Prevent emissions, then capture them

Air-pollution reduction combines changes in energy use, regulations and control devices. Always identify the pollutant being targeted and explain how the action reduces its release.

1. CONSERVATION AND CLEANER ENERGY

Conservation, efficient equipment and shared transport reduce fuel use. Replacing coal with natural gas lowers many air pollutants but still produces CO_2 and NO_x. Lower-sulfur fuels target sulfur emissions; wind and solar avoid combustion emissions during operation. Compare life-cycle impacts.

2. REGULATORY PRACTICES

Emission standards limit releases from sources; fuel standards can limit pollutant-forming ingredients. Monitoring and enforcement make limits meaningful. Regulations can encourage source reduction and require appropriate controls. Naming a law alone does not explain which emissions fall or why.

3. VAPOR RECOVERY: CAPTURE FUMES DURING REFUELING

As gasoline enters a vehicle tank, it displaces gasoline vapor. A vapor-recovery nozzle captures that vapor instead of letting VOCs escape into outdoor air.



Arrows show the vapor path, not the liquid-fuel path. This is pump-based recovery; some vehicles use onboard vapor capture instead.

The device targets evaporative VOC emissions. It does not treat tailpipe exhaust, and capturing vapors does not eliminate the emissions from later burning the fuel.

Pump-based and onboard vapor capture: US EPA, Gasoline Dispensing Facilities.
Regulatory approaches: US EPA, Regulatory and Guidance Information - Air.
Fuel and energy options: US EPA, Cleaner Fuels and Air Emissions.
Fuel switching and its limitations: US EIA, Natural Gas and the Environment.

Scope: College Board AP Environmental Science CED, Topic 7.6, p. 147.

Catalysts change exhaust chemistry

A three-way catalytic converter reduces carbon monoxide, unburned hydrocarbons and nitrogen oxides in gasoline-engine exhaust. It promotes reactions rather than simply trapping these gases in a filter.

1. THREE POLLUTANT TARGETS

CARBON MONOXIDE

CO is oxidized to carbon dioxide.

$$2\ CO + O_2 \rightarrow 2\ CO_2$$

HYDROCARBONS

Unburned fuel is oxidized to carbon dioxide and water.

$$\text{Hydrocarbons} + O_2 \rightarrow CO_2 + H_2O$$

NITROGEN OXIDES

Nitrogen oxides are reduced to nitrogen gas.

$$2\ NO + 2\ CO \rightarrow N_2 + 2\ CO_2$$

CO and NO equations are balanced examples; hydrocarbon line is a word summary.

2. WHAT THE CATALYST DOES

A catalyst provides a lower-activation-energy reaction pathway without being consumed overall. In a converter, exhaust contacts catalytic surfaces. Correct operating conditions and maintenance matter; different engines may require different combinations of after-treatment devices.

3. LESS HARMFUL IS NOT ZERO IMPACT

Converting CO and hydrocarbons to CO_2 reduces toxic and smog-forming exhaust constituents, but CO_2 remains a greenhouse gas. A catalytic converter is not carbon capture. It also does not replace vapor recovery or a dedicated particulate filter.

Two-way versus three-way converters: US EPA, Aftermarket Catalytic Converters.
How catalysts change reaction pathways: US Department of Energy, Catalysts.

Scope: College Board AP Environmental Science CED, Topic 7.6, p. 147.

Match industrial controls to the job

Coal-burning power plants can use several controls together. An electrostatic precipitator targets particles; a desulfurization scrubber targets sulfur dioxide. One device does not remove every pollutant.

1. ELECTROSTATIC PRECIPITATOR: COLLECT PARTICLES

A. Charge: ions give suspended particles an electrical charge.
B. Collect: the electric field moves them onto collecting surfaces.
C. Remove: accumulated material enters a collection system.
The target is particulate matter such as fly ash, not CO_2 gas. Captured solids still need management.

2. WET SCRUBBER: CONTACT WITH A LIQUID

Exhaust contacts liquid droplets or a liquid film. Depending on the design, particles are captured and soluble or reactive gases are absorbed. For sulfur dioxide control, an alkaline slurry such as limestone reacts with the gas. The liquid or sludge must be treated or managed; droplets must be separated from the exhaust.

3. DRY SCRUBBER: REACT, THEN COLLECT

A dry alkaline sorbent can be injected into exhaust to react with acid gases such as sulfur dioxide. A downstream particulate collector removes solid reaction products and unused reagent. Spray-dry systems introduce slurry but evaporate the water, leaving dry solids. Dry does not mean no waste or no energy use.

4. EXTENSION: USE EMISSION RATES TO CHECK PERFORMANCE

Suppose sulfur dioxide entering a control system is 500 kg/h and the outlet is 50 kg/h, measured under comparable operating conditions.

Removal efficiency = (500 - 50) ÷ 500 × 100% = 90%
The system prevents release of 450 kg/h of SO_2, but 50 kg/h remains. Compare the result with the required target and consider water, energy, reagent and waste costs.

Particle charging and collection: US EPA, Electrostatic Precipitators.
Gas-liquid contact and operating conditions: US EPA, Wet Scrubbers.
Wet, spray-dry and dry systems: US EPA, Flue Gas Desulfurization Fact Sheet.

Scope: College Board AP Environmental Science CED, Topic 7.6, p. 147.