CLEANUP – CLEAN AIR
DIESEL EMISSIONS & GREENHOUSE GAS REDUCTIONS

Clean Diesel Technologies and Alternative Fuels at Superfund Sites

The goal of Cleanup—Clean Air is to encourage, facilitate, and support diesel emissions and greenhouse gas reductions technologies and practices at Superfund cleanup and redevelopment sites.

What's Inside?

Clean Diesel Technologies and Alternative Fuels

Clean diesel technologies include newer engines and retrofit devices that significantly reduce harmful pollutants, especially particulate matter (PM) and nitrogen oxides (NO_x). While new engines will soon be mandated to be constructed with advanced emission control technologies, older engines run cleaner after retrofitting, replacement, or using cleaner fuels. The two most widely used retrofit technologies are diesel particulate filters (DPFs) and diesel oxidation catalysts (DOCs). Also, cleaner fuels, like ultra-low-sulfur diesel, (ULSD) and alternative fuels, such as biodiesel, emit lower emissions compared to conventional diesel.

Purpose of Cleanup—Clean Air

The Cleanup-Clean Air Initiative (CCA) is focused on encouraging, facilitating and supporting implementation of diesel emissions and greenhouse gas reductions technologies and practices at Superfund cleanup and redevelopment sites. To accomplish the diesel emissions reductions goal, Cleanup – Clean Air:

→ Raises awareness of the potential for diesel emissions reductions from heavy duty vehicles and equipment used at Superfund cleanup and redevelopment sites;

→ Provides coordination and facilitation support for potential Cleanup-Clean Air projects;

→ Creates a forum for information sharing among diesel emissions reductions advocates, and works to leverage significant new resources to expand voluntary diesel emissions mitigation efforts; and

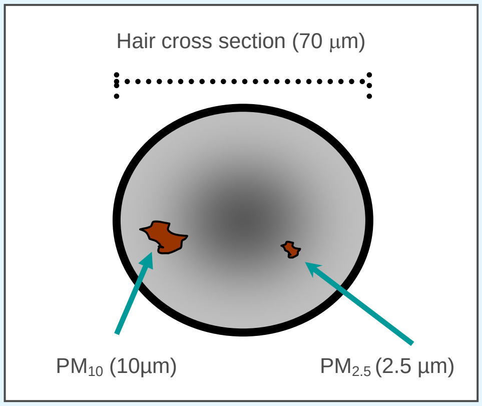
→ Creates momentum for future diesel emission reduction efforts within the Superfund Program and elsewhere.

Importance of Reducing Diesel Emissions

Reducing emissions from diesel engines is one of the most important air quality challenges facing the country. Diesel engines emit a complex mixture of air pollutants including both solid and gaseous materials that have serious human and environmental impacts. The EPA has deemed diesel exhaust as a "likely human carcinogen."[1] The State of California has classified over 40 diesel exhaust pollutants as "toxic air contaminants."[2] Diesel pollution is of concern for site workers and surrounding communities. The pollutants that cause the most concern are particulate matter and nitrogen oxides.

Particulate matter (PM):

PM is the general term for a mixture of solid particles and liquid droplets found in the air.[3] Diesel engines emit particles smaller than 10 micrometers (µm) in diameter and nearly all are under 2.5 µm. Human exposure to $PM_{2.5}$ is especially dangerous because these particles can penetrate deep into the lungs and cause serious problems including asthma, heart attacks, and even premature death.[4]



Size of diesel particulate matter compared with hair cross section. Image courtesy U.S. EPA West Coast Diesel Collaborative[5]

Human and Environmental Health Risks from Diesel Pollutants[6]

PARTICULATE MATTER (PM)

- IRRITATION OF AIRWAYS
- COUGHING
- DIFFICULTY BREATHING
- AGGRAVATED ASTHMA
- DECREASED LUNG FUNCTION
- LUNG AND HEART DISEASE
- ACUTE AND CHRONIC BRONCHITIS
- IRREGULAR HEARTBEAT
- HEART ATTACKS

NITROGEN OXIDES (NO_x)

- ACID RAIN
- CLIMATE CHANGE
- WATER QUALITY DETERIORATION
- VISIBILITY IMPAIRMENTS
- SMOG/PRECURSOR TO GROUND-LEVEL OZONE
- FORMATION OF TOXIC CHEMICALS
- ASTHMA IN CHILDREN
- INCREASES LUNG SUSCEPTIBILITY TO TOXINS AND MICROORGANISMS

In 2002, U.S. off-road diesel construction vehicles emitted about 764,000 tons of NO_x into our air.[7]

Nitrogen Oxides (NO_x):

NO_x is the term for a group of highly reactive gases that contain nitrogen and oxygen in varying amounts. NO_x form when fuel is burned at high temperatures, such as in a diesel engine. NO_x emissions contribute to human health and environmental problems.

Carbon Monoxide (CO) and Sulfur Oxides (SO_x): These pollutants are present in lower amounts in diesel exhaust but may also pose a risk to human health. CO can cause fatigue in healthy people and chest pain in people with heart disease. Exposure to moderate concentrations may cause angina, impaired vision, and reduced brain function. Higher concentrations can cause headaches, dizziness, confusion, nausea, and can even be fatal. SO_x can cause breathing problems for people with asthma. SO_x can also aggravate heart disease and induce respiratory illness and is a major component of ambient PM. In addition, this pollutant is a major component in acid rain formation, which harms ecosystems and degrades buildings and statues.

Front loader retrofitted with DPF. Image courtesy U.S. EPA[8]

Nationwide PM

- **In 2002, roughly 71,000 tons of PM_{10} were emitted from diesel construction equipment. About 95% of it was $PM_{2.5}$.[9]**
- **PM causes about 15,000 premature deaths a year (comparable to the number of deaths from 2nd hand smoke and traffic accidents in California).[10]**
- **Diesel emissions result in approximately 6,000 children's asthma-related emergency room visits every year.[11]**
- **PM causes about 15,000 heart attacks per year.[12]**

Approaches to Reduce Diesel Emissions

RETROFIT engines with EPA or California Air Resources Board verified diesel emission control technologies.

MAINTAIN in accordance with engine manual (e.g., change air filters, check engine timing, fuel injectors and pumps) and keep engines well tuned.

REFUEL with biodiesel, other alternative fuels, or with cleaner fuels such as ultra-low-sulfur diesel (ULSD).

MODIFY OPERATIONS by reducing operating and idle time.

REPLACE existing engines with new cleaner diesel engines, hybrid engines, or engines compatible with alternative fuels.

According to a Union of Concerned Scientists report, in California alone, diesel PM contributes to $21.5 billion per year in healthcare related costs.[13]

Emission Control Technologies

Engines can be retrofitted with many kinds of emissions control devices. This chart provides information on those that are most widely used. For a list of verified diesel emissions control technologies, go to: www.epa.gov/otaq/retrofit/verif-list.htm and www.arb.ca.gov/diesel/verdev/vt/cvt.htm.

	Diesel Particulate Filter (DPF)	Diesel Oxidation Catalyst (DOC)	Selective Catalytic Reduction (SCR)
Technology Description	Wall-flow type filter installed in the exhaust system, much like a muffler, in which PM emissions are trapped. Active DPFs require regular maintenance to regenerate or burn off accumulated PM, when the engine is not in use. Passive DPFs regenerate during engine operation if exhaust temperature requirements are met. (see image on page 2)	Canister-like device containing a honeycomb structure that is installed in the exhaust system. A catalyst oxidizes CO and hydrocarbons as the exhaust flows through, which breaks them down into less harmful components.	Device that injects urea, or some form of ammonia, into the exhaust stream and reacts over a catalyst to reduce NO_x emissions.
Cost per retrofit varies with engine size	$7,000-$10,000[14]	$500-$2,000[15]	$12,000 with DOC $20,000 with DPF[16]
Emissions Reductions	• PM reduced 60%-90% • Hydrocarbons (HC) reduced 60%-90% • Carbon monoxide reduced 60%-90%	• PM reduced 40%-50%[18] • HC reduced 50% • CO reduced 50%	SCR without DOC or DPF • PM reduced 25% • NOx reduced 80% • HC reduced 80%
Benefits	• Can be coupled with an exhaust gas recirculation system to further reduce NO_x (up to 40%) and PM (up to 85%) (MECA) though may not be compatible with currently verified DPFs[17] • Can also be coupled with a SCR to reduce NO_x and PM	• Should not effect fuel economy, shorten engine life nor adversely affect drivability • Less restrictive than DPF because DOCs are less affected by exhaust loading • Works well with older, higher emitting engines • Use of ULSD increases efficiency	• Commonly used in stationary applications. • Often used with a DOC or catalyzed DPF to achieve greater PM reductions
Considerations	• Annual maintenance costs approximately $150-$310[19] • Active DPFs require maintenance to keep filters clean. Passive DPFs oxidize PM via catalysts or high exhaust temperatures • Off-road applications may require active DPFs • Diesel equipment needs to meet minimum temperature requirements specific to individual filter technologies • Slight fuel economy penalty from pressure buildup in the exhaust system; pressure and temperature monitors are necessary • Requires ultra-low-sulfur diesel • 1995 and older engines may overload passive filters but may be compatible with active regeneration systems	• May suffer thermal degradation when exposed to temperatures above 650˚C for prolonged periods of time but these are unlikely conditions during normal operation • Requires normal exhaust maintenance	• Requires periodic refilling of an ammonia or urea tank • Requires low-sulfur diesel (500 ppm sulfur) or ULSD

Steps to Retrofitting a Fleet

- **Step 1** Inventory the fleet for each engine and determine:
  - Type of equipment (backhoe, loader, etc.)
  - Engine model year, make, model, horsepower, displacement
  - Engine family name
  - If a diesel emissions reduction device is already in place. New engines may have one installed.
  - Turbocharged or naturally aspirated
  - Mechanically or electrically controlled
  - If it employs exhaust gas recirculation

IMPORTANT ENGINE INFORMATION
2000 THIS ENGINE CONFORMS TO U.S. EPA AND CALIFORNIA
50S REGULATIONS APPLICABLE TO 2000 MODEL YEAR NEW HEAVY DUTY DIESEL CYCLE ENGINES. THIS ENGINE HAS A PRIMARY INTENDED SERVICE APPLICATIONAS A HEAVY DUTY ENGINE.
FUEL RATE AT ADV. HP 205 . 6 MM3 / STROKE — ADV. HP 500 AT 2100 RPM
INITIAL INJECTION TIMING 14 DEG. BTC — DISP. 12 . 7 LITERS
ENGINE FAMILY YDDXH12.7EGL — MIN. IDLE 600 RPM
MODEL SERIES 60, 12 . 7L — MFG. DATE FEB 2000
UNIT 06R0577657 — CONFORMS TO AUSTRALIAN DESIGN RULE 30

Example of engine emissions label where the family name can be found

- **Step 2** Visit the EPA and CA Air Resources Board (CARB) verification websites to determine compatible retrofit devices.
- **Step 3** Work with vendors to assess the compatibility of your diesel equipment with a retrofit. They may need additional information such as: location for mounting retrofit device (on the muffler or on the side of the vehicle), size of the exhaust system, and if there will be any changes to the exhaust system (sometimes the retrofit device does not replace the muffler).
- **Step 4** Typically, datalogging is required before installing DPFs to determine if the exhaust temperatures are sufficient for passive DPF systems. Passive filters require high exhaust temperatures to burn off the accumulated soot on the filter. Vendors will datalog temperature information for a few days on each engine to see if required temperature minimums are met. Datalogging may cost about $200-$300 for 2-3 days of monitoring.[21] Active DPF systems do not require high exhaust temperatures but do require maintenance.
- Equipment retrofitted with DPFs should always include a device to monitor the increased pressure buildup in the exhaust system. These devices, called back-pressure monitoring systems, may also be installed with DOCs. A warning light in the cab will notify the equipment operator if back-pressure is too high and maintenance is necessary.
- Retrofit installation may take place on-site or at the dealership, depending on the contract with the dealer.
- It is generally not recommended to remove a retrofit device from an engine for which it was designed and use it on another engine. Though this is possible if the engines are similar, it may not be in proper verified use, and may result in damage to the engine or retrofit device.
- DPFs may take 1.5 hours to a full day to install. DOCs usually take 1.5 -4 hours to install. Installations cost from $170 to $500 for each engine for DOCs and DPFs. [22]
- SCRs require installation of a tank for ammonia (or other reagent), as well as the necessary catalyst and associated piping and controls. These retrofits can be much more involved than DPFs or DOCs.

Exhaust Gas Recirculation (EGR)

Engine combustion chambers can reach temperatures greater than 2500° F. At these temperatures, nitrogen and oxygen react to form nitrogen oxides that contribute to smog. An EGR device is used to lower NO_x formation. A valve recirculates exhaust into the air intake stream. These gases displace some of the normal intake, lowering the peak temperature of the combustion process by hundreds of degrees and reduce the amount of oxygen available to form NO_x.[20] However, an EGR system increases PM emissions and are not compatible with many verified retrofit technologies.

Engine Family Name

The Engine Family Name is a 12 digit alphanumerical code designated to engines by the EPA. It identifies engines by make, year, displacement, and emissions characteristics. It is important to get the Engine Family Name for each engine as well as individual pieces of information to facilitate the process of finding the appropriate retrofit device. EPA and CARB verify retrofit technologies for certain engines and other requirements (such as minimum engine temperature). This code can be found on a sticker on the engine itself (see image above). If the Engine Family Name cannot be found, retrofit dealers may be able to determine it from the other engine information provided. Nonroad engines manufactured before 1996 typically do not have an engine family name.

Alternative and Cleaner Fuels

Though retrofits minimize emissions, adopting the use of alternative fuels will also help. Most retrofit technologies require the use of low or ultra-low-sulfur diesel. For information on where these fuels are available, visit http://www.eere.energy.gov/afdc/fuels/stations.html.

	Ultra-Low-Sulfur Diesel[23]	**Biodiesel**[24]	**Natural Gas**[25]	**Emulsified Fuel**[26]
Fuel Description	Ultra-low-sulfur diesel (ULSD) has less than 15 ppm sulfur content. Low-sulfur diesel (LSD) contains less than 500 ppm sulfur content.	Renewable fuel made from animal or vegetable fats. Can be blended with conventional diesel. Usually found in 2% (B2), 20% (B20), and 100% (B100) blends.	Gas consisting mainly of methane. In the forms of compressed natural gas and liquefied natural gas.	Fuel that is mixed with water and injected with additives to lower combustion temperatures which reduces NO_x and PM. Refer to the CARB verification list (page 3) for verified emulsified fuels.
Emissions Reductions	PM 13% NO_x 3% CO 6% HC 13%	B20 PM 10% NO_x* -2% CO 10% HC 21% Sulfates 20% CO_2 15%	PM 90% NO_x 50% CO 90% HC 50-75% CO_2 25%	PM 16%-58% NO_x 9%-20% CO 13% HC -30% to -99%
Cost	• $0.04 -$0.05 more per gallon than low-sulfur diesel	• As of July '07, B20 was the same price as conventional diesel [27]	• ~15%-40% less than gasoline per gallon	• ~$0.20 more per gallon than conventional diesel
Considerations	• Most verified retrofit technologies require the use of LSD or ULSD. In June 2006, CARB mandated the use of ULSD in both on- and off-road vehicles. Nationwide mandates for ULSD use in on-road engines came into effect in 2006 and mandates for LSD use in off-road vehicles came into effect in 2007.	• Biodiesel blends lower than B20 experience insignificant difference in torque, horsepower, and fuel economy compared to conventional diesel. Its greater engine performance is attributed to its higher cetane number. • Using higher biodiesel blends may require changing fuel filters and replacement of rubber compound fuel system components with compatible rubber. • Use biodiesel that meets the ASTM D6751 standard. • Monitor performance in cold weather operation and ensure proper additives are used to prevent gelling.	• Needs more frequent fueling. • Natural gas vehicles cost about $3,500 to $6,000 more than gasoline equivalents.	• May affect horsepower in some applications. • Can be used in any diesel engine.

*NREL and U.S. EPA are conducting further evaluations to determine potential NO_x increase.

Calculate Emissions Reductions

Calculate diesel emissions from cleanup and redevelopment using EPA's online tool, The Quantifier.

http://cfpub.epa.gov/quantifier/

Funding Resources

National Clean Diesel Campaign
EPA program that works to reduce pollution resulting from existing diesel vehicles and equipment by encouraging fleet owners to install pollution-reducing devices on the vehicles and to use cleaner-burning diesel fuel. Listing of potential funding resources:
www.epa.gov/cleandiesel/grantfund.htm

Carl Moyer Clean Engine Incentive Program
Grants for private companies or public agencies operating heavy-duty engines in CA.
www.arb.ca.gov/msprog/moyer/moyer.htm

U.S. DOT Congestion Mitigation Air Quality (CMAQ) Improvement Program
The CMAQ program provides financial assistance to areas striving to attain federal air quality standards. State Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and transit agencies can invest more than $1.6 billion annually until 2009 in projects that reduce criteria air pollutants regulated from transportation-related sources. Clean diesel retrofit projects are eligible for CMAQ consideration.
Contact:
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www.fhwa.dot.gov/environment/cmaqpgs/

EPA Office of Research and Development Consolidated Research/Training
Supports research and development to determine the environmental effects of air quality, drinking water, water quality, hazardous waste, toxic substances, and pesticides. Available to each State, territory and possession, and Tribal nation of the U.S., including the District of Columbia. Eligible entities include public and private State universities and colleges, hospitals, laboratories, State and local government departments, other public or private nonprofit institutions, and in some cases, individuals who have demonstrated unusually high scientific ability.
Contact:
Mark Thomas (202)564-4763 thomas.mark@epa.gov
http://12.46.245.173/pls/portal30/CATALOG.PROGRAM_TEXT_RPT.SHOW?p_arg_names=prog_nbr&p_arg_values=66.511

EPA Air Pollution Control Program Support
Assists State, Tribal, Municipal, Intermunicipal, and Interstate agencies in planning, developing, establishing, improving, and maintaining adequate programs for prevention and control of air pollution or implementation of national primary and secondary air quality standards.
Contact:
William Houck (202)564-1234 houck.william@epa.gov
http://12.46.245.173/pls/portal30/CATALOG.PROGRAM_TEXT_RPT.SHOW?p_arg_names=prog_nbr&p_arg_values=66.001

EPA Pollution Prevention (P2) Grants
Provides matching funds to state and tribal programs to support P2 activities across all environmental media and to develop state programs.
www.epa.gov/oppt/p2home/pubs/grants/ppis/ppis.htm

Information Resources

National Clean Diesel Campaign
www.epa.gov/cleandiesel

West Coast Collaborative
www.westcoastcollaborative.org

Clean Construction USA
www.epa.gov/cleandiesel/construction/

Diesel Technology Forum
www.dieselforum.org

National Biodiesel Board
www.biodiesel.org

Alternative Fuel Station Locater
http://www.eere.energy.gov/afdc/fuels/stations.html

Clean Diesel Fuel Alliance
www.clean-diesel.org

Manufacturers of Emission Controls Association
www.meca.org

PM Air Trends
http://www.epa.gov/airtrends/pm.html

Clean Air Task Force
http://www.catf.us/projects/diesel/

Cleanup-Clean Air Website

www.epa.gov/region9/cleanup-clean-air

♦ Cleanup-Clean Air Pilot Projects ♦ Smart Energy Resources Guide ♦ Factsheets ♦ Cleanup-Clean Air Updates ♦ Cleanup-Clean Air Staff Contact Info

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*All weblinks active as of October 18, 2007.

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