Experience in Reducing Diesel Emissions from Waste Haulers, Fire Engines, and Cargo Handling Cranes:

Report on the 2007–2010 Mid-Atlantic Diesel Collaborative Demonstration Grant

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1 Overview

The Mid-Atlantic Regional Air Management Association (MARAMA), working in partnership with city and state agencies and local non-profit organizations in Pennsylvania and Maryland, implemented the Diesel Emission Reduction Initiative 2006 to demonstrate effective urban diesel and port emission control technology applications in support of the Mid-Atlantic Diesel Collaborative. This project, which included diesel particulate filter (DPF) installations on a municipal waste hauling fleet, and diesel oxidation catalyst (DOC) installations on a public fire engine fleet and port cargo handling equipment, demonstrated the emission reduction capability of innovative control applications and addressed potential installation and operational barriers.

The focus of this grant effort was to demonstrate that DPFs and DOCs could be applied to waste haulers, fire engines and cranes without affecting the normal operation of the equipment in "real life" applications. Each project lead (Pittsburgh, Philadelphia and Baltimore) developed key metrics for tracking equipment operation once the diesel technology was installed and reported on the installation process for the equipment. Because the three projects were implemented in urban nonattainment areas, the potential emission reduction impacts of the equipment retrofits were sizable.

Equipment retrofits carried out by the partners for this project included:

- 13 waste haulers in Pittsburgh, representing about 19 percent of the City's fleet of 67 waste hauling vehicles,[1]
- 68 fire engines serving 53 fire houses throughout Philadelphia,[2]
- 2 cargo handling cranes in Baltimore that have large emission reduction potential due to their extensive hours of usage.

Based on the verified emission reductions of the DPF and DOC technologies installed for this project, substantial reductions in particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO) were expected as a result of the waste hauler, fire engine, and crane retrofits. This project showed that these technologies can be installed with no or minimal disruption to operation and, to date, with no negative impacts on normal operation. The successful implementation of the DPFs and DOCs has stimulated further interest in retrofit projects. All

[1] Of the 67 waste hauling vehicles in its fleet, Pittsburgh identified 49 as being eligible for retrofit. The remaining 18 vehicles were either too old to retrofit or were purchased with original equipment manufacturer (OEM) combustion and exhaust systems.

[2] All of the fire engines in the fleet have been retrofitted. Retrofits of the remaining 10 vehicles of the 78 diesel units in the City's fire engine fleet that were eligible for retrofit were paid for with Supplemental Environmental Project (SEP) funding from a 2005 consent decree agreed to by Sunoco. The consent decree included $1.2 million to retrofit public fleet vehicles as part of Philadelphia's Diesel Difference program. https://ework.phila.gov/philagov/news/prelease.asp?id=141

three cities have installed, or have secured funding to install, additional diesel emission reduction technologies: Pittsburgh received a grant to retrofit 33 additional waste haulers, Philadelphia retrofitted the remaining eligible fire engines in its fleet, and the Port of Baltimore retrofitted 11 additional cranes.

2 Project Goals

While the three projects were all focused on the installation and field operation of the retrofitted vehicles, each project identified and reported on additional project goals.

2.1.1 Shared Goals

- Reduce emissions that may adversely affect the health of drivers/vehicle users and people exposed to emissions from these vehicles in the three cities.
- Build local capacity to implement diesel retrofit projects on urban fleets.

2.1.2 Pittsburgh – Specific Goals

- Develop public awareness of the adverse health effects associated with local diesel emissions.
- Demonstrate the efficacy of using DPFs to reduce diesel emissions on local fleets.
- Document the performance of DPF retrofits on vehicles that have low speed, long-day duty cycles.
- Document DPF installation and operation issues as well as hardware and installation costs.

2.1.3 Philadelphia – Specific Goals

- Document issues associated with installing DOCs on a wide variety of make and model year fire trucks.
- Provide insights into the cost and acceptance of DOC technology for first responder equipment.

2.1.4 Baltimore – Specific Goals

- Document issues associated with installing and operating DOCs on ship-to-shore (STS) and rubber-tired gantry (RTG) cranes.
- Meet an objective and target, reducing air emissions, of the Maryland Port Administration's (MPA) environmental management system.

3 Program Grant Funding

The U.S. Environmental Protection Agency (EPA) Region 3, Office of Air Protection & Radiation provided funding for this project via Grant number XA-97351001–0.

MARAMA's budget for this project was $300,000 of which $264,500 was equipment: $127,000 originally budgeted for Pittsburgh, $89,000 for Philadelphia and $48,500 originally budgeted for Baltimore. The remaining $35,500 was for project administration. When the Maryland Port Administration (MPA), the Baltimore project lead, requested a reduction in the scope of its project (*i.e.*, reduce the number of cranes from seven to two and reduce its funding allotment to $12,500), the funds were re-allocated so that the City of Pittsburgh received an additional $36,000 for equipment. Pittsburgh used the increase in its funding to install DPFs on three additional waste haulers.

The period of performance for this grant was initially 24 months; it was extended to 36 months to accommodate project revisions and delays in equipment acquisition.

4 Support from Project Partners

The City of Pittsburgh, Clean Water Action (CWA) and the Group Against Smog and Pollution (GASP) coordinated the Pittsburgh project, obtained a technology provider and worked with the City of Pittsburgh Fleet Services to schedule DPF installations. They also reported on the progress of the project and prepared a final report documenting the equipment retrofitted, the retrofit technology installed, installation issues, operations and maintenance issues, and environmental outputs and outcomes. CWA and GASP provided considerable in-kind staff resources and expertise to facilitate the pilot program in conjunction with the City of Pittsburgh.

Paul Ostrowski, Fleet Contractor Manager for the City of Pittsburgh, described the project partnership in the following way (Paul Ostrowski, personal communication, January 22, 2010):

> This Pittsburgh Experiment assembled a dynamic team: MARAMA, CWA, GASP, City of Pittsburgh & Cummins Bridgeway. Each of these agencies exemplified cooperation, communication and coordination from the initial development stages to equipment installations, to processing payment invoices. Additionally the City of Pittsburgh Departments of Finance and Public Works Environmental Services (PWES) and their fleet maintenance contractor, First Vehicle Services (FVS) worked extremely well coordinating and supporting all project goals without interruption of required public works solid waste removal service to City neighborhoods.

CWA and GASP worked with the City of Pittsburgh, as well as other local governmental and non-profit organizations and foundations to spur interest in funding additional retrofits for local diesel sources. The success of the pilot project funded by this demonstration grant led to the City of Pittsburgh securing funding through the American Recovery and Reinvestment Act of 2009 to retrofit an additional 33 vehicles of its Waste Hauler Fleet.

Philadelphia's Air Management Services (AMS) coordinated the Philadelphia project and contributed in-kind administrative and project management support. AMS was responsible for overseeing the transfer of $59,447 in matching funds from a Sunoco consent decree toward retrofits for the 68 fire engines. AMS used additional Sunoco Supplemental Environmental Project (SEP) funding to retrofit ten more fire engines, for a total of 78 retrofitted fire engines in the City of Philadelphia. AMS and Fleet Management worked with Captain Mike Carrol, the Apparatus Officer at the Philadelphia Fire Department, to coordinate logistics for the DOC installations. AMS also reported on the progress of the project and prepared a final report documenting the equipment retrofitted, the retrofit technology installed, installation issues, operation and maintenance issues, and environmental outputs and outcomes.

In Baltimore, the Maryland Port Authority (MPA) provided $12,389 in cash to help fund this project. MPA also provided the incremental cost of Ultra Low Sulfur Diesel (ULSD) fuel consumed at $0.04 per gallon, and in-kind support to manage the project and procure a retrofit contractor and the DOCs. MPA worked with Cummins Power Systems, LLC, the crane engine manufacturer and DOC provider.

5 Project Descriptions and Results

5.1 Pittsburgh – Waste Hauler Project

5.1.1 Background

Pittsburgh is located in Allegheny County, PA, a nonattainment area for fine particulate matter ($PM_{2.5}$). To reduce the contribution of the City's diesel waste haulers to particulate matter and other air pollution in the greater Pittsburgh area, the City of Pittsburgh, working with Clean Water Action (CWA) and the Group against Smog and Pollution (GASP), retrofitted part of the City's waste hauling fleet with DPFs

Each vehicle in the City's fleet of 68 waste haulers averages about 9,600 miles per year (operating ten hours/day, 250 days/year). From a list of eight primary and four alternate vehicles for retrofit, Pittsburgh initially identified ten waste haulers, model year 2006 or earlier with the potential for a long service life. When offered additional funding, the City selected three more vehicles to retrofit. Retrofitting waste haulers in Pittsburgh benefits the health of truck operators

and loaders, people who live and work along municipal garbage routes, and residents in the greater Pittsburgh area.

Compared to DOCs, DPFs are capable of achieving larger PM reductions (up to 85 percent or more vs. 10 to 40 percent for DOCs). Unlike DOCs however, which have near-universal applicability, DPFs are not feasible in all retrofit applications due to their tighter space and operating characteristic requirements. Because the waste haulers met these tighter requirements, DPFs were selected for the largest possible emission reductions.

In addition to sizable PM reductions, this project provided the City of Pittsburgh, CWA and GASP with the knowledge and experience needed to implement other diesel emission reduction projects together with other partners in the greater Pittsburgh area.

5.1.2 Implementation

The project began in the fourth quarter of 2007 with the signing of the subaward agreement and a report/quote from a technology provider, Cummins Bridgeway, LLC, following its testing of Waste Hauler ES-256. During project implementation, specific vehicles for retrofit were selected based on cost, feasibility, and emission reduction potential. The original list of candidate vehicles included eight primary and four alternate vehicles. Waste Hauler ES-256 was added to the retrofit list and two originally selected model year 2000 Waste Haulers were removed due to DPF cost and availability issues. Two additional vehicles (ES 238 and ES 243) were added in July 2008 to replace the model year 2000 vehicles ES 224 and ES 257, and all "Alternate" vehicles were added to bring the total number of Waste Haulers to be retrofitted to 13. Waste Hauler model year 2006 ES 238 was subsequently replaced by model year 2000 ES 205, to keep all of the vehicles model year 2004 or older. During the project analysis phase, Cummins Bridgeway, LLC discovered that Waste Hauler ES 243 would not generate adequate and reliable combustion temperature ranges to inter-phase with the specified DPF systems; therefore, ES 213 was substituted for ES 243. Finally, ES 271 was found to have a long term failure. ES 224, which had been previously removed, was re-added to replace ES 271 when it was determined that appropriate technology was available for ES 224.

Table 1 shows the vehicles on the original, intermediate and final retrofit lists, as well as those originally identified as "Alternate" or "Primary." Vehicles in italics were replaced on the list by the next vehicle on the list. The "Final List" column and the column with numbers 1 – 13 indicate vehicles that were retrofitted in this project.

Table 1 Waste Hauler Vehicle Equipment List

	Model Year	Make	Unit No.	Primary/ Alternate	Original List?	Intermediate List?	Final List?
1	2004	Crane/Carrier	ES 210	P	YES	YES	YES
2	2002	Peterbilt	ES 216	A	YES	YES	YES
3	2003	Crane/Carrier	ES 228	A	YES	YES	YES
4	2002	Peterbilt	ES 237	P	YES	YES	YES
5	2003	Peterbilt	ES 254	P	YES	YES	YES
	2000	*Peterbilt*	*ES 257*	*P*	*YES*	*NO*	*NO*
	2004	*Crane/Carrier*	*ES 243*		*NO*	*YES*	*NO*
6	2000	Peterbilt	ES 213		NO	NO	YES
7	2003	Crane/Carrier	ES 262	P	YES	YES	YES
8	2004	Crane/Carrier	ES 269	A	YES	YES	YES
9	2004	Crane/Carrier	ES 270	P	YES	YES	YES
	2002	*Peterbilt*	*ES 271*	*A*	*YES*	*YES*	*NO*
10	2000	Peterbilt	ES 224	P	YES	NO*	YES
	2006	*Crane/Carrier*	*ES 238*		*NO*	*YES*	*NO*
11	2000	Peterbilt	ES 205		NO	NO	YES
12	2002	Peterbilt	ES 272	P	YES	YES	YES
13	2004	Crane/Carrier	ES 256		NO	YES	YES

*Unit No. ES 224 was removed from the original list, but later replaced ES 271 when ES 271 was found to have long term failure.

Cummins Bridgeway, LLC identified the best retrofit technology based on cost and availability for the selected vehicles and determined that Continuously Regenerating Technology (CRT) DPFs were the best match. In July 2008 Cummins Bridgeway, LLC began installing the DPFs, completing the first seven by the third Quarter of 2008. Approximately 30 days (200 – 300 miles) after installation, major movement and displacement of the DPF units was noticed. The City staff, FVS, and Cummins Bridgeway team determined that the movement and displacement were due to the weight of the DPF units and the initial installation configurations. With input from FVS technicians, Cummins Bridgeway designed brackets to secure the DPFs and support their weight, and fabricated and installed the brackets. For the remaining vehicles, Cummins Bridgeway fabricated and installed support brackets as part of the installation process. Also in the third Quarter of 2008, Cummins Bridgeway, LLC installed a Donaldson DPF Pulse Cleaner at the City of Pittsburgh 29th Street Vehicle Maintenance Center and provided staff training on its use.

By the end of the fourth Quarter of 2008, three additional waste haulers had been successfully retrofitted, and the City of Pittsburgh requested a six month extension in their Agreement to design, furnish, and install DPFs for the three vehicles that were added to the list when funding for the project increased. The City encountered technical difficulties in the DPF design for two of the three additional vehicles, Waste Haulers ES 238 and ES 243, that necessitated replacing them with other vehicles (ES 205 and ES 213) and delayed the purchase and procurement of the

DPFs. The purchase and procurement delay affected the implementation schedule and led to the six month extension.

Pittsburgh held an "OFFICIAL KICK-OFF" ceremony on April 25, 2008 with Mayor Luke Ravenstahl to announce the grant and introduce the project. Participants included:

- Luke Ravenstahl, Mayor of Pittsburgh
- Donald Welsh, EPA Region III's Regional Administrator
- James Thompson, Air Director, Allegheny County Health Department/Mid-Atlantic Regional Air Management Association (MARAMA)
- Rachel Filippini, Executive Director of GASP
- Ashleigh Deemer, Program Organizer of CWA
- Susan Stephenson, Senior Policy Analyst, MARAMA

The Pittsburgh Post Gazette, Tribune Review and Environment News Service covered the project announcement.[3] Coverage emphasized the grant funding of the project, the collaboration of public and non-profit partners, and the health effects of diesel emission reductions. Bill LeSesne, Pittsburgh's coordinator of environmental services, said in the Tribune Review of the waste hauler emission reductions that "for the neighborhoods we go through, this is a huge benefit."

5.1.3 Outputs and Outcomes

Output 1: *The project reduced particulate matter and other air pollution emitted by diesel waste haulers in the greater Pittsburgh area.*

Table 2 shows annual and lifetime expected emission reductions for the 13 waste haulers:

Table 2 Waste Hauler Emission Reduction Estimates

Pollutant	Annual Emission Reduction for the fleet (Tons per Year)	Emission Reduction Over the Life of the Fleet (Tons)
Particulate Matter (PM)	0.047	0.69
Hydrocarbons (HC)	0.06	0.87
Carbon Monoxide (CO)	0.29	4.14

[3] "City garbage trucks going greener," April 25, 2008 <http://www.post-gazette.com/pg/08116/876409-53.stm>; "'Green' devices scrub city trucks' toxic exhaust," April 26, 2008 <http://www.pittsburghlive.com/x/pittsburghtrib/s_564402.html>; and "Pittsburgh Diesel Trash Trucks Upgraded for Cleaner Air," April 30, 2008 <http://www.ens-newswire.com/ens/apr2008/2008-04-30-092.asp>.

The emission reduction estimates were derived using the Environmental Protection Agency's Diesel Emissions Quantifier (DEQ), based on a per vehicle annual average of 9607 miles traveled, 3479 gallons fuel used and 517 hours of idling. DEQ emission reductions for DPF installations on this fleet are: 85% PM, 90% HC, 90% CO.

***Output 2**: The project achieved reductions of diesel emissions from an urban fleet.*

The City of Pittsburgh estimates that each waste hauling truck operates about 9,600 miles per year (10 hours/day, 250 days/year.) For the 13 trucks that were retrofitted in this project, that is an annual total of about 125,000 miles (or 32,500 hours) that the fleet operated with PM emissions reduced 85 percent, HC emissions reduced 90 percent and CO emissions reduced 90 percent. The City will benefit from annual PM reductions of 0.047 tons, HC reductions of 0.06 tons and CO reductions of 0.29 tons. Lifetime emission reductions for the 13 retrofitted trucks will be 0.69 tons PM, 0.87 tons HC and 4.14 tons CO.

James Clark, a Pittsburgh garbage and recycling truck driver, said of the retrofitted waste haulers in a post-gazette.com article, "As a driver I'm smelling diesel exhaust all day, but with those trucks I don't. The smoke is cut, the diesel smell is cut, and they run better."[4]

***Outcome 1:** Attracted attention to and developed public interest in the adverse health effects associated with local diesel emissions.*

When announcing the Waste Hauler project at the "OFFICIAL KICK-OFF" ceremony the speakers focused attention on the adverse health effects related to local diesel emissions.[5] Mayor Ravenstahl noted that the American Lung Association named Pittsburgh second worst (behind the region of Los Angeles) for particulate pollution and that DPFs reduce particulate pollution by an estimated 85 percent. Rachel Filippini of GASP spoke extensively about the health risks of ground level diesel exhaust emitted by on-road vehicles, including increased risks of asthma attacks, asthma onset, cancer, bronchitis, strokes, heart attacks and premature deaths. She noted that "retrofitting even a small number of waste haulers will have a positive impact on the health of people who live and work along those municipal garbage routes, the truck operators themselves and residents of the greater Pittsburgh area." Ashleigh Deemer of CWA reiterated Ms. Filippini's comments on the adverse health effects of diesel emissions, noting the role of adverse health effects in EPA's mandate that, beginning in 2007, new vehicles be equipped with cutting-edge emission reduction technology.

[4] Hopey, Don, "City to reduce emissions from garbage truck fleet," post-gazette.com. 17 October 2009

[5] Deemer, Ashleigh; Filippini, Rachel; Ravehstahl, Luke. "Pittsburgh Waste Hauler Retrofit." 25 April 2008. Online video clip. YouTube. Accessed on 15 December 2009. < http://www.youtube.com/watch?v=ukN6lQVXygo>

The message of the adverse health effects of diesel emissions was reinforced in October 2009 with the announcement of the $443,100 ARRA grant to retrofit 33 additional waste haulers in Pittsburgh. During the announcement of the ARRA funding to retrofit 33 additional waste haulers in Pittsburgh, John Hanger, secretary of Pennsylvania's Department of Environmental Protection reinforced the role of diesel exhaust in respiratory problems, noting that diesel exhaust is of particular concern for vehicles such as waste haulers that make frequent stops.[6]

Outcome 2: *Demonstrated the efficacy of using diesel particulate filters to reduce diesel emissions on local fleets.*

The project demonstrated that emissions from waste haulers could be successfully reduced without adversely affecting operations.

On its website, http://pghdieselcleanup.wordpress.com/local-projects/, GASP describes the City of Pittsburgh Waste Hauler retrofits as one of its most successful projects; based on its initial success the City applied for U.S. EPA funds to retrofit additional Waste Haulers. On October 16, 2009 the Allegheny County Health Department received $443,100 in ARRA funds to retrofit 33 of the City of Pittsburgh's Waste Haulers with DPFs.[7] Completion of these 33 ARRA-funded retrofits will bring the percentage of Pittsburgh's Waste Hauler fleet that has been retrofitted to approximately 73 percent of total (67 vehicles) and 96 percent of eligible (49 vehicles).

Outcome 3: *Provided project partners with experience in how to implement diesel retrofit projects on urban fleets.*

The project engaged the Allegheny County Partnership to Reduce Diesel Pollution, led by two local environmental groups, GASP and CWA, as well as the City of Pittsburgh and a local technology vendor. Together they worked through all aspects of the project. Rachel Filippini, Executive Director of GASP said of the Waste Hauler project," I feel the original demonstration project, funded by MARAMA, to retrofit 13 City of Pittsburgh waste haulers provided the City with the confidence in the technology that they needed to pursue additional funding for a more comprehensive retrofit project." Following their successful collaboration in this project, the "Diesel Partnership" together with the City, the Pennsylvania Department of Environmental Protection (PA DEP) and the Allegheny County Health Department, applied for and received funding to install DPFs on 33 additional waste haulers.

[6] "Allegheny County Health Department gets stimulus money for emission-trapping filters on garbage trucks," Pittsburgh Business Times. 16 October 2009.
< http://pittsburgh.bizjournals.com/pittsburgh/stories/2009/10/12/daily44.html>.

[7] From the Pennsylvania Department of Environmental Protection Daily Update: http://www.depweb.state.pa.us/news/cwp/view.asp?a=3&q=549251.

Outcome 4: *Produced new information on DPF retrofits on diesel waste hauling vehicles, which have low speed, long-day duty cycles.*

Vehicle and DPF performance depend on matching the DPF design to the vehicle's temperature profile. Because of the low-temperature duty cycles of the Waste Haulers, a technology provider had initially recommended that the City of Pittsburgh purchase and install passive Continuously Catalyzing Regenerating Technology (CCRT) DPFs to ensure proper operation of the trucks and to avoid excessive maintenance time and costs. The City based its preliminary list of vehicles to be retrofitted on this recommendation. When analysis of the selected vehicles began, it was discovered that a cost-effective CCRTDPF was not available and that Continuously Regenerating Technology (CRT) DPFs would be the appropriate technology. In addition to DPF cost-effectiveness, careful vehicle selection is important due to the need for certain temperatures and durations in order to ensure that the DPF will work without problems.

Outcome 5: *Produced new information on DPF installation and operation issues and hardware and installation costs.*

About 30 days (200 – 300 miles) after having the DPFs installed, major movement and displacement of the DPFs was noticed and the first seven retrofitted vehicles were brought back in for service installation of a bracket to support the additional weight of the DPFs. With input from FVS technicians on the design, Cummins Bridgeway designed, fabricated, and installed the brackets. For the remaining six vehicles, brackets were included as part of the installation process; fabricating and installing the brackets added $465.00 to the cost of each DPF.

Beginning in the fourth Quarter of 2008, First Vehicle Services (FVS) began documenting non-routine maintenance and repairs for the ten Waste Haulers that had been retrofitted. As of October 28, 2009, FVS had performed 110 repairs on the Waste Haulers, of which 100 were determined to be unrelated to DPF installation. The remaining ten exhaust, engine and fuel system repairs were not verified as being related to the DPF installation. Other repairs included, but were not limited to, tires, hopper seals, hydraulics, fuel assemblies and filters, batteries, compactors, bushings and springs. FVS's maintenance reporting by quarter included the following:

- **2008, fourth Quarter:** FVS performed 23 repairs on eight of the ten Waste Haulers; none of the repairs was project related. FVS's lead technician commented that "all systems are working satisfactorily at this time (and hopefully long into the future.) The units appear to be getting enough highway miles to purge the filters and keep the restrictions down to a bare minimum…"
- **2009, first Quarter:** FVS performed 18 repairs on eight of the ten Waste Haulers; none of the repairs was project related.

- **2009, second Quarter:** During this Quarter, equipment operators realized that the DPF "RED LIGHT" WARNING on the instrument panel required maintenance of the DPF element. FVS performed 34 repairs on nine of the ten Waste Haulers; seven of the repairs were possibly, but not verified as, DPF-related. FVS continued to monitor progress and performance of the Waste Hauler units and DPF equipment. FVS also serviced and cleaned two DPF filters using the Donaldson Diesel Particulate Filter Pulse Cleaner.
- **2009, third Quarter:** FVS performed 35 repairs on all ten Waste Haulers; three of the repairs were possibly, but not verified as, DPF-related. FVS's Operations Manager reported no DPF cleanings during the third Quarter.
- **2009, fourth Quarter:** FVS's Operations Manager indicated on October 12, 2009 that "(a)t the present time all the units seem to be running at or above normal operating specs."

Outcome 6: *Reduced emissions that may adversely affect the health of Pittsburgh sanitation workers and the people who live and work in Pittsburgh.*

As explained above, the installation of DPFs on the waste haulers reduced emissions. See Table 2 for specific reduction amounts.

5.1.4 Insights and Lessons Learned

1) Project Feasibility – "A definite Initial Plan identifying required equipment, costs and anticipated results is required." (Paul Ostrowski, Fleet Contractor Manager for the City of Pittsburgh; personal communication, January 22, 2010).

With PM reduction capabilities of 85 percent or more, DPFs are the most effective technology for reducing PM emissions. They are not, however, appropriate for every application. For example, DPFs have minimum operating temperature and duration requirements to ensure proper operation and they are often larger and heavier than the mufflers they replace, so adequate space and support are necessary. When considering the feasibility of a DPF retrofit, it is essential to match the DPF design to the vehicle's temperature profile and space limitations. Mr. Ostrowski added (personal communication, January 22, 2010): "When considering a DPF retrofit, properly "marry" the vehicle and diesel engine mechanical characteristics to the required legal/economic/technical equipment available." Additionally, Mr. Ostrowski recommended that when considering a DPF retrofit "plan on at least a three day route data log to obtain truck diesel engine temperature and pressure cycles in DPF design stages."

2) Care and flexibility in the selection of primary and, if possible, alternate fleet vehicles are important.

Even when the DPF design is carefully matched to the vehicle, other issues may arise. In this project, the DPFs that were initially recommended were not cost-effective, which meant that the list of candidate retrofit vehicles needed to be adjusted. For the project, Pittsburgh had initially identified eight primary and four alternate vehicles; two of the primary vehicles were dropped and, in the end, all four alternate vehicles were retrofitted. Pittsburgh also took advantage of additional funding that became available and chose three more vehicles for retrofitting. For the 13 Waste Haulers that were retrofitted under this grant, Pittsburgh evaluated the feasibility of 17 vehicles and made five changes. In its 2008 second Quarter report, the City commented on MARAMA's "positive direction and flexibility in review and approval of unexpected problems encountered in project implementation." This flexibility and Pittsburgh's preparedness with alternate vehicles contributed to the success of the project. Mr. Ostrowski noted (personal communication, January 22, 2010): "The selection of Primary and Alternate (add 20 percent) diesel engine trucks is highly recommended with an understanding that a change is likely to occur."

3) Support for Additional Projects.

Mr. Ostrowski assessed the Waste Hauler project as follows (personal communication, January 22, 2010): This project "demonstrate(d) that DPF technology can be applied in an urban environment on older diesel engine Waste Hauler units operating at low speed and long cycles." Such demonstrations can encourage other operators of similar urban fleets to proceed with retrofit projects that, without knowledge of prior success, they may have been reluctant to undertake.

5.2 Philadelphia – Fire Engine Project

5.2.1 Background

The City of Philadelphia's Air Management Service (AMS) oversaw the Office of Fleet Management's (OFM) installation of DOCs on an urban fleet of 68 fire engines. The City of Philadelphia is a nonattainment area for $PM_{2.5}$ and ozone, and air quality in and around the trucks they use every day is a concern to the Philadelphia firefighters. Due to maintenance requirements, fire engines often idle inside fire houses, the same buildings where firefighters eat, sleep, and generally spend much of their time. The ambient air quality around the City's 53 fire stations is of special concern to the City since firefighters are disproportionately exposed to air contaminants in their daily activities. Commercial, residential, and industrial fires emit chemical compounds that are hazardous to individuals in or near these fires. Diesel engines further expose firefighters to hazardous air pollutants. In addition to improving air quality for firefighters, the

City of Philadelphia benefitted from the project's reduction of particulate matter (PM), hydrocarbons (HC) and carbon monoxide (CO).

The 68 retrofitted fire engines vary by location and duty cycle. The duty cycles are characterized by mileage, speed, load, and temperature. Idling times also vary depending on the type of incident, such as house fire, medical assistance, etc. Vehicle loads vary, since each truck is equipped differently (*e.g.*, a pumper truck can carry a variety of pumps). Pumpers might supply seven or eight fire hoses at once, each a thousand feet long. Again, this will vary upon the pumper vehicle. Many of the pumpers include piston pumps, rotary pumps, and single and multistage impeller pumps (serial and parallel centrifugal pumps.) These vehicles are high performance and are designed to carry out a specific task. Most of the vehicles are in and out of the fire house frequently during a given 24 hour period; therefore, continued restarts are an issue and create wear on the engine.

5.2.2 Implementation

This project was led by AMS in coordination with the OFM, and the Philadelphia Fire Department. Additional collaborators included: the City of Philadelphia's Managing Director's Office, Law Department, and Department of Public Health; the Philadelphia Diesel Difference; the Clean Air Council; the Mid-Atlantic Diesel Collaborative; and the technology provider Cummins Bridgeway, LLC. The City's OFM led the contracting and installation process for the equipment, conducted testing and maintenance on the equipment, and provided performance data to Philadelphia's AMS. AMS and OFM worked with the Apparatus Officer at the Philadelphia Fire Department to coordinate logistics for the DOC installations.

According to Chris Cocci, Deputy Fleet Manager of the Office of Fleet Management (OFM), installation costs for parts and labor averaged approximately $2500 per vehicle and took between two and five hours (personal communication, December 17, 2009). Richard Sinclair, Fleet Maintenance Supervisor of the OFM, explained how installation time decreased as the project progressed (personal communication, January 21, 2010):

> It's difficult to say exactly how much labor it took to retrofit each truck. In the beginning of the project, each installation took approximately 5 hours, but as the project progressed, installation time gradually became less, and the last few were taking 2 hours. In the beginning, we were not sure exactly which parts (clamps, pipes, hangers, etc.) needed to be replaced or modified for each retrofit. Therefore, those early installs took much longer than expected. After we had a number of installs under our belts, we had everything that was needed and knew exactly what we had to do and how to do it. There's a bit of a learning curve when you're doing retrofits like this, and by the end of the project, the last few trucks took us half the time as the first ones did. I would say an average installation time for this project was 3 hours per truck.

The retrofits were done during routine comprehensive preventive maintenance (PM) between January 8, 2008 and October 31, 2009. Since loaner engines are provided for use during PM, which takes three to four days, the retrofits were completed without compromising public safety, which was of concern because most of Philadelphia's fire stations have only one pumper truck, and none possess more than two.

As part of PennFuture's "Next Great City" effort, diesel retrofits were highlighted at an October 15, 2008 event. A key recommendation for the Next Great City effort was the cleanup of the City's diesel fleet via diesel retrofits. The event highlighted the fire engine retrofits and included an actual retrofitted engine as the backdrop for the event.

Information on the fleet of vehicles retrofitted is provided below in Table 3.

The retrofitted vehicles all have Detroit Diesel Corporation Series 60 engines, but vehicle use varies by location and duty cycle. Operation and maintenance of the retrofitted vehicles have been closely monitored since DOC installations and more than two years after retrofit installation began, no operational problems have been observed on any of the DOC-fitted equipment.

Table 3 Retrofitted Philadelphia Fire Engines

NUMBER	UNIT NUMBER	VEHICLE MAKE	VEHICLE MODEL	DATE COMPLETE
1	E-52	KME	Pumper	1/8/2008
2	E-22	KME	Pumper	1/8/2008
3	E-35	KME	Pumper	1/8/2008
4	E-46	KME	Pumper	1/23/2008
5	E-51	KME	Pumper	1/24/2008
6	E-7	KME	Pumper	2/12/2008
7	E-36	KME	Pumper	2/12/2008
8	E-14	KME	Pumper	2/13/2008
9	E-59	KME	Pumper	2/20/2008
10	E-64	KME	Pumper	2/26/2008
11	E-25	KME	Pumper	2/26/2008
12	E-71	KME	Pumper	2/28/2008
13	E-41	KME	Pumper	3/10/2008
14	E-54	KME	Pumper	3/10/2008
15	E-50	KME	Pumper	3/11/2008
16	E-10	KME	Pumper	3/20/2008
17	E-2	KME	Pumper	4/2/2008
18	E-6	KME	Pumper	4/4/2008
19	E-73	KME	Pumper	4/4/2008
20	E-53	KME	Pumper	4/14/2008
21	E-1	KME	Pumper	4/17/2008
22	E-12	KME	Pumper	4/30/2008
23	E-11	KME	Pumper	5/20/2008

Table 3, continued: Retrofitted Philadelphia Fire Engines

NUMBER	UNIT #	VEHICLE MAKE	VEHICLE MODEL	DATE COMPLETE
24	E-19	KME	Pumper	6/16/2008
25	E-40	ALF	Pumper	7/2/2008
26	L-3	ALF	Ladder	7/31/2008
27	E-5	KME	Pumper	8/4/2008
28	E-34	ALF	Pumper	8/7/2008
29	E-13	ALF	Pumper	8/7/2008
30	L-14	ALF	Ladder	9/4/2008
31	L-8	ALF	Ladder	9/5/2008
32	E-29	ALF	Pumper	9/20/2008
33	E-70	ALF	Pumper	10/2/2008
34	SQ-47	ALF	Pumper	10/24/2008
35	E-63	ALF	Pumper	10/28/2008
36	E-68	KME	Pumper	11/7/2008
37	E-61	ALF	Pumper	11/13/2008
38	E-60	E-One	Foam Pumper	11/22/2008
39	SQ-57	ALF	Squirt	11/25/2008
40	L-34	ALF	Ladder	11/25/2008
41	L-20	ALF	Ladder	12/2/2008
42	Q-69	Simon Duplex	Quint	12/11/2008
43	SQ-43	ALF	Squirt	12/12/2008
44	SQ-9	ALF	Squirt	12/18/2008
45	E-49	ALF	Pumper	12/18/2008
46	E-28	ALF	Pumper	12/19/2008
47	SQ-8	ALF	Squirt	12/23/2008
48	E-44	ALF	Pumper	1/6/2009
49	L-1	ALF	Ladder	1/6/2009
50	E-58	ALF	Pumper	1/20/2009
51	E-45	ALF	Pumper	1/26/2009
52	L-13	ALF	Ladder	1/30/2009
53	L-22	ALF	Ladder	2/20/2009
54	E-24	KME	Pumper	3/2/2009
55	SQ-72	ALF	Pumper	3/3/2009
56	E-3	ALF	Pumper	3/5/2009
57	E-62	ALF	Pumper	3/6/2009
58	E-20	ALF	Pumper	3/9/2009
59	L-31	ALF	Ladder	3/14/2009
60	L-18	ALF	Ladder	3/18/2009
61	L-19	ALF	Ladder	3/19/2009
62	L-21	ALF	Ladder	4/7/2009
63	L-30	ALF	Ladder	4/22/2009
64	E-56	ALF	Pumper	4/24/2009
65	L-16	ALF	Pumper	5/8/2009
66	E-27	ALF	Pumper	5/12/2009
67	L-12	ALF	Ladder	10/31/2009
68	L-9	ALF	Ladder	10/31/2009

5.2.3 Outputs and Outcomes

Output 1: *Emission reductions were achieved in city fire stations, along city streets and highways, and at fire and emergency responder locations.*

Table 4 shows annual and lifetime expected emission reductions for the 68 fire trucks in Table 3 above, using Ultra Low Sulfur Diesel (ULSD) fuel:

Table 4 Fire Engine Emission Reduction Estimates

Pollutant	Annual Emission Reduction for the Fleet (Tons per Year)	Emission Reduction Over the Life of the Fleet (Tons)
Particulate Matter (PM)	0.026	0.35
Hydrocarbons (HC)	0.152	2.05
Carbon Monoxide (CO)	0.372	4.94

The emission reduction estimates were derived using the Environmental Protection Agency's Diesel Emissions Quantifier (DEQ), based on a per vehicle annual average of 8059 miles traveled, 2706 gallons fuel used and 100 hours of idling.

Output 2: *This DOC demonstration program improved air quality in the Philadelphia PM nonattainment area, in the urban canyons of central city Philadelphia, and in minority and low-income communities.*

The City's Fire personnel respond to many incidents in Philadelphia's minority, low-income, and underserved communities. Philadelphia is a nonattainment area for ozone and fine particle pollution. Table 4 above quantifies estimated annual and lifetime PM, HC and CO reductions. Reducing the emissions of the fire engines that serve Philadelphia communities helps mitigate emissions in these areas.

Outcome 1: *This project provided project participants with practical, real-world experience in dealing with diesel retrofit projects on urban fleets.*

Alison Riley, of the City of Philadelphia's Department of Public Health, Air Management Services (AMS), observed (personal communication, January 26, 2010):

> The process of retrofitting the vehicles became streamlined with each subsequent installation. Although there was a learning curve associated with the first few vehicles, installers quickly learned to properly handle the units, adjust to the configuration of each vehicle, and prevent any problems from arising.

Since the retrofits were done while the fire engines were out of service for routine preventive maintenance, no extra time out of service was required for the DOC installations.

Outcome 2: *The project shed new light on the issues associated with installing DOCs on a wide variety of makes, models, and model year fire trucks.*

> A number of different types of vehicles were retrofitted and each truck had to have its parts customized. Temperature and space considerations helped determine how each unit would be installed and what additional equipment would be needed. In some cases, the additional weight of the units had to be considered (Alison Riley, personal communication, January 26, 2010).

Outcome 3: *Fleet managers, Fire Department officials, AMS staff, and Mid-Atlantic Diesel Collaborative partners gained insights into the cost and acceptance of DOC technology.*

Installation, operation and maintenance are keys to DOC technology acceptance, on which Alison Riley of AMS commented (personal communication, January 26, 2010):

> We are now able to say with confidence that retrofit devices can work even on critical units like first responder vehicles, and that installation is not prohibitively difficult and does not significantly increase the amount of time the unit is out of service.

Mr. Cocci added (personal communication, December 17, 2009): "Since the DOC installs, maintenance costs have remained unchanged. We haven't seen any significant changes in fuel mileage since the DOC installations."

Outcome 4: *Cost and acceptance information was shared with the Mid-Atlantic Diesel Collaborative to broaden acceptance of this diesel emission reduction strategy.*

> The cost of each unit averaged around $2500 per vehicle, which is extremely reasonable considering the size of the units and the comparative cost of alternative technologies such as particulate filters. Installations were done in-house, which helped to defray the total cost and the time each vehicle spent out of service (the alternative would have been to send the vehicles to be serviced by a private company on a contractual basis) (Alison Riley, personal communication, January 26, 2010).

Outcome 5: *This project reduced emissions that may adversely affect the respiratory health and quality of life of Philadelphia firefighters, the people who live and work near fire stations, and the general public.*

The 68 retrofitted City of Philadelphia fire engines average about 8059 miles per vehicle annually for a yearly total of about 548,012 miles that these fire engines operated with PM emissions reduced 20 percent, HC emissions reduced 50 percent and CO emissions reduced 30 percent. The City will benefit from annual PM reductions of 0.026 tons, HC reductions of 0.152 tons and CO reductions of 0.372 tons and lifetime emission reductions of 0.35 tons PM, 2.05 tons HC and 4.94 tons CO from these 68 fire engines.

5.2.4 Insights and Lessons Learned

More than two years after DOC retrofit installations began, no operational problems due to installation /operation of DOCs have been observed in the 68 retrofitted City fire engines.

Chris Cocci, Deputy Fleet Manager of the Office of Fleet Management, who oversaw the DOC installations, commented that "Each installation had to be customized for that particular vehicle" (personal communication, December 17, 2009).

He noted the following issues that affected installation:

> Installation cost parts and labor for fire pumpers and ladder trucks averaged around $2500.00 per unit and took between 2 to 5 hours to complete. Some of the problems we encountered were due to the additional weight, configuration and size of the DOC muffler. Inlet and outlets for the DOCs were slightly different and required varying degrees of modifications to vehicle in order to route the piping. Each installation had to be customized for that particular vehicle. Brackets and/or hangers had to be altered or fabricated for many of the installations. The additional heat generated by the DOC mufflers also had to be considered, so that any components, hoses, or wiring harnesses would not be damaged by the additional heat. Wiring harnesses and hoses had to be re-routed or protected on many vehicles. Since the DOC installs, maintenance costs have remained unchanged. No significant changes in fuel mileage have been reported since the DOC installations.
>
> The City was unable to complete the installation on vehicle #970293. Space limitations under the truck prevented the installation of the DOC without possibly damaging or disabling nearby components. The undercarriage of the truck has limited space available and this prohibits a safe and dependable installation.

The parts were purchased in bulk quantities and placed into shop inventory. As installs were performed, parts were drawn from inventory. Parts were not ordered for each individual vehicle. Each part number is specific to the actual dimensions of the muffler and location of the inlet and outlet pipes. A specific part number may fit on multiple makes, models, and years of vehicles (personal communication, December 17, 2009).

5.3 Baltimore – Port Crane Project

5.3.1 Background

The Maryland Port Administration (MPA), located in Baltimore City and Baltimore County, manages the seven public terminals that are located within the Port of Baltimore. There are also 23 private terminals and facilities that are considered part of the Port of Baltimore. The MPA's public terminals account for approximately 24 percent of the total cargo tonnage transiting the Port of Baltimore.

In 2006, MPA completed an emission inventory that characterized emissions from the operation of landside activities at MPA terminals. This emission inventory indicated that of the landside cargo handling equipment (CHE), cranes owned by the MPA were a contributor to the overall emissions of the public terminal but not as significant a contributor as other CHE owned and operated by private-sector terminal operators. Nevertheless, the MPA committed to reducing its contributions to air emissions.

MPA owns and maintains ship-to-shore (STS) and rubber-tired gantry (RTG) cranes as part of its cargo handling operations. The STS cranes move cargo to and from ships and the RTG cranes move cargo on and off trucks. The MPA has nine STS diesel/electric cranes at the Dundalk Marine Terminal and 12 RTG cranes at its Seagirt Marine Terminal. These cranes are critical to the continued operation of the Port and are among the most important pieces of equipment on MPA property.

As part of its environmental management system, MPA determined that the reduction of air emissions was one of its areas for improvement. To determine the feasibility of this objective and target, with funding from this grant, the MPA retrofitted the engines of one STS crane and one RTG crane with diesel oxidation catalysts (DOCs). The cranes were chosen due to their extensive hours of usage, and consequent potential for significant emissions reduction.

MPA was the first Port to install DOCs on STS and RTG cranes, and this project involved the first installation of DOCs on MPA cranes.[8] Its primary goal in installing the DOCs was to

[8] Maryland Port Administration, Environmental Management System "2008 Annual Review: Achievements & Improvements."

decrease the particulate matter (PM), volatile organic compounds (VOCs) and carbon monoxide (CO) emitted by the two cranes involved in the demonstration. It was critical to MPA that the DOCs had no adverse effect on the cranes, either by causing damage to the cranes or by impairing the crane operations by increasing either the time it takes to move cargo or the time out of service.

Retrofitting cranes at MPA reduced emissions from the Port that may adversely affect the health of crane operators, port workers and the health of the low-income and minority residents who live near the port, which is part of the Baltimore nonattainment area for ozone. The Baltimore area also experiences fine particle matter ($PM_{2.5}$) concentrations approaching the ambient standard. Additionally, this port sector project was an opportunity to demonstrate the effectiveness of diesel emission technologies outside of California. As such, it served as a regional example of emission reductions achieved in the port sector, as well as a national model.

DOC installation on the STS and RTG cranes was a new application of an EPA-verified technology. The project provided information related to the use of emission reduction technologies on Port cranes in the Mid-Atlantic Region. Without proven technology within the Region on a number of units, Port operators are unlikely to take advantage of new diesel emission reduction equipment. The Port itself initially proceeded with caution, reducing the number of cranes to be retrofitted as part of this demonstration project from 19 to 2, but by the end of 2009 had retrofitted its remaining eleven RTG cranes.

5.3.2 Implementation

MPA installed the DOCs on the STS and RTG crane engines and began data tracking in April 2008. Data tracking included monitoring crane downtime and breakdowns and determining if the DOCs had been responsible. The effect of DOC installation on crane reliability is an important factor in assessing retrofit feasibility. Any malfunction of the engines could significantly hamper port operations by slowing cargo movement, causing loss of revenue and other damages to MPA and its customers. Malfunction of the engines could also increase rather than decrease air pollution caused by the cranes. While the project was short in duration and only involved two cranes, it provided basic information about the operation and durability of DOCs in port crane applications.

5.3.3 Outputs and Outcomes

***Outcome 1*:** *Emissions from diesel engines on two cargo handling cranes were reduced.*

Cummins Power Systems, LLC, the crane engine manufacturer and DOC installer, modeled 2006 pre-installation emission values and post-installation expected emission reductions for the

two cranes. Table 5 shows the expected emission reduction percentages during operation with ultra low sulfur fuel and DOCs:

Table 5 Expected Post-installation Emission Reductions for STS and RTG Cranes

Pollutant[9]	**Reduction**
PM	20%
HC (VOC)	80%
CO	90%

Applying the expected emission reduction percentages in Table 5 to the modeled 2006 emissions for both cranes yields the predicted annual emission reductions shown below in Table 6:

Table 6 Predicted Annual Emission Reductions based on 2006 Operations

	RTG Crane 8			**STS Crane 8**		
Pollutant	Pre-installation (tons/year)	Post-installation (tons/year)	Tons/year reduced	Pre-installation (tons/year)	Post-installation (tons/year)	Tons/year reduced
PM	0.22	0.176	0.044	0.202	0.1616	0.0404
VOC	0.14	0.028	0.112	0.244	0.0488	0.1952
CO	1.806	0.1806	1.6254	0.745	0.0745	0.6705

For each crane, MPA tracked operating time for the six months following DOC installation. Based on Cummins Power Systems, LLC post-installation modeling of RTG Crane 8's expected emission reductions and its monthly operating minutes for each month of the six month evaluation, Table 7 shows reductions achieved in tons for each pollutant. Table 8 shows the same information for STS Crane 8.

Table 7 RTG Crane 8 – Estimated Actual Emission Reductions during Six Month Post-installation Evaluation

Month	**Minutes Operated**	**PM reduction (tons)**	**VOC reduction (tons)**	**CO reduction (tons)**
April	8745	0.0007	0.0019	0.0270
May	7250	0.0006	0.0015	0.0224
June	4840	0.0004	0.0010	0.0150
July	9120	0.0008	0.0019	0.0282
August	5580	0.0005	0.0012	0.0173
Sept.	11,005	0.0009	0.0023	0.0340
TOTAL (6 month)	**46,540**	**0.0039**	**0.0099**	**0.1439**

[9] PM = particulate matter, HC = hydrocarbons, VOC = volatile organic compounds and CO = carbon monoxide. MPA wants to reduce VOCs, but the model estimates THCs which include methane and ethane as well as VOCs. Assuming that the contributions of methane and ethane in THCs are negligible, VOCs are approximately equal to THCs. Expected emission reductions provided by the DOC provider, Universal Emission Technologies.

Table 8 STS Crane 8 – Estimated Actual Emission Reductions during Six Month Post-installation Evaluation

Month	Minutes Operated	PM reduction (tons)	VOC reduction (tons)	CO reduction (tons)
April	4680	0.0004	0.0018	0.0062
May	2985	0.0002	0.0011	0.0038
June	4030	0.0003	0.0015	0.0051
July	5275	0.0004	0.0020	0.0067
August	4475	0.0003	0.0017	0.0057
Sept.	2890	0.0002	0.0011	0.0037
TOTAL (6 month)	**24,335**	**0.0019**	**0.0091**	**0.0313**

For both cranes, the estimated actual emission reductions in the first six months of operation after the DOC installation are less than half of the annual emission reductions predicted using 2006 operations. Future emission reductions will be proportional to hours of operation.

Outcome 2: *Downtime on the two cranes, pre- and post-installation, was evaluated for six months following installation; no downtime incidents were caused by installation or operation of the DOCs.*

For six months after DOC installation (April – September 2008), MPA monitored downtime for the two cranes. Table 9 below shows the results:

Table 9 Downtime incidents for the Ship-to-Shore and Rubber-Tired Gantry Cranes

	STS Crane 8		**RTG Crane 8**	
Month	Downtime (minutes)	Cause	Downtime (minutes)	Cause
April	120	Diesel issue	0	
May	5	Hoist problem	15	Spreader
June	0		0	
July	35	Hoist issue	0	
August	0		0	
September	0		0	

During more than 405 hours of operation during the six month evaluation period, STS Crane 8 had three downtime incidents, none of which was caused by the DOC installation or operation. RTG Crane 8 operated for more than 775 hours during the same period with one downtime incident, which was also not caused by the DOC installation or operation.

Outcome 3: *The DOCs were not a cause of crane engine breakdowns based on six months of post-installation data*.

The MPA reported that no engine or crane breakdowns occurred as a result of the DOC installation on either crane.

5.3.4 Insights and Lessons Learned

1) DOC installation on cargo handling cranes is feasible and can reduce emissions of PM, VOC, and CO without compromising operations.

While this two crane retrofit project was small scale, it did demonstrate the feasibility of DOC installation: the two installations went smoothly, did not cause any crane engine breakdowns, and resulted in estimated emission reductions of 0.0058 tons PM, 0.019 tons VOC and 0.1752 tons CO total for the two cranes during the six month post-installation evaluation.

The Port of Baltimore has a total of 21 cranes: 12 RTG and 9 STS cranes that in 2006 had a combined average annual 1244 operating hours. At this level of operation, retrofitting all 21 cranes could reduce the Port's annual PM emissions by 0.7 tons, VOC emissions by 1.46 tons and CO emissions by 9.4 tons. If, as the American Association of Port Authorities (AAPA) expects, the total volume of cargo shipped by water by 2020 is double that of 2001, annual operation of port cranes would likely increase as well, resulting in even greater emission reductions for retrofitted cranes.[10]

2) Successful completion of a small pilot project can result in additional retrofits.

Since completing this project, the Port of Baltimore applied for and was awarded $3.5 million by the EPA under the American Reinvestment and Recovery Act and National Clean Diesel Campaign to implement its Clean Diesel Program. The program includes four diesel emission reduction subprograms, one of which awards grants to owners of Cargo Handling Equipment (*e.g.*, yard tractors and forklifts) to retrofit, repower or replace equipment. In addition to the EPA, the Maryland Port Administration has the following state, local and private sector partners for this program: Maryland Department of the Environment, Maryland Environmental Services, the University of Maryland Environmental Finance Center, the Maryland Motor Truck Association, and the Baltimore Port Alliance.

[10] American Association of Port Authorities website, Port Industry Information, U.S. Port Industry, "What Moves Through Ports." Page 2.
http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=1022&navItemNumber=901

3) Attempt to identify all involved parties and address their concerns at the beginning of the process.

Concerns with Technology Demonstration – MPA initially proposed to retrofit up to 12 RTG cranes and up to seven STS cranes, but their operations staff was concerned about committing that much equipment to this project. After internal MPA discussion their operations staff agreed to participate in the project, but only at the significantly reduced equipment commitment of one of each type of crane. While they were eager to see emission reductions, they moved conservatively in project implementation. Breaking new ground, especially when down time by the cranes has direct negative economic impacts, was a risk for the Port.

D) Projects can be delayed by key staff changes and numerous approvals required of award conditions.

It took significant time to work through the various layers of authorization needed from the MPA. While this ultimately produced a working agreement, it delayed final signoff of the subgrant and project implementation. MPA received the original draft grant package in June of 2007 and a final fully executed agreement was not signed until January 11, 2008. MPA had concerns about various components of the agreement, which were resolved. However, as the package was circulated for internal signoff, other issues arose. Again these were resolved, but each round of review took additional time. A major factor that contributed to this slow review process was the loss of MPA's lead for the project in September of 2007.

6 Data Collection and Management

To ensure proper data collection and management MARAMA worked with the project leads to develop Quality Assurance Plans (QAPP) for each project. As summarized below, these plans detailed what data was collected, its purpose, key staff and procedures for addressing any data quality issues.

6.1 Data Collection

The following types of data were collected during this project:

Pittsburgh:

- Tracked three vehicles via existing maintenance tests already performed.
- Secured reports for each tracked vehicle prior to installation of DPF.
- Secured reports for each tracked vehicle post installation at 1 month, 3 months and 6 months.
- Also tracked installation of the units: how long it took, how long vehicle out of use.

Philadelphia:

- Tracked six vehicles via the weekly exercise/testing already performed.
- Secured reports for each tracked vehicle prior to installation of DOC.
- Secured reports for each tracked vehicle post installation at 1 month, 3 months and 6 months.
- Also tracked installation of the units: how long it took, how long vehicle out of use.

Baltimore:

- Measured emission reductions by comparing pre-installation to post-installation modeling for the two cranes.
- Evaluated downtime on the two cranes, pre and post installation, for six months following installation and documented downtime.

6.2 Data Management

A key element of the QAPP was maintaining written documentation of activities associated with assessing the effect of the retrofits on waste hauler, fire truck and crane operations.

The City of Pittsburgh, Philadelphia Fire Department and MPA submitted data from each vehicle/crane to MARAMA. MARAMA relied on this information to create this final report. The draft of this report prepared by MARAMA was reviewed by project partners and revised in response to their comments.

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