

METR/ENVS 113

Lecture 6: Air Pollution Emissions

SJSU Fall Semester 2020

Module 2: Outdoor Air Pollution

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Outline

- **Air Pollution Emissions: Basic Concepts**
 - Definitions
 - Emissions → Concentrations → Impacts
- **Air Pollution Emissions: Sources & Processes**
 - Stationary vs. Mobile
 - Combustion: Major Anthropogenic Emission Process
 - Others: Fugitive, Evaporative, Dust, Wildfires, etc ...

*Air Pollution Emissions
(Basic Concepts)*

Air Pollution Emissions

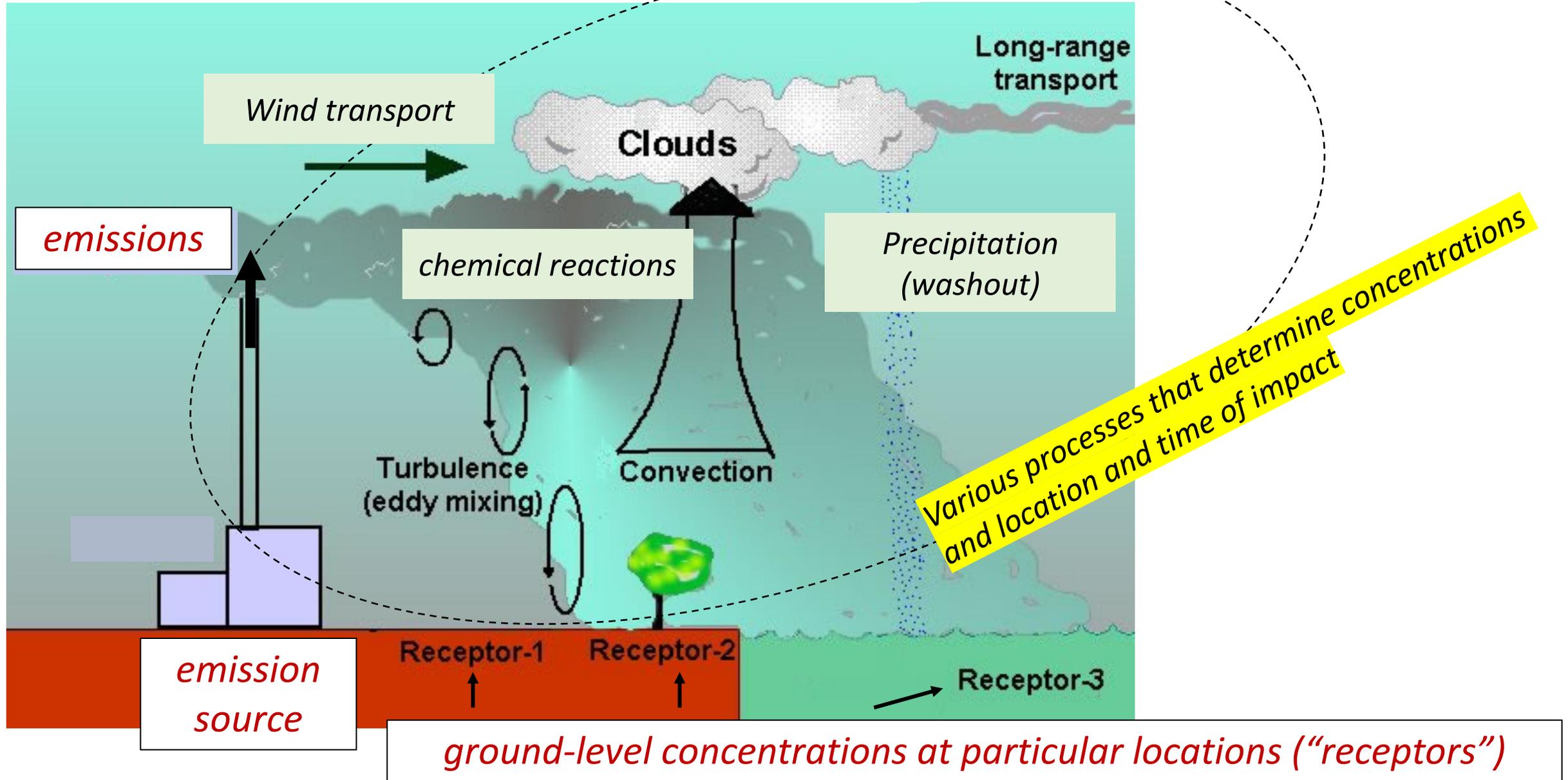
- Emissions: The amount of pollutant coming from a pollution source over some time.
- Annual emissions: tons per year, pounds per year, etc ...
- Other ways: pounds per day, kilograms per day, grams per second, milligrams per second.
- Emissions per unit area per time: mg per square km per day, tons per acre per year
- Care must be taken to understand what a reported emission number means (read the footnotes and other “fine print”).

Air Pollution Concentrations

- Concentration: The amount of pollution per amount of air.
- Parts per Million (ppm), Parts per Billion (ppb)
 - # of molecules of pollutant compound per million (billion) molecules of air
 - Example - 40 ppbv of O₃: “ for every billion molecules of dry air, 40 of them are ozone molecules
 - Applicable to gases
- Mass concentrations
 - mass of pollutant gas or particles per volume of air
 - Example - 150 µg/m³ of airborne dust = “150 micrograms of dust per cubic meter of air”
 - Applicable to both gases and particulates

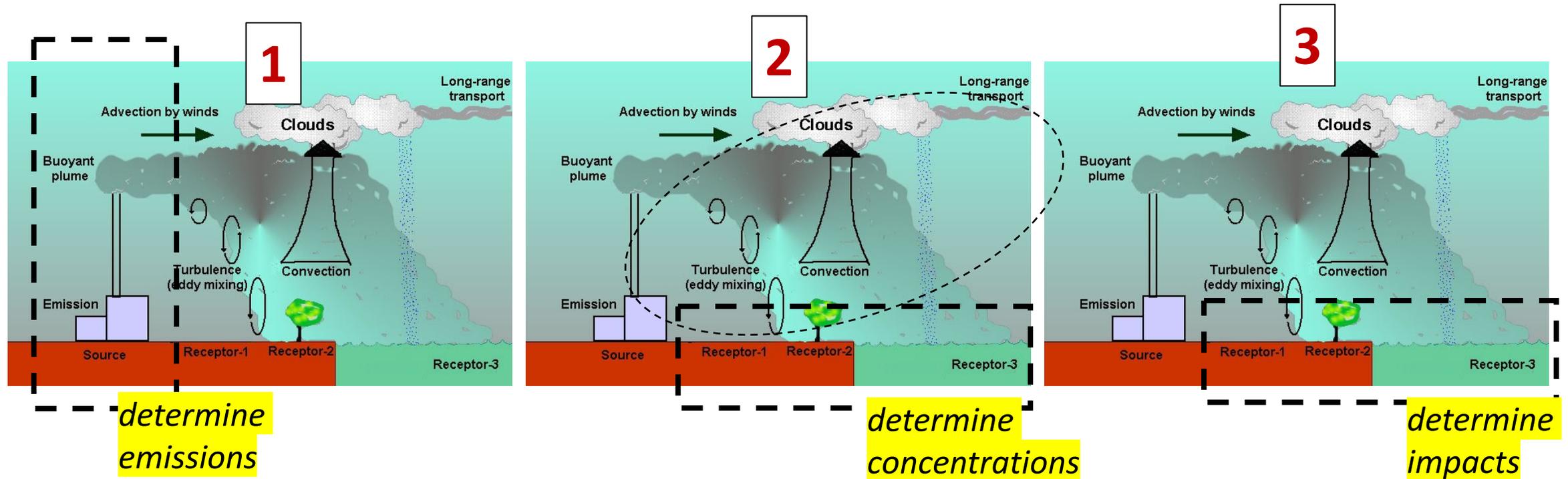
Depiction: Emissions → Concentrations

(Example, pollution emitted from a smokestack)



Addressing Air Pollution Problems: Three Steps

(Emissions -> Concentrations -> Impact Assessment)



1. Determine **emissions** from source(s).
2. Determine **concentrations** at locations of interest resulting from emissions from source.
3. Determine **impact** at locations of interest by comparing concentrations to some relevant standard, threshold or level of concern.

*Air Pollution Emissions
(Sources & Processes)*

Emission Source Categories: “Stationary” versus “Mobile”

- **Stationary Source:** Fixed in Space
 - Major stationary sources are large **factories, refineries, industrial facilities**
- **Mobile Source:** Moving in Space
 - Usually refers to **motor vehicles** (cars, trucks, routine traffic)



A large stationary source



mobile source

Emission Processes

(Several others ... here just a sampling of common processes)

- Combustion
- Fugitive
- Evaporative
- Dust
- Wildfires

Combustion

- Automobile tailpipe emissions.
- An example of a “mobile source”.
- Combustion of gasoline and diesel fuel

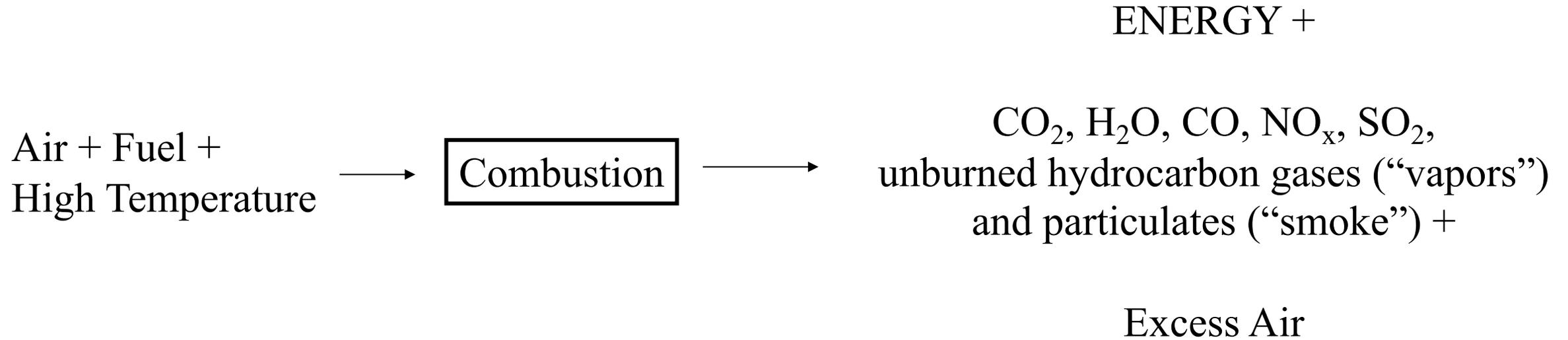


- A major industrial facility.
- An example of a “stationary source”.
- Many industrial boilers, ovens, engines ...
- Fired by combustion of hydrocarbon fuel stocks.

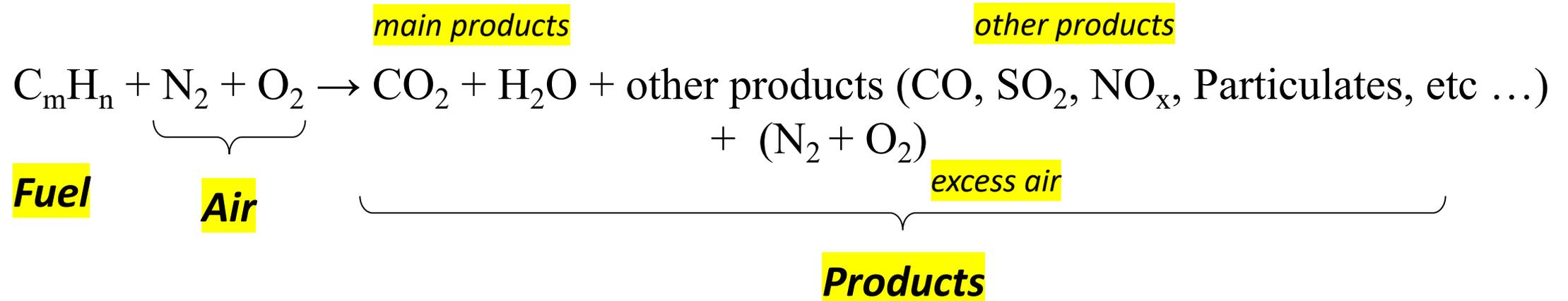
“Combustion” is burning something ...

- For example ...
 - Burning gasoline in automobiles
 - Burning diesel in trucks
 - Burning jet fuel in airplanes
 - Burning coal in power plants
 - Burning natural gas (methane, CH₄) in power plants and residences.
 - Burning wood in homes and controlled burns.
 - Burning crops and other biomass for agriculture.
 - Burning residual oil (bunker fuel) to power ships
 - Burning coke in a refinery.
- Underlined “fuels” above are all carbon-based fuels (hydrocarbon fuels). All except wood & biomass are fossil fuels ... derived from crude oil or natural gas extracted from earth.

Emissions from Combustion (1)



Basic Chemical Reaction



Emissions from Combustion (2)

- Complete Combustion: All carbon and hydrogen in fuel and oxygen in air is reacted to carbon dioxide (CO_2) and water vapor (H_2O). Requires a 14.7 to 1 ratio of air to fuel (“stoichiometric ratio”).
- Incomplete Combustion: Some carbon/hydrogen/oxygen goes to other products (carbon monoxide, various “unburned” hydrocarbon gases, smoke particles, etc ...). Fuel-rich conditions are ratios less than 14.7 to 1. Fuel-lean conditions are ratios greater than 14.7 to 1.
- Carbon based air pollutants (CO, smoke, unburned HCs) tend to favor fuel-rich conditions.
- A small portion of the nitrogen in air is converted to nitrogen oxides ($\text{NO}_x = \text{NO} + \text{NO}_2$). Tends to favor fuel-lean conditions.
- Sulfur in fuel is mainly converted to sulfur dioxide (SO_2). Mostly associated with coal since coal has high sulfur content.

Clean Air vs. Combustion Gas

- Clean Air
 - Nitrogen (75%)
 - Oxygen (20%)
 - Water Vapor (1 – 4%)
 - Carbon Dioxide (0.04%)
- Combustion Gas (Exhaust Gas - released to air after combustion)
 - Nitrogen (70%)
 - Oxygen (0-6%)
 - Water Vapor (~ 10%)
 - Carbon Dioxide (10 – 15%)
 - Other products (trace amounts): CO, SO₂, NO_x, Particulates, unburned HC gases.

Fugitive

- Oil extraction facility
- Gases escape to air during processing.
- An example of “fugitive” emissions.



- An industrial facility
- Gases escape to air during operations.
- Another example of fugitive emissions.

Evaporative



- Gasoline is very evaporative (“volatile”)
- Organic hydrocarbon gasoline vapors readily escape to atmosphere.
- A major source of “**volatile organic compounds**” (VOCs)



- An industrial facility
- Gases escape to air during operations.
- Another example of fugitive emissions.

Volatile Organic Compounds (VOCs)

- Organic **hydrocarbon*** compounds with relatively low boiling points. (50-200 °C)
- They readily evaporate into the air.
- Gasoline and other hydrocarbon fuels
- Indoor Sources: adhesives, solvents, building materials, paints, tobacco smoke, room deodorizers, cooking, carpets, cleaning agents, upholstery
- “BTEX”: Benzene, Toluene, Ethene, Xylene
- Others: formaldehyde, acetone (nail polish remover)
- Alcohols: ethanol, methanol



** A hydrocarbon is chemical compound containing hydrogen (H) and Carbon (C).*

Dust

- Construction / agricultural equipment.
- Kicks up dust to air.
- An example fugitive dust emissions.



Dust can reduce visibility as well

A major "haboob" windblown dust event in Phoenix, AZ



- Windblown dust
- An increasingly important problem in U.S. Southwest
- Requires sustained winds > 10 mph.
- Many health problems associated w windblown dust.

Wildfires



Wildfire smoke

Satellite image of Camp Fire (Northern California, Nov 2018)

