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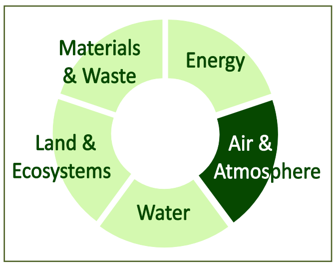
Green Remediation Best Management Practices:
Clean Fuel & Emission Technologies for Site Cleanup

Office of Superfund Remediation and Technology Innovation | Quick Reference Fact Sheet

The U.S. Environmental Protection Agency (EPA) *Principles for Greener Cleanups* outlines the Agency's policy for evaluating and minimizing the environmental "footprint" of activities undertaken when cleaning up a contaminated site.[1] Use of the best management practices (BMPs) recommended in EPA's series of green remediation fact sheets can help project managers and other stakeholders apply the principles on a routine basis, while maintaining the cleanup objectives, ensuring protectiveness of a remedy, and improving its environmental outcome.[2]

Overview

Cleanup of hazardous waste sites can involve significant consumption of gasoline, diesel, or other fuels by mobile and stationary sources. Minimizing emission of air pollutants such as greenhouse gases (GHGs) and particulate matter (PM) resulting from cleanup activities, including those needing fossil or alternative fuel, is a core element of green remediation strategies. Efforts to reduce these emissions during site investigation, remedial or corrective actions, and long-term operation and maintenance (O&M) must meet Clean Air Act (CAA) requirements and state air quality standards as well as requirements of federal and state cleanup programs.



Deployment of green remediation BMPs can help reduce negative impacts of cleanup activities on public health and the environment. The CAA currently specifies nitrogen dioxide (NO_2), ozone, lead, carbon monoxide (CO), sulfur dioxide (SO_2), and PM as the nation's criteria air pollutants. EPA's air quality criteria and national ambient air quality standards (NAAQS) for criteria pollutants must be met in all state implementation plans.

The Agency has studied impacts of six key GHGs in the atmosphere: carbon dioxide (CO_2), methane, nitrous oxide (N_2O), hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Studies found that emissions of these GHGs from new motor vehicles and new motor vehicle engines contribute to GHG pollution threatening public health and welfare.[3]

The Centers for Disease Control and Prevention and EPA have identified numerous risks posed by the direct inhalation of toxic air particles and by wet or dry deposition of acidic pollutants (smog) released during fossil fuel burning.[4]

Health Effects

- Respiratory problems such as coughs or breathing difficulty
- Decreased lung function and increased susceptibility to respiratory infection
- Aggravated asthma and chronic bronchitis
- Arrhythmia and heart attack

Environmental Effects

- Increased smog (and reduced visibility) primarily due to increased ground-level ozone that oxidizes other pollutant gases such as SO_2
- Acidification of lakes and streams
- Nutrient imbalance in coastal waters and river basins
- Nutrient depletion in soil and toxic deposition on soil
- Damage to sensitive forests and farm crops
- Decreased populations and diversity of fish and other aquatic animals and plants
- Corrosion of stone (and man-made materials or structures)

Opportunities for reducing emission of air pollutants from *internal combustion engines in vehicles and stationary sources* used during remedy construction and implementation include maximizing use of:

- Effective *operations and maintenance* to assure efficiency of vehicles and field equipment *[page 1]*
- *Advanced diesel technologies [page 4]*
- *Alternative fuels and fuel additives [page 6]*, and
- *Fuel efficient and alternative vehicles [page 8]*.

Operations and Maintenance

Strategies for reducing unneeded engine use and fuel consumption (and associated air emissions) on a routine basis can be incorporated into site management plans, transportation plans, procurement documents for cleanup services or products, and internal training programs. The strategies focus on engine idle reduction, preventive maintenance to ensure peak operating efficiency, changes in daily routines, and effective fleet management.

Idle Reduction

Long duration idling consumes over one billion gallons of fuel annually in the United States, at a cost of over $2.5 billion. Idling of trucks, alone, is estimated to emit 11 million tons of CO_2, 180,000 tons of nitrogen oxides (NOx), and 5,000 tons of fine PM each year. A single hour of truck engine idling consumes approximately one gallon of fuel and emits approximately 20 pounds of CO_2. Idling also:

- Shortens engine service life
- Poses health and safety risks to vehicle and cab occupants in the event of emission leaks, and
- Increases pollution and noise in nearby communities.

Idling often occurs during site cleanup when loading or unloading materials, operating auxiliary equipment, and cooling or heating the interior of a vehicle or cab. A "no idling" policy can be implemented through corporate policy and onsite signage that displays idling time requirements meeting or exceeding those of state or local agencies.

EPA recommends idle reduction plans that include use of mobile on-board technologies such as:

- Automatic shut-down devices programmed to cut an engine after a predetermined time limit such as three minutes, unless engine operation is needed for intermittent activities such as well drilling
- Direct-fired heaters consuming only small amounts of a vehicle's diesel supply, which will eliminate the need for idling to warm the engine or cab interior
- Auxiliary power units or generators to provide power for certain activities, and
- Battery or alternative powered units to provide heating or air conditioning of cabs.

Other onboard technologies include commercial micro-solar units, which can be tailored to operate equipment traditionally relying on engine idling that provides battery power. An inexpensive 5-watt photovoltaic panel, for example, can be installed below the rear window of a passenger car and connected directly to a vehicle's battery to power local communications or radios.

Solar-powered telecommunications and video display systems can be installed in cab bulkheads, for easy access to site maps without a need for engine idle.

Use of off-board technologies for engine idle reduction can help reduce offsite as well as onsite footprints of a cleanup project. Long-distance haulers of outgoing waste or incoming supplies, for example, can periodically recharge various types of equipment at electrified parking spaces connected to a stationary electrical grid.

Equipment Maintenance

Green remediation strategies rely on maximizing equipment efficiencies of many site activities. Often overlooked efficiencies in fuel conservation can be gained through proper use and maintenance of all vehicles and equipment.

Transporters and field workers should ensure proper inflation and maintenance of tires at all times. Rolling resistance, an indicator of a tire's fuel efficiency, differs from tire to tire. Under-inflated tires increase the rolling resistance of vehicles and, correspondingly, decrease their fuel economy. Tire pressure monitoring systems on new vehicles are not a substitute for proper tire maintenance.

Decisions regarding tire purchases are expected to soon become more informed. In March 2010, the U.S. Department of Transportation (DOT) established test procedures to be used by tire manufacturers in a new consumer information program that generates comparative performance information for tire replacement. When fully implemented, the program will provide point-of-sale and online information (including a rating system) on fuel efficiency, safety, and durability of passenger car tires.

EPA recommends instituting vehicle and equipment maintenance plans that assure:

- Engine tune-ups in accordance with manufacturer recommendations, including optimal frequency
- Absence of dirt or insects in the fuel tank or line
- Tight connections and well lubricated moving parts
- Periodic replacement of filters in air and fuel systems
- Use of the manufacturer's recommended grade of motor oil, which can impact fuel economy up to 2%, and
- Effective operation of equipment ballast to keep wheels from slipping.

Project managers also need to plan periodic "housekeeping" of onsite fuel storage tanks to assure:

- Minimal contact between the fuel and water; every tank should be emptied periodically to remove any water from the tank bottom
- Sampling and testing of any standing water in tanks to determine existence of microbial populations; microbial organisms can degrade fuel (particularly biodiesel) and cause plugging in dispensers and vehicle fuel filters, and
- Addition of biocides for both conventional and biodiesel fuels wherever biological growth in the fuel has been a problem; biocides used with diesel fuels work equally well with biodiesel.

Stationary sources (or point sources) of air pollutants caused by fuel use during cleanup primarily involve the onsite facilities that operate ex situ groundwater, soil, or sediment treatment systems and the onsite equipment used to generate power. Components of many treatment systems may be powered by fuel such as diesel, gasoline, and propane or by electricity generated onsite from fossil fuels.

Facilities typically are required to install state-of-the-art pollution controls to prevent degradation of ambient air quality in areas that have achieved the NAAQS or to install the most protective pollution controls to help an area meet the NAAQS. Particularly in non-attainment areas, hazardous waste site cleanups should minimize negative impacts on minority populations, low-income populations, and sensitive subpopulations.

Pending the issuance of regulations and guidance on stationary diesel engines, EPA encourages project managers to take steps to reduce emissions from non-mobile diesel equipment.[5] Significant fuel and air emission reductions during site cleanup can be gained by properly maintaining and retrofitting diesel-fueled compression engines in equipment such as pumps, blowers, and air compressors or diesel-powered electricity generators. The California Air Resources Board (CARB) list of verified diesel emission control strategies includes control devices applicable to small stationary engines.[6]

Additional opportunities for reducing air emissions from stationary sources include:

- Replacing gasoline engines with ones powered by diesel, which is more powerful and 30-35% more fuel efficient
- Using solar or wind energy resources instead of diesel to generate electricity for operating small equipment such as groundwater circulation pumps, and
- Considering hydrogen and fuel cell generators in emergencies; fuel cell power generators relying on newly developed dry fuel cartridges also can be used in long-term support systems such as telecommunications.

Cleanup equipment should be reassessed on a frequent basis to determine when to replace equipment as a result of age or availability of advanced technologies. Public/private grants or incentives may be available to offset these engine repower (replacement) costs. Frequent reassessment also helps identify opportunities for equipment downsizing to reduce fuel use as site conditions change. Green remediation BMPs specific to remedies involving pump and treat technology, bioremediation, soil vapor extraction or air sparging, and other commonly used cleanup technologies are described in companion fact sheets available from EPA's Office of Solid Waste and Emergency Response (OSWER).[7]

Daily Routines

Transportation plans developed during remedial action planning should evaluate anticipated fuel use and specify strategies to minimize fuel consumption through efficient transportation routes, transfer of only full loads, and selection of appropriately sized vehicles for the task at hand. Using an undersized excavator for contaminated soil removal, for example, may extend cleanup duration and ultimately use more fuel, increase air emissions, and increase project costs. Similarly, use of an oversized truck to transport a small amount of hazardous waste to an offsite disposal facility would result in wasted fuel.

Site management plans should include BMPs to protect land surfaces and manage or minimize waste during cleanup, such as:

- Selecting high-quality equipment lubricants made of biodegradable ingredients such as food-grade grease and canola-based hydraulic fluid; associated purchasing costs are typically higher than petroleum-based oil but lower than synthetic products

Adding retrofitting devices such as a lean NOx catalyst and a diesel particulate filter could reduce these emissions by as much as 25% for NOx and 90% for PM.

Diesel Consumption in an Illustrative Excavation and Soil Amendment Project	Diesel Consumption (gallons)	PM Emission (pounds)[a]	NOx Emission (pounds)[a]	CO_2 Emission (tons)[a]
Removing contaminated soil through use of an earth mover with a 1990 200-hp engine operating for 100 days	6,400	100	1,100	70
Hauling 35,000 yd^3 of excavated soil to an offsite waste disposal facility 300 miles away, by way of 60-yd^3, 425-hp tractor trailers[b]	77,000	770	10,970	850
Importing wood milling and agricultural waste from sources 50 miles away, by way of a 60-yd^3, 300-hp truck[b]	2,400	100	1400	30
Applying 2,000 tons of soil amendments over 20 acres, using a 1990 290-hp, 60-yd^3 dump truck and 1990 170-hp grader	260	8	1	3
Using two medium-duty pickup trucks for site preparation and remedy construction over six months[b]	380	7	170	4
Total diesel consumption and air emissions [a] Diesel Emissions Quantifier; http://cfpub.epa.gov/quantifier/view/welcome.cfm [b] including use of ultra low-sulfur diesel, as required for on-road applications	**86,440 gallons**	**985 pounds**	**13,641 pounds**	**957 tons**

- Cleaning up any spilled fuels immediately to avoid damage to vehicles or engine bodies, inadvertent removal of safety decals, and seepage to soil or water
- Handling all materials used to absorb fuel spills in accordance with health and safety requirements and storing the material in noncombustible containers, and
- Properly disposing or recycling spent materials or liquid waste such as tires, transmission or brake fluids, used oil and filters, wash-rack waste, coolant, and spent solvent.

Efficiencies can be gained through better planning and combining of onsite or offsite trips to reduce overall mileage traveled and by avoiding "cold starts" that use more fuel. Simple changes in driving techniques can also improve fuel economy:

- Avoid rapid acceleration, braking, and excessive speeds, which can lower gas mileage as much as 30% on highways
- Learn the speed limit for optimal economy of specific vehicles; each 5-mph speed increment above 60-mph highway travel can be equivalent to paying an additional $0.24 at the gasoline pump
- Remove unneeded items in a vehicle; each 100 pounds of extra weight can reduce gas mileage up to 2%, and
- Use overdrive gearing to reduce an engine's speed, which in turn reduces engine wear.

Vehicle Fleets

The Energy Independence and Security Act of 2007 requires federal agencies to achieve a 20% reduction in fleet consumption of petroleum and 10% annual increase in fleet consumption of alternative fuel by 2015, as compared to a 2005 baseline. These goals can be achieved through measures such as substitution of cars for light trucks, an increase in vehicle load factors, a decrease in vehicle miles traveled, and a decrease in fleet size. Some states require reductions in fossil fuel use and GHG generation that exceed these federal targets.

Executive Order (E.O.) 13514 of October 2009 requires federal agencies to develop and implement innovative policies and practices for reducing GHG emissions, including GHG planning, reporting, and accounting procedures. EPA recommends that plans for operating vehicle fleets used for site cleanup emulate the fuel conservation strategies of E.O. 13514, which focus on:

- Using low GHG-emitting vehicles such as alternative fuel vehicles
- Optimizing the number of vehicles in a fleet, and
- Reducing the total consumption of petroleum products by fleets (of greater than 20 vehicles) by a minimum of 2% annually through 2020, relative to a 2005 baseline.

E.O. 13514 prohibits federal fleets from acquiring vehicles that are not low GHG-emitting vehicles and uses GHG reduction strategies such as:

- Incorporating incentives to reduce GHG emissions through changes in utility or delivery services, modes of transportation, or other supply chain activities
- Implementing strategies and accommodations for transit, travel, training, and conferencing that actively support lower-carbon commuting and travel by workers, and
- Working with vendors and service contractors to obtain information for tracking and reducing "scope 3" GHG emissions, which apply to sources not owned or directly controlled by an agency but relating to agency activities.

Influential factors affecting GHG emission include hours of equipment use, load factor, fuel consumption, density conversion, emission factors, and engine horsepower/tier level. Tracking and reporting of GHG and criteria pollutants during site cleanup can be simplified by new commercial or government-sponsored software as well as services offered by equipment rental organizations. EPA offers several planning tools, including the:

- Motor Vehicle Emission Simulator (MOVES) to predict gram-per-mile emissions of hydrocarbons (HC), CO, NOx, CO_2, PM, and air toxics under various conditions, and
- NONROAD Model, for estimating air pollution inventories of nonroad engines, equipment, and vehicles.[8]

Requirements for emission reduction and tracking can be integrated into contracts for cleanup services and products, including those applying to long-term O&M. Examples of contracting language currently used in EPA regions are available in EPA's *Green Response and Remedial Action Contracting and Administrative Toolkit*.[9] The Northeast Diesel Collaborative and some state or local government agencies also have developed model contract language to control diesel emissions from construction projects.[10]

Advanced Diesel Technologies

EPA has set specific limits on the amount of air pollutants that can be released into the environment from various engine types. These standards are structured in a four-tiered progression, with each tier being phased in (based on horsepower rating) over several years. The first federal standards (Tier 1) for new nonroad diesel engines were issued in 1994 for engines over 50 hp and phase-in from 1996 to 2000. In 1998, EPA issued Tier 1 standards for vehicles under 50 hp and more stringent standards (Tier 2 and Tier 3) for all equipment with phase-in from 2000 to 2008. Tier 3 standards only apply to engine sizes of 50 to 750 hp.

In 2004, EPA introduced Tier 4 standards to be phased in from 2008 through 2015. These standards require 90% reductions in emissions of PM and NOx. The reductions can be achieved through integration of advanced diesel technologies for engines and exhaust systems, such as oxidation catalysts and particulate filters.

Clean diesel technologies applied to on-road and nonroad vehicles can significantly reduce diesel pollution created during site investigation and remediation. EPA recommends using three primary strategies to reduce diesel emissions:

- Rebuild engines to meet a cleaner emission standard
- Replace (repower) aged engines or entire vehicles with cleaner burning ones, or
- Retrofit vehicles and equipment with technologies to reduce harmful impacts of diesel exhaust, preferably using technologies verified through EPA's National Clean Diesel Campaign[11] or CARB; many EPA regions now recommend or require machinery and equipment to be retrofit with advanced diesel technologies, as part of regional "green cleanup" policies.[12]

Diesel engines tend to last longer than gasoline engines and are commonly retrofit with a form of advanced exhaust aftertreatment to reduce emissions. One form of advanced technology is the *diesel oxidation catalyst* (DOC), which is a flow-through device that oxidizes CO, gaseous hydrocarbons, and some particulate matter. A DOC can:

- Be installed on almost any new or used engine
- Be used with conventional diesel fuel, biodiesel, and other alternative fuels
- Reduce emission of PM by 20-40%, HC by 40-75%, and CO up to 60%, and
- Cost $1,000-$2,000 for a base metal catalyst.

A *diesel particulate matter filter* (DPF) is a device usually made of ceramic that collects particulate matter in an exhaust stream. High temperatures of the exhaust or an added heat source enable particles collected in the filter to oxidize into less harmful components. Passive DPFs rely on exhaust heat to oxidize trapped particles, while active DPFs employ heating devices powered by electricity or fuel burning. A DPF:

- Can be installed on engines with sufficient exhaust temperatures, such as 250-300°C for passive systems or lower temperatures for active systems
- Typically reduces emission of PM by 95%, hydrocarbons by 90%, and CO by 90%
- Requires use of ultra low-sulfur diesel (ULSD)
- May need periodic cleaning to remove accumulated ash or soot, and
- Typically costs more than $8,000, depending on vehicle types, engine sizes, and installation requirements.

A *partial diesel particulate filter* (pDPF) combines beneficial features of a DOC and DPF. One example of a pDPF frequently used in the cleanup industry is the diesel multi-stage filter (DMF). As a flow-through device, a pDPF experiences less pressure drop than a DPF, while its particle oxidation technology often achieves higher removal efficiency than a DOC. Vehicles retrofit with pDPFs must meet minimum exhaust temperatures for the filters to be effective. A pDPF can:

- Be used on most four-stroke engines in on-road applications if minimum temperature criteria are met
- Reduce emissions by amounts generally ranging between those of a DOC and a DPF
- Need less frequent cleaning or replacement
- Eliminate the need for routine cleaning of ash from exhaust systems, and
- Range in cost from $4,000 to $8,000.

Retrofitting of this emergency response vehicle with a DMF was completed in 2008 as part of EPA Region 10's ongoing clean emission initiative.

DOC, DPF, and pDPF equipment often is combined with closed crankcase ventilation technology, which reduces HC and PM emission from an engine crankcase or oil pan.

Another option for advanced retrofitting is *selective catalytic reduction* (SCR), an emerging NOx emission reduction technology that can be combined with filter and catalyst technologies to reduce emissions of other criteria pollutants. SCR involves injection (into an engine exhaust stream) of urea or other chemicals that will react over a catalyst to form ammonia; the ammonia subsequently reacts with NOx to form N_2 and water. SCR technology requires use of ULSD and periodic refilling of the chemical reservoir. Several applications undergoing verification in the Clean Diesel Emerging Technologies Program suggest that SCR technology could reduce NOx by 65%. SCR systems range in cost from $12,000 to $20,000.

Project managers may be able to take advantage of government funding sources to help cover the costs of retrofit installations and downtime. For example, the California Carl Moyer Memorial Air Quality Standards Attainment Program and the Texas Emissions Reduction Plan offer grants for clean diesel programs.[13]

Emission Reductions and Costs of Diesel Retrofit Technologies[14, 15]

	PM	HC	CO	NOx	Cost Range
Diesel oxidation catalyst (DOC)*	20-40%	40-75%	<60%	-	$1,000-$2,000
Diesel particulate matter filter (DPF)*	95%	90%	90%	-	>$8,000
Partial diesel particulate filter (pDPF)	50%	75%	75%	-	$4,000-$8,000
Selective catalytic reduction (SCR)	-	-	-	65%	$12,000-$20,000

*DOC and DPF technologies can be combined in modular configurations for higher performance, at a cost of $8,000-$10,000

Alternative Fuels and Fuel Additives

Transportation fuel can be used in engines of mobile or stationary equipment and machinery needed for cleanup as well as the on-road or nonroad vehicles used for a project. EPA recommends selecting the most suitable type of fuel(s) for site cleanup based on evaluation of the tradeoffs associated with each fuel's: (1) primary energy source, (2) particular production process and inputs, and (3) availability and transport. In general, substitution of conventional gasoline with diesel can reduce GHG emissions up to 30% due to the higher combustion efficiency of diesel.

Ultra Low-Sulfur Diesel

ULSD is a refined, cleaner diesel fuel with a sulfur content of 15 ppm or less that can be used in any diesel engine. Although only new on-road diesel engines are currently required under federal regulations to use ULSD, after December 1, 2010, ULSD also will be required for nonroad engines (when sourced from large refiners and importers) and in all highway sales of diesel fuel. By 2012, it will be required for marine and locomotive engines.[16]

Similar requirements have become or are becoming effective in some states prior to the federal requirements. All diesel imported to or produced in California since 2006, for example, has been ULSD. States also may require ULSD use in particular programs. The Minnesota Pollution Control Agency uses this approach for leaking underground storage tank projects funded by the American Recovery and Reinvestment Act;[17] all off-road diesel-powered vehicles and equipment (both mobile and stationary) with engine ratings of 50 hp or more must use ULSD and be equipped with retrofit emission control devices verified by EPA or CARB.

Advantages of ULSD include:

- Capability for storage in the same tanks as conventional diesel and use of the same fueling systems
- A 5-9% reduction in PM (without any filters), depending on baseline sulfur levels, and up to a 95% reduction in sulfur dioxide levels
- Compatibility to deploy advanced emission control technologies (DOC, DPF, and SCR) on new and retrofitted diesel engines, resulting in additional emission reductions, and
- Reduced engine wear and tear and potential increase in time between manufacturer-specified oil changes, and generally lower maintenance costs.

Project managers can anticipate that remaining transition from conventional diesel to ULSD may slightly increase fuel costs (+$0.05/gallon) but save more than $0.03/gallon in maintenance costs for heavy equipment and vehicles.

All heavy machinery deployed for removal of petroleum HC-contaminated soil at the Terminal 4 portion of the Portland Harbor Superfund Site in Oregon has used ULSD in advance of federal requirements.

Biofuel

Increased use of *biomass-based renewable fuel* can be another opportunity for reducing air polluting emissions. The quantity of fossil fuel in a transportation fuel can be replaced or reduced by including renewable fuel produced from one or more biomass sources. While conventional biofuel is derived from corn starch, advanced biofuel is produced from other renewable biomass such as:

- Cellulose, hemicellulose, or lignin
- Sugar or non-corn starch
- Waste material such as agricultural crop residue
- Planted trees and tree residue
- Animal waste material and animal byproducts
- Slash and pre-commercial thinning of vegetation
- Algae, or
- Separated food waste such as recycled cooking grease.

Renewable fuel also can be derived from degradation of biomass at landfills or sewage waste treatment facilities. This biogas consists mainly of methane rather than ethanol.

Biodiesel blends contain biodiesel mixed with petroleum-based diesel fuel. Blends of 80% petroleum diesel with 20% biodiesel (B20) can be used in unmodified diesel engines. Procedures for converting to use of blends containing higher percentages of biodiesel typically involve cleaning the tanks that were previously used to store conventional diesel.

Preventive maintenance for equipment rigs using higher blends includes more frequent replacement of the fuel filters. Carrying extra filters "on rig" can significantly avoid work disruption and additional field demobilization and remobilization otherwise needed for filter replacement. Some biodiesel blends also could clog a pDPF; manufacturer confirmation for a particular filter's compatibility with a particular blend is recommended.

Using pure biodiesel (B100) may require engine modifications to avoid maintenance and performance problems. Handling and storage precautions also may be needed for B100 and some biodiesel blends, depending on site-specific climates as well as a fuel's petroleum and biomass constituents.[18] Any biodiesel used for blending should meet ASTM D6751 standards.

Substitution of conventional diesel with B100 can:

- Reduce tail pipe emissions up to 47% percent for PM, 67% for unburned HC, and 48% for CO, but increase NOx emissions up to 10%
- Reduce emission of sulfates up to 100% and HC precursors of ozone by 50%
- Help protect sensitive environments in the event of spills, due to their reduced toxicity (less toxic than table salt) and biodegradable nature (faster than sugar), and
- Improve lubricity of some engines, consequently reducing engine wear and tear.

Depending on the selected blend of biodiesel and site-specific conditions, biodiesel use may be impacted by:

- Slight differences in power, torque, and fuel economy
- Freezing points higher than petroleum diesel, which can cause fuel to gel and related pouring difficulty, and
- Potential need for a stability additive when stored for extended periods.

The price of biodiesel may be slightly higher (an average of +$0.08 per gallon) than regular diesel in some regions, depending on the production processes and availability. The National Biodiesel Board maintains maps of biodiesel retailer locations across the United States.[19]

In addition to considering GHG generation during fuel burning, selection of biofuel should account for a fuel's full lifecycle emission impacts. The impacts include both direct and indirect emissions from factors such as land use changes that result from increased biofuel demand. Project managers can learn more about biofuel production, distribution, and use in analytical reports and other materials compiled by EPA's Renewable Fuel Standard Program, including the Agency's annual renewable fuel standards.[20] The U.S. Department of Energy (DOE) Office of Energy Efficiency & Renewable Energy (EERE) also offers online information about selecting biofuels based on constituent biomass.[21]

Availability and selection of renewable biofuels at a site undergoing cleanup may also be driven by state standards. In early 2010, for example, CARB adopted a Low Carbon Fuel Standard to reduce use of carbon-intensive transportation fuels. Regulations supporting implementation of the standard may include fuel specifications for gasoline with 85% ethanol (E85) and biodiesel/renewable diesel produced or sold within the state.

Cleanup project managers can investigate other renewable biofuel options at sites in close proximity to innovative fuel producers. Sites in or near San Francisco, CA, King County, WA, or Philadelphia, PA, for example, can now purchase commercial-grade biodiesel made from recycled cooking grease or other types of "brown grease." Similarly, algae-produced biodiesel may soon be available from government or commercial test facilities in some U.S. regions. Advantages of algae-based fuel are expected to include:

- Avoidance of competition with agricultural land, products, or fresh water use
- A higher yield per acre (over 100 times more) than biodiesel produced from plants or vegetable oils, and
- Potential use of microalgae strains capable of thriving on seawater or treatment plant wastewater.[22]

Gasoline blends with up to 85% ethanol can be used in all flexible fuel vehicles (flex-fuel vehicles, or FFVs). FFVs typically experience no performance loss but operate 20-30% fewer miles per gallon (mpg) when fueled with E85. Information about modifying vehicles to operate on alcohol blends and other alternative fuels is available online from EPA's Office of Transportation and Air Quality (OTAQ).[23]

Profile: Marine Corps Base Camp Pendleton
San Diego County, CA

- *Used clean diesel technology to excavate 120,000 yd^3 of soil contaminated by metals, dioxins/furans, and pesticides*
- *Selected biodiesel blends (primarily B20) to power all field equipment used for excavation*
- *Retrofitted two equipment pieces with DPFs, which reduced particulates by more than 85%*
- *Selected six equipment pieces classified as Tier 3 technology, which reduced PM10 emissions by 63% when compared to Tier 1 technology*
- *Transported 30,380 tons of excavated soil by way of train rather than trucks, an equivalency of removing 1,215 trucks (of 25-ton capacity) off southern California highways*
- *Potentially integrating cleanup activities into Camp Pendleton's shift to clean fuel technology, which includes use of 320 electric vehicles routinely charged at an onsite 8-station charging facility powered by solar resources.*

Fuel Additives

Project planning can also take advantage of many fuel additives available from specialty fuel retailers. Additives can enhance fuel performance and often result in improved fuel economy and lower air emissions. Although many gasoline, diesel, biodiesel, and detergent additives are available, as registered with EPA,[24] certain categories can achieve significant reductions in targeted compound emissions.

Emulsified diesel is a blended mixture of diesel fuel, water, and emulsifying and stabilizing additives that can reduce emissions of PM up to 60% and NOx up to 20%. One example is PuriNOx, a water emulsion alternative fuel verified by EPA in reducing emission of PM by 16-58% and NOx by 9-20% in heavy-duty 2- and 4-cycle engines when used at temperatures higher than 20°F.[11]

Other EPA-verified fuel additives to consider include cetane enhancers, which can reduce NOx emission up to 5%, and platinum-based fuel additives undergoing additional EPA research. Fuel-borne catalysts verified under EPA's Environmental Technologies Verification Program provide another option.[25] More information on verified alternative fuels and additives is available from EPA[26] and CARB.[27]

> *It's Only One SUV !* A 15-mpg passenger vehicle used during site preparation, remedy construction, and five years of remedy operation, traveling a weekly average of 100 miles for onsite and local activities, would consume more than 1,700 gallons of gasoline . . . emitting the equivalent of 15.1 metric tons of CO^2.
>
> *Greenhouse Gas Equivalencies Calculator:* http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Fuel Efficient and Alternative Vehicles

From 1990 through 2006, transportation accounted for 47% of the net increase in total U.S. emissions of GHG. In 2006 alone, mobile sources caused an estimated 28% of the U.S. GHG emission. Mobile sources used during site cleanup typically include:

- Light-duty vehicles, which constitute a category of vehicles with a gross vehicle weight rating (GVWR) below 8,500 pounds, such as passenger cars, sport-utility vehicles (SUVs), light-duty trucks, and medium-duty passenger vehicles
- Heavy-duty commercial vehicles such as cargo vans or light trucks rated above 8,500 pounds GVWR; a truck of this weight class is commonly used during site cleanup as a base platform for equipment such as hollow-stem auger drill rigs, and
- Nonroad mobile sources powered by internal combustion engines but not used for transportation (and subject to other CAA regulations), including construction machinery such as bulldozers, excavators, and forklifts.[28]

> *Each gallon of gasoline consumed during site cleanup results in a 20-pound emission of CO_2.*

Replacement of aged vehicles with newer ones operated by more fuel-efficient engines or relying on alternative fuel can significantly reduce fossil fuel consumption and associated air emissions. Deploying vehicles with higher fuel efficiency for both onsite and offsite activities should also lead to lower fuel costs for site cleanup. Additional savings can be gained by non-government fleet owners when purchasing alternative vehicles qualified for federal or state tax credits.

Alternative vehicles include those using electric, hybrid gasoline/electric, or compressed natural gas fuel systems. When purchasing alternative vehicles, project managers and fleet owners can use life cycle analysis to evaluate the options and optimize decisions. Environmental benefits of converting to electric vehicles (EVs), for example, can be greatly enhanced if the needed electricity is produced from onsite or "upstream" renewable resources.

Decisions on whether, and when, to replace aged vehicles with new models may be affected by upcoming changes in the automotive market. For example, standards proposed by EPA and DOT's National Highway Safety Administration in September 2009, would require all 2012-2016 model light-duty vehicles (which are responsible for nearly 60% of all transportation-related GHG) to meet specific criteria for GHG emissions and fleet average gas mileage.[29]

Electric Vehicles

Increased substitution of conventional vehicles with EVs is one option for integrating alternative vehicles during site cleanups. An EV employs an electric motor powered by an onboard, rechargeable storage battery that is periodically recharged by an external source of electricity. Vehicles powered by electricity offer the advantages of:

- Cleaner operation than conventionally powered vehicles, due to the absence of polluting byproducts generated by internal combustion engines
- A "tank-to-wheels" efficiency about three times higher than the typical 20% conversion efficiency of an internal combustion engine vehicle (due to engine friction, air pumping, and wasted heat)
- Potential incentives offered by government agencies, which can offset higher capital costs
- Quieter operation, and
- Fewer moving parts, with no oil changes.

Project managers can consider use of low-speed neighborhood electric vehicles (NEVs) for local trips or onsite activities such as maintaining field equipment or collecting field data. Full recharge of a NEV can be completed in 2-3 hours when using a 220-volt outlet or in 6-8 hours with a standard 110-volt outlet. Larger all-electric vehicles expected to enter the U.S. market in 2010-2012 are predicted to travel 100-200 miles before needing a recharge.

Hybrid Vehicles

Another option is to substitute conventional vehicles with hybrid vehicles. A hybrid vehicle uses two or more distinct sources of power. The most common is a hybrid electric vehicle that employs an internal combustion engine and one or more electric motors. Hybrid vehicles offer the advantages of:

- Regenerative braking that activates drivetrain resistance, causing the wheels to slow down; in return, energy from the wheels turns the motor (which functions as a generator) to convert energy normally wasted during coasting and braking into electricity, which is stored in a battery until needed by the electric motor
- Electric motor drive/assist that provides additional power for engine acceleration, allowing a smaller, more efficient engine to be used, and
- Automatic start/shutoff systems programmed to cut an engine when a vehicle comes to a stop and restart it when the accelerator is pressed; this feature prevents wasted energy from idling.

Plug-in hybrid electric vehicles (PHEVs) expected to become available by 2012 will rely on battery-supplied electricity to travel longer distances (10-40 miles) before activation of the gas engine. Full recharging of a PHEV battery will take approximately 6 hours when using a 220-volt circuit.

Another innovative technology is used in hydraulic hybrid vehicle (HHVs), which integrate new designs for regenerative braking, optimum engine control, and engine shut-off during "stop and go" operation. HHV demonstration has shown that HHV technology can improve fuel efficiency of light-duty trucks and SUVs up to 70% and reduce their CO_2 emissions by 40%.[30]

*EPA **Clean Air Excellence Awards** merited in 2009 for clean air technology included the:*

- *Caterpillar D7E track-type tractor, which uses an electric drive system to decrease fuel consumption by 10-30% and increase dozing efficiency by 25%, while using fewer mechanical parts and fluids*
- *Kenworth natural gas powered vehicle, which uses a small injection of diesel to more effectively ignite natural gas serving as the primary fuel source (reducing NOx emissions by 27%, PM by 40%, and CO_2 by 24% when compared to diesel fueling)*

Information on other award-winning technologies applicable to vehicles used for cleanup is available at: http://www.epa.gov/air/caaac/recipients.html.

Compressed Natural Gas Vehicles

Compressed natural gas (CNG) is one alternative fuel targeted under the Energy Policy Act. Natural gas vehicles (NGVs) are fueled exclusively with CNG or are capable of natural gas and gasoline fueling (bi-fueling). Many light-duty vehicles can be retrofit to use CNG engines, and natural gas engines and fueling systems are available for heavy-duty vehicles such as waste hauling trucks. Advantages of NGVs include:

- Combustion resulting in lower amounts of harmful emissions such as GHG, NOx, PM, and other pollutants, when compared to gasoline or diesel
- Ready availability of CNG in the fuel distribution market (although retail fueling stations are sparse), and
- Demonstrated success in many industrial or government fleets.

Fuel economy of an NGV is comparable to vehicles powered by conventional gasoline.

EERE offers more information on performance, energy efficient technologies, and comparisons of alternative vehicles.[31] In partnership with EPA, EERE also offers information about fuel economies of the various alternative vehicles.[32]

*EERE's **Alternative Fueling Station Locator** provides online mapping of refueling stations for biodiesel, compressed natural gas, electric, ethanol, and hydrogen fuel.[33]*

Key Resources

Federal or state programs offer tools and information resources to help implement vehicle- and fuel-related BMPs for green cleanups.

- EPA's *National Clean Diesel Campaign* provides information and incentive funding for cost-effective, verified technology to reduce harmful diesel emissions.[34]
- EPA's *SmartWay®* collaborates with the freight industry to reduce air emissions and improve fuel efficiency by selecting certified vehicles, tractors, and trailers.[35]
- The *EPA Environmental Technology Verification* program provides information on verified technologies for products such as mobile source devices, emulsified fuels, and baghouse filtration systems.[36]
- The *California Air Resource Board* offers information on diesel or alternative fuels and verifies diesel emission control products.[37]
- Regional *Clean Diesel Collaboratives*, which are public-private partnerships, aimed at improving air quality through projects using innovations in diesel engines, alternative fuels, and renewable energy technologies. Members of the (now seven) collaboratives work together to leverage funding, share technology, and professional expertise.[38]

A Sampling of Success Measures for Clean Fuel & Emissions

- *Lower rates of fuel consumption as a result of using more efficient vehicles, machinery, and equipment*
- *Increased substitution of fossil fuel with fuel produced from renewable resources*
- *Lower emission of GHG, PM, and other air toxics and associated global warming*
- *Reduced air emissions and fugitive dust impacting local communities*
- *Lower cleanup costs due to reduced fuel consumption and equipment repairs*
- *Beneficial use of industrial or agricultural waste as fuel feedstock*
- *Increased energy independence of sites undergoing cleanup*
- *Reduced loads on fuel production and transport infrastructures*

Clean Fuel & Emissions: Recommended Checklist

Operations and Maintenance

- ✓ Implement an idle reduction plan
- ✓ Assure proper tune-ups of vehicles and equipment and maintenance of fuel storage tanks
- ✓ Establish routines for daily activities such as using biodegradable lubricants, closely managing petroleum-product waste materials, driving efficiently, and inflating tires properly
- ✓ Track fuel consumption and associated emission of GHG and air toxics and set reduction goals

Advanced Diesel Technologies

- ✓ Rebuild engines to meet cleaner emission standards
- ✓ Repower vehicles with new engines or replace aged vehicles with new vehicles
- ✓ Retrofit existing equipment with aftertreatment devices

Alternative Fuels and Fuel Additives

- ✓ Retrofit all existing nonroad equipment to use ULSD
- ✓ Use biodiesel produced from waste or agricultural products with reduced lifecyle GHG emissions
- ✓ Select fuel with additives that can further reduce air emissions

Alternative Vehicles

- ✓ Replace conventional vehicles with electric fuel, hybrid, or compressed natural gas vehicles

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