



INTEGRATION

Air Pollutant Reduction Strategies in Clean Air Plans and Their Effect on Greenhouse Gases

Introduction

Many strategies to reduce emissions under Port clean air plans also affect emissions of greenhouse gases (GHGs). Often, the effect is to decrease the amount of GHGs emitted in addition to reducing air pollutant emissions. These are referred to as strategies that have “co-benefits.” In some cases, however, clean-air strategies may result in an increase to GHGs, either directly from the operation, or indirectly through increased energy or material use – a “co-disbenefit.” This section of the toolbox describes general circumstances leading to co-benefits and disbenefits to GHG emissions that arise from implementation of air pollution reduction strategies.

Because they are more common, and desirable, this section focuses on co-benefits. It begins with a general discussion of circumstances leading to co-benefits and follows with a description of four general clean air strategies that also have distinct GHG benefits. Brief discussions of co-disbenefits and cases where benefits may be uncertain are included in some of the co-benefit discussions. For a quick-reference, all of the strategies listed in the Air Pollutant Toolbox have been put into a table at the end of this section that succinctly describes their effect, if any, on GHG emissions.

GHG Co-Benefits from Air Pollutant Reduction Strategies

Although air pollution reduction strategies are primarily designed to achieve reductions in diesel emissions and other toxic pollutants that are detrimental to public health, some of these strategies also result in concurrent GHG emission benefits. These strategies should play a key role in achieving the goals for both clean air and climate protection plans. Well understood examples of clean air plan strategies with GHG co-benefits include the use of shore power for hotelling operations and reduced cruising speed for ocean-going vessels. GHG emission benefits associated with these strategies have already been quantified and reported in many ports’ clean air plans. So for a climate protection plan, these same strategies may only need minimal revision to focus on GHG benefits.

Other clean air strategies may provide slight reductions in GHG emissions that may require in-depth investigation to discern if a GHG co-benefit exists. For example, requiring the use of low sulfur fuel in OGV engines and boilers may result in slightly decreased CO₂ emissions because of the higher energy to carbon content of the distillate fuel compared to heavy fuel oil. However, there may also be small increases in fuel-cycle CO₂ emissions because of the increased energy at the refining stage to produce the distillate fuels which may offset the small CO₂ benefits. Discerning GHG effects for measures like these are dependent on local supplies and conditions, requiring significant research and effort to calculate. While the most intensive study may seek to discern such details, strategies being developed with limited resources may find it more prudent to focus on only the measures that have clearest and most significant co-benefits associated with them.



The single most prominent mechanism for co-benefits from clean air plan strategies is reducing fuel consumption. This can be accomplished through a wide variety of methods, most of which fall into one of four categories:

1. Improving the efficiency of the vehicles by requiring purchase of newer/cleaner vehicles
2. Operational improvements that accomplish equivalent tasks using less fuel
3. Substituting a lower or zero-emission fuel for a higher emission one
4. Add-on technologies that reduce vehicle emissions

These four categories are described in the following sections:

Co-Benefit Strategy #1)

Improve Vehicle Efficiency with Newer, Cleaner Vehicles

While most port equipment and vehicles will last ten to twenty years or more before they need to be replaced, a program to hasten the turnover can greatly reduce both air pollutant and GHG emissions. Such programs may achieve their goals through financial incentives for operators or performance mandates, but their underlying motivation is to take advantage of significant technology improvements that have occurred in recent years (and continue to occur) that have resulted in cleaner, more efficient vehicles and equipment. A fleet of newer equipment that is replaced more frequently has significant operational benefits including reduced down-time, but it can be capital-intensive to undertake.

Example: Truck Fleet Modernization

In the United States, requiring that all trucks servicing a port meet national 2007 standards will significantly reduce NO_x and PM because of improved vehicles emissions technologies that are required to be present on all new vehicles of that year. For most ports in the US, the age of trucks bringing containers to and from terminals is greater than 10 years, meaning that post-2007 technologies could reduce emissions of both NO_x and PM by at least 90% for most trucks. Technology that removes NO_x will also reduce N₂O, a potent greenhouse gas. The main GHG reduction, though, comes from these newer trucks being more fuel efficient, translating to an equivalent reduction in CO₂ emissions.



Co-Benefit Strategy #2) Operational Improvements to Reduce Energy Use

Operational improvements are adjustments made to a given system that result in the functions of that system being accomplished with fewer overall emissions. Any system that consists of vehicles or equipment engaged in repeated tasks likely has some potential to increase the efficiency with which those tasks are accomplished. There may also be opportunities to reduce emissions from equipment operating in the system that have minimal effect on the function and efficiency of the system as a whole but greatly reduce pollutants. Looking at a port and its related operations as a series of distinct, interacting systems is common practice in the industry because it allows for optimal coordination of logistics functions. The same approach can also be a robust strategy for identifying opportunities to reduce emissions.

For instance, container terminals are designed to optimize the movement, organization, and dwell of containers as they transition from water-side vessels to land-side transportation. Optimal terminal layouts use the least amount of space and energy to accomplish this transition. Likewise, a terminal optimized for emissions reductions may seek to accomplish the transition with minimal equipment acceleration and deceleration. It also may position electrification infrastructure and choose sub-systems that allow for maximum electrification of operations. Overall, a systems approach to reduce emissions of both air pollutants and GHGs will seek to minimize need for speed and frequent acceleration, minimize distance traveled, and maximize availability of electrification infrastructure. The following example illustrates these concepts applied to vessels as they come to berth.

Example: Vessel Speed Reduction

A Vessel Speed Reduction (VSR) program requires participant vessels to slow down as they approach or depart a port. The primary objective of the VSR program is to reduce emissions from OGVs during vessel transit near a port. When ships slow down, the load on the main engines decreases considerably, compared to the engine load at higher speeds, leading to a decrease in the total energy required to move the ship through the water. This energy reduction in turn reduces emissions for this segment of the transit. Since the load on the main engines affects power demand and fuel consumption, this strategy significantly reduces all pollutants including PM, NO_x, SO_x, and GHG emissions. Though VSR reduces fuel consumption and may save operating costs, these savings and the emission reduction benefits must be balanced by the increase in time it will take for a vessel to reach the port and the costs associated with that delay.



Co-Benefit Strategy #3: Reducing Emissions with Cleaner Energy

Fuel and energy costs are among the highest costs associated with operating vessels and ports. Therefore, discussions about the best energy source have been fundamental to the industry throughout its history. The incentive to reduce energy costs drove the industry to use the cheapest form of fuel available to power the ships that move millions of containers around the world. Up until recently, shore-side equipment around the world was also using some of the least refined fuels that would allow their modern engines to function with sufficient power. Development of targeted regulations are forcing changes to how and when vessels and equipment burn various types of fuel, but significant progress can be made beyond even the most stringent regulations to reduce emissions of both air pollutants and GHGs even further.

In many cases, key air pollutants can be reduced through the use of more refined, desulfurized, or plant-derived fuels. These options often have minimal or unclear effects on GHG emissions because their GHG impacts require investigation of “life-cycle” emissions that can vary significantly with source and process. While these types of fuel may be desirable for other reasons, incorporating them into a climate protection plan should be done with caution. To alleviate this problem, “low-carbon fuel” standards are currently being developed to help rigorously and uniformly identify the potential GHG benefits associated with alternative fuels. Switching to natural gas has the advantage that reductions to both air pollutant and GHG emissions are well understood.

The ideal approach to reducing both air emissions and GHGs with cleaner energy is to switch from hydrocarbon-powered engines to electric power. Even in the worst case scenario, where electricity is sourced from minimally controlled coal-fired power, electric power offers significant benefits over hydrocarbon-based power:

- An electric motor is 2-3 times more efficient, per unit energy, than the equivalent diesel engine and is better suited to operations with frequent high torque requirements
- The coal fired power plant is often located away from population centers while the diesel engine emissions will be emitting closer to where people are concentrated
- Coal fired power plants can reduce their emissions with control equipment while it is expensive and logistically difficult to refit controls on all equipment and vessel engines
- Existing coal sourced power *could* be replaced with clean energy sources in the future. Coal power will likely become more expensive as emerging carbon markets drive up the cost of dirty energy and reduce the cost of clean energy.
- The variety of sources for electricity make for a much more secure power source that will fluctuate less in price from season to season
- Widespread electrification will reduce the potential for oil spills around sensitive waterways and reduce the amount of oil that is introduced to aquatic ecosystems nearby ports through stormwater run-off



Example A: Shore Power for At-Berth OGV Emission Reductions

Based on the above description of the benefits of electrification, the preferred approach for reducing at-berth emissions is shore-power -- transferring the electrical generation needs for OGVs while at berth from onboard diesel-electric generators to the cleaner shore-side power grid, which generates power through regulated/controlled stationary sources. Reducing emissions occurring during dwelling (hotelling) from OGVs while at berth has significant air quality and GHG emission co-benefits because it eliminates almost all of the ships' direct emissions. The shore-power approach is generally best suited for vessels that make multiple calls per year, require a significant power demand while at berth (a function of dwelling load and time at berth), and will continue to call at the same terminal for multiple years. The most common ship types that are good candidates for shore-power are large string-service containerhips, cruise ships, reefer ships, and specially designed crude tankers that have diesel-electric powered pumps.

Shore-power requires extensive infrastructure improvements onboard vessels that would use the system, as well as on the terminal side for supplying the appropriate level of conditioned electrical power. The onboard infrastructure costs are dependent upon the candidate vessel's current configuration, conduit space, and electrical panel space. Despite the broad range of applications and complex technical concerns, working groups and standardization efforts over the last 3 years have led to draft guidelines that have been finalized by the ISO and are now being reviewed by the International Electrotechnical Commission (IEC). The draft report is expected to be publically available by mid-2009.

Example B: Electric Trucks

Trucks that move containers in and around terminals are ubiquitous and generate significant GHG and air pollutant emissions over thousands of hours they each operate in a given year. They represent an ideal target for emissions reductions both for this reason and because they fit within an operational profile that corresponds to the capabilities of current electric vehicle technology. During their short range of travel, they are required to stop and start frequently and idle about 50% of the time. Electric trucks eliminate idle emissions and will regenerate electricity every time the truck stops. On acceleration, electric motors deliver starting power much more efficiently than diesel engines. By switching to electric trucks, not only is the fuel cleaner, but the overall process is much more energy efficient. Prototypes of electric trucks are currently being tested in real-life terminal operations. Several types of hybrid trucks, including a plug-in serial hybrid, have also been announced by manufacturers.



Co-Benefit Strategy #4: Add-on Technology to Increase Efficiency and Reduce Emissions

Any equipment or process that can be added to existing equipment that improves the efficiency of that equipment is likely to result in co-benefit emission reductions. Most add-on equipment for air-quality improvement, however, adds additional engine loads or external power requirements that may lead to a co-disbenefit for GHGs. This is because things like pumps, heaters, and blowers add a parasitic load to an engine that reduces the power available to the engine's primary function. With these additional loads, the engine has to work harder to accomplish the same task and operate these systems or energy has to be introduced externally to power them. In either case, additional load implies additional emissions either directly from the engine or indirectly through power generation.

In some cases, the add-on equipment can make up for inefficiencies in the original system. These inefficiencies could exist because the more efficient technology was not available at the time of the original design or because the capital cost of the technology exceeded the perceived future benefits at the time of purchase. A clear example of this type of add-on technology is a hybridization package for rubber-tired gantry cranes (RTGs). In this case, a basic hybrid system, consisting of electric motor, battery, and control equipment, is refit to the existing RTG and functions to capture power generated by containers as they are lowered. The electric motor, then, is used to supplement power for raising containers and other movements where the diesel engine is less efficient. By recapturing energy and allowing the diesel engine to operate more efficiently, manufacturers have claimed a ~70% reduction in fuel use and related air pollutant and GHG emissions. Increasing interest in electrification and rapid improvement of battery and other energy storage systems will make such hybrid and electrification refit options even more cost effective.

Example: OGV Engine Retrofits

Numerous technologies for reducing vessel engine emissions are currently under development and testing. Much of the focus has been placed on reducing NO_x emissions. Technologies such as selective catalytic reduction (SCR), sea-water scrubbers, dry low NO_x combustion, humid air injection, water fuel emulsion, direct water injection, exhaust gas recirculation, electronic engine controls, etc. can be used for NO_x, but none of these also contribute to significant decreases in GHG emissions. Slide-valves, on the other hand, are relatively new, more efficient types of fuel injectors that reduce emissions of NO_x and PM by minimizing the sac volume in the fuel-valve nozzle tip. Slide-valve technology was introduced in 2002 and today most MAN Diesel main engines are delivered with this technology. Slide-valves can also be retrofit in to existing MAN Diesel main engines. Because slide valves increase the combustion efficiency, they also reduce GHG emissions.



IAPH Tool Box for Port Clean Air Programs

Source Category	General Strategy / Specific Strategy	Co-Benefit	Co-disbenefit or Uncertainty
Ocean Going Vessels			
	<ul style="list-style-type: none"> • Vessel Speed Reduction • Operational Improvements <ul style="list-style-type: none"> Reconfigure Terminals Deepen Channels, Improve Access, On-dock Rail Speed Up Vessel Load/Unload Reduce Vessel Dwell Time Improve Electrical Infrastructure for AMP, Regen Cranes, Etc. • Clean Fuels <ul style="list-style-type: none"> LNG Low-Sulfur Fuel 	<p>GHG Benefit due to reduced overall emissions</p> <p>Likely GHG Benefit, but depends on specific strategy</p> <p>Likely, if overall operation is more efficient or favors lower fuel use</p> <p>Larger ship capacity and direct rail transfers can reduce emissions</p> <p>Likely, due to increased efficiency, less ship hoteling time</p> <p>Not directly, but facilitates strategies that bring co-benefits</p> <p>Depends on fuel</p> <p>Yes, due to lower intrinsic GHG production in combustion</p> <p>Higher energy density may enhance combustion efficiency</p>	<p>Low S fuel processing adds emissions, may not enhance combustion</p>



IAPH Tool Box for Port Clean Air Programs

<ul style="list-style-type: none">• Emission Control Technologies	Depends on Technology.	Adds parasitic load to operate system
Slide Valves	Likely, due to enhanced combustion	
Seawater Scrubbing		
Engine Upgrades, Repower	Likely, due to increased efficiency and enhanced combustion control	
<ul style="list-style-type: none">• Shore Power	GHG Benefit	



IAPH Tool Box for Port Clean Air Programs

Harbor Craft

<ul style="list-style-type: none"> • Engine Replacement with Engines Meeting Cleaner Standards • Clean Fuels <ul style="list-style-type: none"> O₂diesel/Bio-Fuels Low-Sulfur Fuel Emulsified Fuels • Emission Control Technologies • Electrification (including Shore Power and Hybridization) 	<p>Likely GHG benefit, but depends on technology</p> <p>Depends on fuel</p> <p>Benefits possible through life-cycle production, but varies with source</p> <p>Higher energy density may enhance combustion efficiency</p> <p>Controls that improve combustion will reduce GHG emissions</p> <p>GHG Benefit</p>	<p>Biodiesel has higher direct emissions due to lower fuel density.</p> <p>Low S fuel processing adds emissions, may not enhance combustion</p> <p>Can reduce efficiency by reducing overall fuel energy content</p> <p>Treatment retrofits may add load to the engine, decreasing efficiency</p>
--	---	---



Cargo Handling Equipment

	<ul style="list-style-type: none"> • Equipment Replacement with Engines Meeting Cleaner Standards • Clean Fuels <ul style="list-style-type: none"> LNG/CNG O₂diesel/Bio-Fuels Low-Sulfur Fuel Emulsified Fuels • Emission Control Technologies 	<p>GHG Benefit most likely</p> <p>Depends on fuel</p> <p>Yes, due to lower intrinsic GHG production in combustion</p> <p>Benefits possible through life-cycle production, but varies with source</p> <p>Higher energy density may enhance combustion efficiency</p> <p>Technologies that improve engine efficiency will bring co-benefit</p>	<p>Biodiesel has higher direct emissions due to lower fuel density.</p> <p>Low S fuel processing adds emissions, may not enhance combustion</p> <p>Can reduce efficiency by reducing overall fuel energy content</p> <p>DPFs, DOC, SCR, etc. may cause minor additional engine loads</p>
--	--	--	--



IAPH Tool Box for Port Clean Air Programs

Locomotives and Rail			
	<ul style="list-style-type: none"> • Equipment Replacement • Operational Improvements • Clean Fuels • Emission Control Technologies • Idle-Reduction Technologies 	<p>Benefit likely, newer engines are more efficient, hybrids available</p> <p>On-dock rail and reduction of system bottlenecks reduce idling</p> <p>Depends on fuel, See CHE Section</p> <p>Controls that improve combustion will reduce GHG emissions</p> <p>AESS, APUs, DDHS, & Plug-ins shut down main engines during lulls</p>	<p>Important to account for emissions from vehicle disposal or re-use</p> <p>Treatment retrofits may add load to the engine, decreasing efficiency</p>



IAPH Tool Box for Port Clean Air Programs

Construction Equipment			
	<ul style="list-style-type: none"> • Equipment Replacement • Operational Improvements • Clean Fuels • Emission Control Technologies • Idle-Reduction Technologies 	<p>Benefit likely, newer engines are more efficient</p> <p>Benefit likely due to Reduced Operating Times</p> <p>Depends on fuel, See CHE Section</p> <p>Controls that improve combustion will reduce GHG emissions</p> <p>Stop/Start Systems, driver education, and idle reduction yield co-benefits</p>	<p>Important to account for emissions from vehicle disposal or re-use</p> <p>Treatment retrofits may add load to the engine, decreasing efficiency</p>