. The cost savings, shown in Table 6-6, are realized in the fuel savings from reduced vehicle drag. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel. Net costs are the installation costs minus the fuel cost savings.

Table 6. Costs of and Cost Savings From Installing Fairings

Year	Installation Costs ($MM)	Diesel Fuel Saved (million gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2013	25.3	3.9	13.3	12.0
2014	25.3	7.7	28.3	-3.0
2015	25.3	11.6	43.9	-18.6
2016	25.3	15.4	59.2	-33.9
2017	25.3	19.3	75.0	-49.7
2018	25.3	23.2	91.0	-65.7
2019	25.3	27.0	106.7	-81.4
2020	25.3	30.9	122.8	-97.5
Total				**-338**

$MM = million dollars. Negative net costs indicate cost savings.

Locomotives

The two technology options considered in the locomotive analysis are based on EPA's SmartWay Transport Partnership (EPA, 2009c). The first option is the retrofitting of switchers and line-haul locomotives with APUs to reduce idling. The second option is the installation of a wheel flange lubrication system on line-haul locomotives to reduce friction. The improved fuel economy and associated GHG emissions reduction for each option are additive.

Locomotives: GHG Reduction from Anti-Idling Technologies

There are two types of locomotives commonly used by railroad companies—switcher and line-haul. Switcher locomotives are used to move materials within a rail yard, while line-haul locomotives are used to move freight across long distances (EPA, 2005). Switchers idle approximately 12 hours a day to avoid difficult startups and possible freezing inside the engine in cold weather (locomotive engines do not use antifreeze). Installing auxiliary engines in these locomotives can decrease fuel consumption, which helps reduce GHG emissions as well as local air pollutants and noise. This reduction is achieved by reducing fuel consumption while idling. Installing an APU is highly cost-effective, with a payback period of 2–2.5 years without taking any environmental benefits into account (EPA, 2005).

Approximately 27 percent of a switcher's annual fuel consumption is attributed to idling (DOE, 2002). While idling, the locomotive's main engine burns about 3 gallons of diesel fuel per hour in warm weather and 11 gallons per hour in cold weather (a higher idle setting is required to keep the engine from freezing). Assuming 4 months of cold weather a year, the average switcher would consume over 24,000 gallons of diesel fuel annually just idling. An APU can reduce fuel consumption to 0.8 gallons per hour, saving 20,500 gallons of fuel (EPA, 2005).

The number of switchers operating in Pennsylvania was estimated using the total fuel consumed for rail transport in Pennsylvania (provided by Michael Baker Consulting, 2009). Since switchers account for roughly 7.5 percent of the total diesel fuel burned by locomotives and an average switcher consumes 89,000 gallons of fuel per year, the number of switchers is calculated by dividing the total fuel consumed by switchers by 89,000 gallons (EPA, 1998). The number of line-haul locomotives operating in Pennsylvania was estimated by multiplying the total number of Class I locomotives operating in the United States (24,143; AAR, 2009a) by the fraction of U.S. rail tons carried in Pennsylvania (0.0237; AAR, 2009b). The number of locomotives in 2009 is grown through 2020 using the annual growth rate of fuel consumption.

The estimated GHG emission reductions from retrofitting locomotives with auxiliary power units are based on the total diesel fuel consumed, the percentage of fuel savings associated with the retrofits, and the penetration rate:

Total fuel savings = (total fuel consumed by switchers)*(0.23)*(penetration rate for switchers)/100) + (total fuel consumed by line-haul)*(0.10)*(penetration rate for line-haul/100)

Table 7. Estimated Number of Switchers and Line-Haul Locomotives in Pennsylvania

Year	Total Fuel Consumed by All Locomotives (thousand gallons)	Total Fuel Consumed by Switchers (thousand gallons)	Total Fuel Consumed by Line-Haul Locomotives (thousand gallons)	Estimated Number of Switchers	Estimated Number of Line-Haul Locomotives
2013	129,093	9,682	119,411	109	652
2014	133,084	9,981	123,103	112	672
2015	137,075	10,281	126,795	116	692
2016	141,066	10,580	130,486	119	712
2017	145,058	10,879	134,178	122	732
2018	149,049	11,179	137,870	126	752
2019	153,040	11,478	141,562	129	773
2020	157,032	11,777	145,254	132	793

Total fuel savings is multiplied by GHG emissions per thousand gallons of diesel fuel consumed (0.00001125 MMt; DOE, 2008) to obtain the total annual GHG emissions reduction. This calculation likely overestimates the incremental benefit of the policy option, since some locomotives are already equipped with APUs.

Table 8. GHG Emissions Reduction From Retrofitting Locomotives With APUs

Year	Penetration Rate of Switcher Retrofits (percent)	Number of Switchers Retrofitted	Penetration Rate of Line-Haul Locomotive Retrofits (percent)	Number of Line-Haul Locomotives Retrofitted	Diesel Fuel Savings (thousand gallons)	GHG Emissions Reduction ($MMtCO_2e$)
2013	80	87	40	261	6,554	0.07
2014	100	112	50	336	8,446	0.10
2015	100	116	60	415	9,967	0.11
2016	100	119	70	499	11,562	0.13
2017	100	122	80	586	13,231	0.15
2018	100	126	90	677	14,974	0.17
2019	100	129	100	773	16,790	0.19
2020	100	132	100	793	17,228	0.19
Total						**1.11**

APUs = auxiliary power units; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Locomotives: Costs Associated With Anti-Idling Technologies
The cost of retrofitting a locomotive with an APU is approximately $27,250 (2007$; EPA, 2009c). The total cost of retrofitting is calculated by multiplying the number of locomotives being retrofitted in a given year by $27,250. The cost savings, shown in Table 6-9, are realized in the fuel savings from reduced idling. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel (DOE, 2009). Net costs are the installation costs minus the fuel cost savings.

Table 9. Costs of and Cost Savings From Retrofitting Locomotives With APUs

Year	Installation Costs ($MM)	Diesel Fuel Saved (thousand gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2013	2.59	6,554	22.99	-20.40
2014	2.74	8,446	30.86	-28.12
2015	2.25	9,967	37.31	-35.06
2016	2.36	11,562	43.38	-41.02
2017	2.47	13,231	49.67	-47.20
2018	2.58	14,974	56.42	-53.84
2019	2.69	16,790	63.44	-60.75
2020	0.64	17,228	65.27	-64.63
Total				**-351.02**

$MM = million dollars; APUs = auxiliary power units. Negative net costs indicate cost savings.

Locomotives: GHG Reduction From Wheel Flange Lubrication System
Ineffective lubrication at the wheel/rail interface of trains results in wear and friction that costs the country's railroads more than $2 billion each year (DOE, 2006). Installing a wheel flange lubrication system significantly reduces track degradation and noise, and decreases line-haul locomotive fuel consumption by 5 percent (Mitrovitch, 2009).

The estimated GHG emission reductions from retrofitting locomotives with wheel flange lubrication systems are based on the total diesel fuel consumed, the percentage of fuel savings associated with the retrofits, and the penetration rate:

Total fuel savings = (total fuel consumed by line-haul)*(0.05)*(penetration rate for line-haul)/100)

Total fuel savings is multiplied by GHG emissions per thousand gallons of diesel fuel consumed (0.00001125 MMt; DOE, 2008) to obtain the total annual GHG emissions reduction. Note that a limited number of PA locomotives may already be equipped with lubrication systems.

Locomotives: Costs Associated With Wheel Flange Lubrication System
The cost of retrofitting a locomotive with an auxiliary power unit is approximately $650 (2007$; Mitrovitch, 2009). The operation and maintenance (O&M) cost of replacing springs and lubrication sticks is approximately $1,110 per year (Mitrovitch, 2009). The total cost of retrofitting is calculated by multiplying the number of locomotives being retrofitted in a given year by $650 and adding the O&M costs for all locomotives with wheel flange retrofits. The cost savings, shown in Table 6-11, are realized in the fuel savings from reduced friction. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel (DOE, 2009). Net costs are the installation costs minus the fuel cost savings.

Table 10. GHG Emissions Reduction From Retrofitting Line-Haul Locomotives with Wheel Flange Lubrication Systems

Year	Penetration Rate of Line-Haul Locomotive Retrofits (percent)	Number of Line-Haul Locomotives Retrofitted	Diesel Fuel Savings (thousand gallons)	GHG Reduction ($MMtCO_2e$)
2013	100	652	11,941	0.13
2014	100	672	12,310	0.14
2015	100	692	12,679	0.14
2016	100	712	13,049	0.15
2017	100	732	13,418	0.15
2018	100	752	13,787	0.16
2019	100	773	14,156	0.16
2020	100	793	14,525	0.16
Total				**1.19**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table 11. Costs of and Cost Savings From Retrofitting Line Haul Locomotives With Wheel Flange Lubrication Systems

Year	Installation Costs ($MM)	Diesel Fuel Saved (thousand gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2013	0.74	11,941	41.88	-41.15
2014	0.76	12,310	44.98	-44.22
2015	0.78	12,679	47.47	-46.68
2016	0.80	13,049	48.96	-48.15
2017	0.83	13,418	50.37	-49.55
2018	0.85	13,787	51.95	-51.10
2019	0.87	14,156	53.49	-52.62
2020	0.89	14,525	55.03	-54.14
Total				**-387.61**

$MM = million dollars. Negative net costs indicate cost savings.

Marine Vessels and Port Machinery

One of the possibilities for evaluating potential GHG emission reductions from marine vessels and port machinery is to examine information available from other states. For example, through the Global Warming Solutions Act of 2006 (AB 32), California has committed to reducing GHG emissions to 1990 levels by 2020. Measure T-6 in the AB32 scoping plan—freight transport efficiency measures—is a broad initiative designed to achieve at least a 3.5-$MMtCO_2e$ reduction in GHG emissions from the freight transport sector by 2020 (CARB, 2008). This represents about a 20 percent reduction in the projected 2020 GHG emissions from this sector. Due to the complexity of this sector and the need for a thorough investigation of a variety of approaches to determine how best to improve freight transport efficiency, an overall emission reduction goal was established for California measure T-6, rather than assigning emission reduction targets to individual measures.

The current components of California's freight efficiency measure are:

1. Port Drayage Trucks (replacement/retirement)
2. Transport Refrigeration Units Cold Storage Prohibition and Energy Efficiency
3. Cargo-Handling Equipment—Anti-Idling, Hybrid, Electrification
4. Goods Movement System-Wide Efficiency Improvements
5. Commercial Harbor Craft—Maintenance and Design Efficiency

6. Clean Ships
7. Vessel Speed Reduction
8. Long-Haul Trucks
9. Locomotives

Since GHG reduction options for trucks and locomotives in Pennsylvania have already been discussed, only items 2 through 7 are considered for the marine emissions reduction strategy. Similar to California, individual reduction targets are not assigned due to the complexity of the sector. Instead, an overall emission reduction goal of 18 percent is evaluated. The reduction target is lower than California's, since some options are simply moving the emissions from ports to power plants. With the electricity generation mix in PA (ReliabilityFirst Corporation [RFC] East subregion), GHG reductions are currently about 50 percent less than in California by switching from diesel fuel to shore power.

The overall GHG savings is calculated by multiplying the projected 2020 GHG emissions from ships (2.71 $MMtCO_2e$; Baker, 2009) and port machinery (0.29 $MMtCO_2e$; assumed to be 10 percent of "other" non-highway emissions; Baker, 2009) in PA by 0.18. Some strategies, such as vessel design improvements, will also achieve GHG emission reductions beyond PA. The costs and costs savings associated with marine reduction strategies are difficult to estimate due to the variety of control options and limited data availability. Thus, GHG reductions and costs associated with the marine sector are not included in Table 6-12.

Table 12. Potential GHG Emission Reductions for Marine Transport

Reduction Measures and Targeted Vehicles	Potential 2020 GHG Reduction ($MMtCO_2e$)	Net Costs ($MM)
All Measures Combined	0.54	Not Quantified
Ocean-Going Vessels		
Commercial Harbor Craft		
Cargo Handling Equipment		
Transportation Refrigeration Units		
Goods Movement System-Wide Efficiency Improvements		

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Marine: Ocean-Going Vessels

Options to improve the fuel efficiency of ocean-going vessels (OGVs) include advanced hull and propeller coatings, advanced engine design, heat recovery, wind power assistive devices, shore power, and vessel speed reduction. The last two options are discussed below.

Providing shore power at port facilities typically requires an up-front capital investment to purchase a more efficient engine, and the cost savings result from reduced fuel usage compared to the original equipment. The length of the payback period for this capital investment is often the most important question when considering the feasibility of an option such as this. While CARB anticipates that the overall savings due to reduced fuel consumption will offset the costs associated with retooling ships and ports in California, the costs may be substantially higher for Pennsylvania, with only modest GHG emissions reduction (CARB, 2008).

Shore power is becoming a major part of the green port strategies being implemented at ports on the U.S. West Coast. For example, the Port of Long Beach has adopted a green port policy that is intended to guide the port's operations in a green manner (CARB, 2006). The port has committed to providing shore power to all new and reconstructed container terminal berths and other berths, as appropriate. Through lease language, the port will require selected vessels to use shore power and all other vessels to use low-sulfur diesel in their auxiliary generators. The primary method for providing shore power at California ports is cold ironing, a strategy whereby ships shut down onboard auxiliary engines while in port and connect to electrical power supplied at the dock. Without cold ironing, auxiliary engines run continuously while a ship is docked, or "hotelled" at a berth, to power lighting, ventilation, pumps, communication, and other onboard equipment. Ships can hotel for several hours or several days.

In an example of cold ironing, an analysis was done on the cost-effectiveness of three ships that each visited the port 17 times during the year. On every trip, the ships were electrified for 60 hours in port, saving a total of 1,478 metric tons of fuel and reducing GHG emissions by 4,741 tCO_2e annually. Given the estimated annual cost of $1,583,000, this means that $334/$tCO_2e$ can be avoided through fuel consumption. However, the production of electricity for use in the ship will reduce the GHG savings with this approach. Using Pennsylvania emission factors, the annual GHG benefits of this program would be reduced to only 1,297 tCO_2e. This would mean a cost of $1,221/$tCO_2e$ reduction from the cold ironing method.

There are several other important factors to consider on the issue of cold ironing. This process has significant up-front costs. While the analysis above considers the annual costs of the program over a 10-year period, the initial costs are considerable. In this example, the port requires an initial investment of $4.5 million to provide electrification, and each of the three ships must undergo a $1.5 million modification to accept electricity from the ports. If very few ships make this modification, then the costs per tCO_2e would increase dramatically. Labor and electricity are also part of the cost estimate, though these are less of a problem in terms of up-front capital. Finally, the example is of ships that use the port 17 times a year. If a ship does not frequent a particular port more than a few times a year, it is unlikely that the owner would want to undertake the modification. And even if the ship were equipped to engage in cold ironing, the benefits of such a case would be far reduced.

Establishing vehicle speed reduction (VSR) zones around ports can reduce GHG emissions by reducing fuel consumption. A California study indicates that reducing the speed of a cargo ship from 22 knots to 12 knots from 6 to 24 miles offshore (outside the 6-mile precautionary zone) saves 1,249 gallons of fuel (CARB, 2008b). This translates into fuel cost savings of approximately $3,600. However, the costs associated with increased transit time must be considered. In the California study, the inbound time spent in the VSR zone was 1 hour longer for a trip traveling at 12 knots. Terminals may incur costs of $10,000–$20,000/hour for vessel delays. Ships may incur costs of up to $5,000/hour for delays if the vessel does not make up time during other segments of the voyage. If ships increase speed outside the VSR zone to make up time, total GHG emissions may increase.

Marine: Commercial Harbor Craft

Reducing GHG emissions from harbor crafts depends upon maintenance and operational improvements. Recommended options to evaluate are optimization of scheduling and vessel speed, improved hull surface finish and reduced hull fouling to reduce friction, and improved propeller design and maintenance.

Marine: Cargo-Handling Equipment

Cargo-handling equipment includes diesel-powered vehicles and cranes operating at ports. Recommended options to evaluate are reduced idling, hybrid propulsion technologies, and electrification of cranes (IAPH, 2009).

Marine: Transport Refrigeration Units

To transport temperature-sensitive products, shipping containers employ refrigeration systems powered by internal combustion engines. To reduce GHG emissions from these transportation refrigeration units, energy efficiency guidelines should be implemented and a best practices guidance document should be prepared to help educate the industry about potential costs and GHG savings.

Marine: Goods Movement System-Wide Efficiency Improvements
Intermodal transport in PA should be evaluated, with emphasis on improving marine, truck, and rail freight movement. All stakeholders, such as railroad operators, shipping companies, terminal operators, trucking companies, government agencies, and the public, should contribute to developing a program to achieve system-wide GHG emission reductions beyond existing individual measures. Such collaboration is likely to present opportunities to reduce GHG emissions from the overall freight movement supply chain.

Table 13 provides CO_2 emission factors from the recent Winebrake et al. *Journal of the Air and Waste Management Association* paper for the three primary freight transport modes. These factors can be used to estimate how shifting 100,000 20-foot equivalent units (TEUs) from rail and truck to ships in Pennsylvania might affect GHG emissions.

Table 13. Data for Transport Modes for Case Studies

Mode of Transport	Cost ($/TEU-mile)	Energy (Btu/TEU-mile)	CO_2 (g/TEU-mile)	PM-10 (g/TEU-mile)	SO_X (g/TEU-mile)
Truck	0.87	10,704	1,001	0.12	0.22
Rail	0.55	2,590	201	0.09	0.04
Ship	0.50	13,040	1,094	0.98	3.33

$/TEU-mile = dollars per 20-ft equivalent units-mile; Btu = British thermal unit; CO_2 = carbon dioxide; g/TEU-mile = grams per 20-ft equivalent units-mile; PM10 = particulate matter 10 microns in diameter or smaller; SOx = sulfur oxides.

Ships vary significantly in their sizes, speeds, and installed power, which means that their energy and emission characteristics vary. The information in Table 6-13 is based on ship characteristics that have been highlighted favorably in recent short sea shipping reports, because this policy option was intended to represent a short movement of freight. The ship used in this analysis a roll-on/roll-off vessel capable of speeds of up to about 25 knots with about 11,000 kilowatts (kW) of power, which carries about 200 TEUs. Using the characteristics of other vessel groups would produce different results than the comparison shown in Table 6-13.

Trucking, Rail, and Marine Freight Transport: The GHG reduction analysis still needs to account for the different commodities, infrastructures, and expected near-term changes occurring in each of the major port areas in PA. This information is briefly summarized below:

Port of Philadelphia—The expectation is that trade will pick up after the recession. A major port expansion is occurring as this port expands south into the Navy yard. This may bring as much as 1 million additional TEUs of freight into this port. The current freight volume via the Port of Philadelphia is 250,000 TEUs. Part of this expansion involves a deepening of the Delaware River channel from 40 to 45 feet. This will allow larger vessels (carrying 1,000 TEUs per vessel) to access this port. With this port expansion comes the need to make infrastructure improvements—mainly to nearby highways. Local truck and rail traffic is expected to increase. Pennsylvania's "America's First Marine Highway Enterprise" would extend the Ben Franklin Corridor (a surface transportation corridor linking the Columbus Regional Airport Authority intermodal terminal in Columbus, Ohio, as well as military depots and commercial distribution hubs in New York, New Jersey, Ohio, and Pennsylvania) to a new marine highway corridor connecting the Port of Philadelphia to other U.S seaports. The project includes highway, rail seaport, and intelligent transportation system solutions consistent with federal policy, as well as a proposed shipbuilding strategy for the U.S. domestic trade. Furthermore, the project supports and leverages considerable investments that the commonwealth of Pennsylvania has already made in upgrading and expanding Philadelphia marine terminals. ~~The Clean Air Council completed a project, "Identifying Strategies to Reduce Pollution from Philadelphia Ports: A Stakeholder Process" which produced reports on air, water and land pollution at the Philadelphia ports. The following pollution reduction projects have already been started. The diesel retrofit installation at Packer and Tioga Terminals resulted in a reduction of emissions on 83 pieces of cargo-handling equipment. The EPA on-road verification for these diesel oxidation catalysts is a 20% reduction in PM, a 40% reduction in CO and a 50% reduction in HC. (Community Action for a Renewed Environment (CARE) Level I Grantee Final Report, pp. 17-18)~~

~~Implemented Targeted Brownfields Assessment on Frankford Creek near Tioga~~
~~Implemented Diesel Retrofit Technologies at Packer and Tioga terminals~~
~~Began outreach on stormwater management~~
~~Began Environmental Management System research~~

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- *Port of Pittsburgh*—This is really 200 miles of a series of privately owned ports along the three rivers. It is expected that the freight volumes will increase with trade. Note that 75 percent of the current freight volume in southwestern Pennsylvania ports is coal transport. Impending EPA and federal legislative requirements for GHG reductions in the energy supply sector would be expected to change historical coal production, transport, and use patterns in this corridor.

- *Port of Erie*—This is a Great Lakes port with the possibility of rapid growth in the 2009-2020 time horizon. Expected growth is a doubling or tripling in cargo handled. Erie is within the bi-national Great Lakes St. Lawrence Seaway system. Therefore, new policies that affect the Port of Erie need to consider their compatibility with the established policies affecting ports within this system.

A December 2007 study by the Texas Transportation Institute found that efficient short sea shipping is more fuel efficient per ton-mile than goods movement by trucks and even railroads. For example, an inland barge enjoys 576 ton miles to the gallon, compared to 155 on a truck and 413 on a train. From a GHG emissions perspective, short sea shipping can offer substantial reductions.

Numerous industry stakeholders agree that the Harbor Maintenance Tax is an onerous roadblock to the energy bill's short sea transportation provisions. This imposes an additional tax on trucking companies that move their cargo from roads and rails to water vessels. Efforts are underway to urge Congress to waive the Harbor Maintenance Tax for short sea transponders. The legislation would not impose the tax to cargo in intermodal cargo containers and loaded by crane on a vessel, or cargo loaded on a vessel by means of wheeled technology. If this is passed by Congress, it would remove a large barrier to implementing the short sea shipping program.

Cost to Regulated Entities: The options that have been evaluated and included in the summary quantification table for trucking and railroads involve some upfront cost to the regulated entities (and in one case some operating and maintenance expenses); however, the fuel savings will be expected to offset the investment costs in a relatively short period of time (one to three years) such that the entities that install these controls will save money.

Ease of Implementation:
Will vary depending on the specific measure.

Implementation Steps:
To be determined. EPA staff have indicated that implementation of SmartWay truck transport initiatives has been more successful via loan programs than by grants.

Key Assumptions:
The trucking analysis assumes that the penetration rates for the aluminum wheel and fairing retrofits are feasible by 2020. The ability to meet these penetration rates depends on the availability of vehicle body shops that can perform the retrofitting.

Since the technology options analyzed for trucks are retrofit options, new trucks entering the fleet are not considered. Under business as usual, the fuel economy of the existing truck fleet is assumed to remain constant through 2020.

Truck and trailer registrations are assumed to be accurate surrogates for the number of trucks operating in Pennsylvania. In reality, interstate transport may add significantly to the number of trucks and trailers operating in Pennsylvania.

The locomotive analysis assumes that no locomotives are currently retrofitted with the technologies evaluated. Since some locomotives are likely to already be retrofitted, the analysis likely overestimates the incremental GHG benefits.

The cold-ironing project estimate makes assumptions regarding the level of use of cold-ironing facilities, and the amount of emissions from OGVs while at sea and in the harbor. These estimates were based on previous analyses of emission reduction projects in New York and Long Beach. If the factors involved in Pennsylvania harbors are significantly different, then the costs and emissions savings would likely change.

Key Uncertainties:
The fuel efficiency gains for truck and trailer retrofits are based on test track conditions. The actual on-road fuel efficiency improvement may be less.

The diesel fuel consumed by heavy-duty trucks in Pennsylvania is approximated based on an estimate of heavy-duty truck VMT in the state. The actual diesel fuel consumed may be different.

Establishing VSR zones may increase overall emissions (outside VSR zones) if ships speed up during other segments of voyage.

Other Potential Benefits and Drawbacks:
Additional potential benefits of changing behaviors to decrease GHG emissions from freight transportation include:

- Decreased emissions of ozone precursors (VOC and NO_x), CO, and PM.
- Decreased motor fuel use.
- Direct support of Smart Transportation initiatives, projects, and programs.
- Reduced congestion.

Potential Interrelationships With Other GHG Reduction Measures:

These measures aimed at changing behavior need to be implemented in coordination with system changes within the transportation sector, and with transportation-focused land-use measures.

Subcommittee/Committee Comments:

The Clean Air Council completed a project, "Identifying Strategies to Reduce Pollution from Philadelphia Ports: A Stakeholder Process" which produced reports on air, water and land pollution at the Philadelphia ports. The following pollution reduction projects have already been started. The diesel retrofit installation at Packer and Tioga Terminals resulted in a reduction of emissions on 83 pieces of cargo-handling equipment. The EPA on-road verification for these diesel oxidation catalysts is a 20% reduction in PM, a 40% reduction in CO and a 50% reduction in HC. (Community Action for a Renewed Environment (CARE) Level I Grantee Final Report, pp. 17-18)

a. Implemented Targeted Brownfields Assessment on Frankford Creek near Tioga
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d. Began Environmental Management System research

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