Air pollution II

Air pollution II

- Microscale air pollution
  - Indoor air pollution
- Mesoscale air pollution
  - Smog
- Global air pollution
  - Acid rain
  - Ozone depletion
  - Global warming
- Air pollution control of stationary sources

Indoor air pollution

- Difficult to regulate!
- CO and NO_x from gas ranges, ovens, heaters, and cigarette smoke
- Cigarette smoke also contains toxic compounds including carcinogens
- Bioaerosols: bacteria, viruses, fungi, mites, and pollen
- Radon: emitted from the ground (high in basements)
- Volatile organic compounds
  - ex) formaldehyde: emitted from building materials ("sick building syndrome")
- Heavy metals: emitted from paints

Smog

The Great Smog of 1952, London

http://www.history.com/news/the-killer-fog-that-blanketed-london-60-years-ago

- Smoke + Fog
- 'London-type' smog
  - Occurs when
    - Emission of sulfur-containing compounds is high (→ high SO_x in the atmosphere)
    - Air contains high liquid contents (ex: fog)

    → High concentration of H_2SO_4 in fog droplets in the air
  - Major source of pollutants: burning of coal

Smog

https://www.treehugger.com/cars/smog--los-angeles-doesnt-quite-sting-it-used.html

- 'Los Angeles-type' smog (photochemical smog)
  - Occurs when
    - Emission of NO_x and reactive hydrocarbons is high
    - There is plenty of sunlight

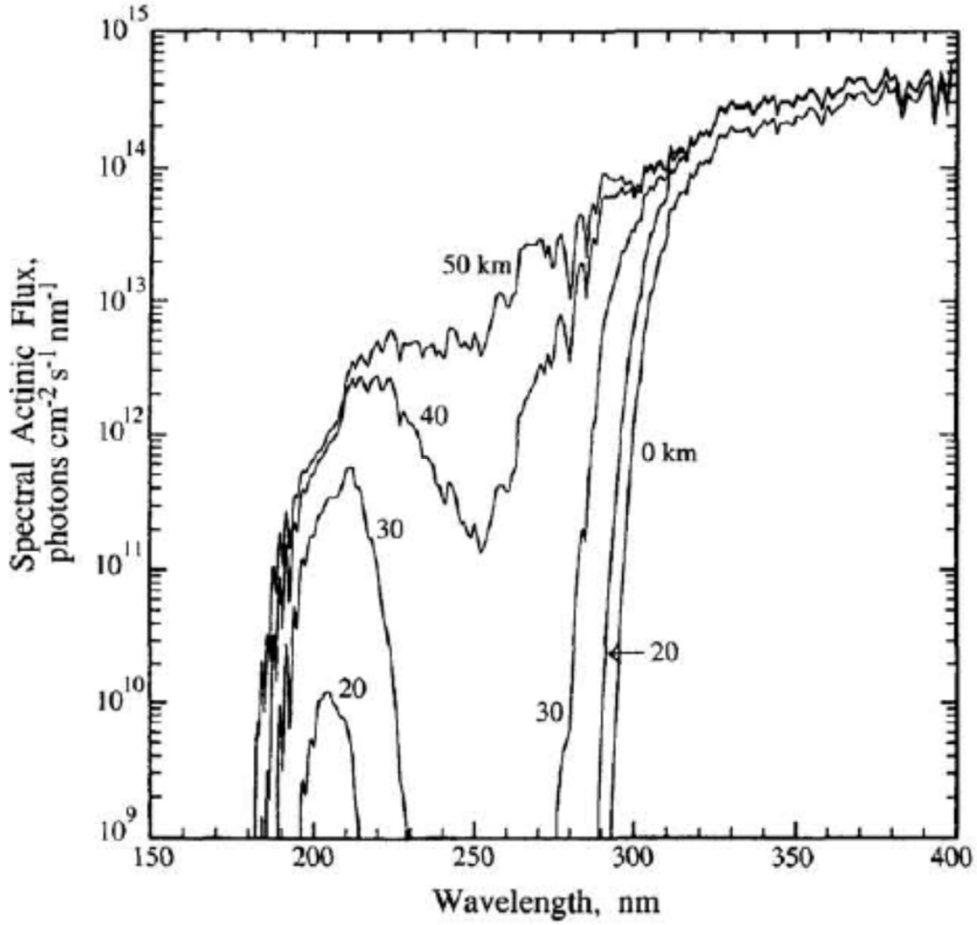
    → NO_x & reactive hydrocarbons undergo photochemical reactions to produce photochemical oxidants
  - Major source of pollutants: automobiles

Acid rain

- SO_2 and NO_x in the air undergo series of reactions to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3)
- pH in natural rain has a pH near 5.6 (why?)
- Rain pH in polluted areas can go below 5, sometimes even close to 2
- Effects: acidification of rivers and lakes (fish deaths), nutrient leaching from soil (plant deaths)

Ozone depletion

- Ozone protects life if it is in the stratosphere
- Ozone layer (20-40 km or up above the ground): absorbs UV light



Formation of ozone layer, UV absorption

- Photoreactions of ozone to absorb UV light

$$O_2 + UV \rightarrow 2O$$

$$O + O_2 + M \rightarrow O_3 + M$$ (*M*: a third molecule)

$$O_3 + UV \rightarrow O_2 + O$$

Ozone depletion by CFCs

- CFCs (chlorofluorocarbons)
  - Good for refrigerants, propellants, and solvents
  - Stable in the troposphere → can reach the stratosphere without break-down
  - Causes ozone depletion
- Ozone destruction mechanism by CFCs

$$CCl_3F + UV \rightarrow CCl_2F + Cl$$

CFCs break down in the stratosphere to produce Cl atoms

$$Cl + O_3 \rightarrow ClO + O_2$$
$$ClO + O \rightarrow Cl + O_2$$

net reaction: $O_3 + O \rightarrow 2O_2$

  - Cl atom acts as a catalyst
  - One CFC molecule can destroy uncountable number of ozone molecules

Efforts to stop ozone depletion

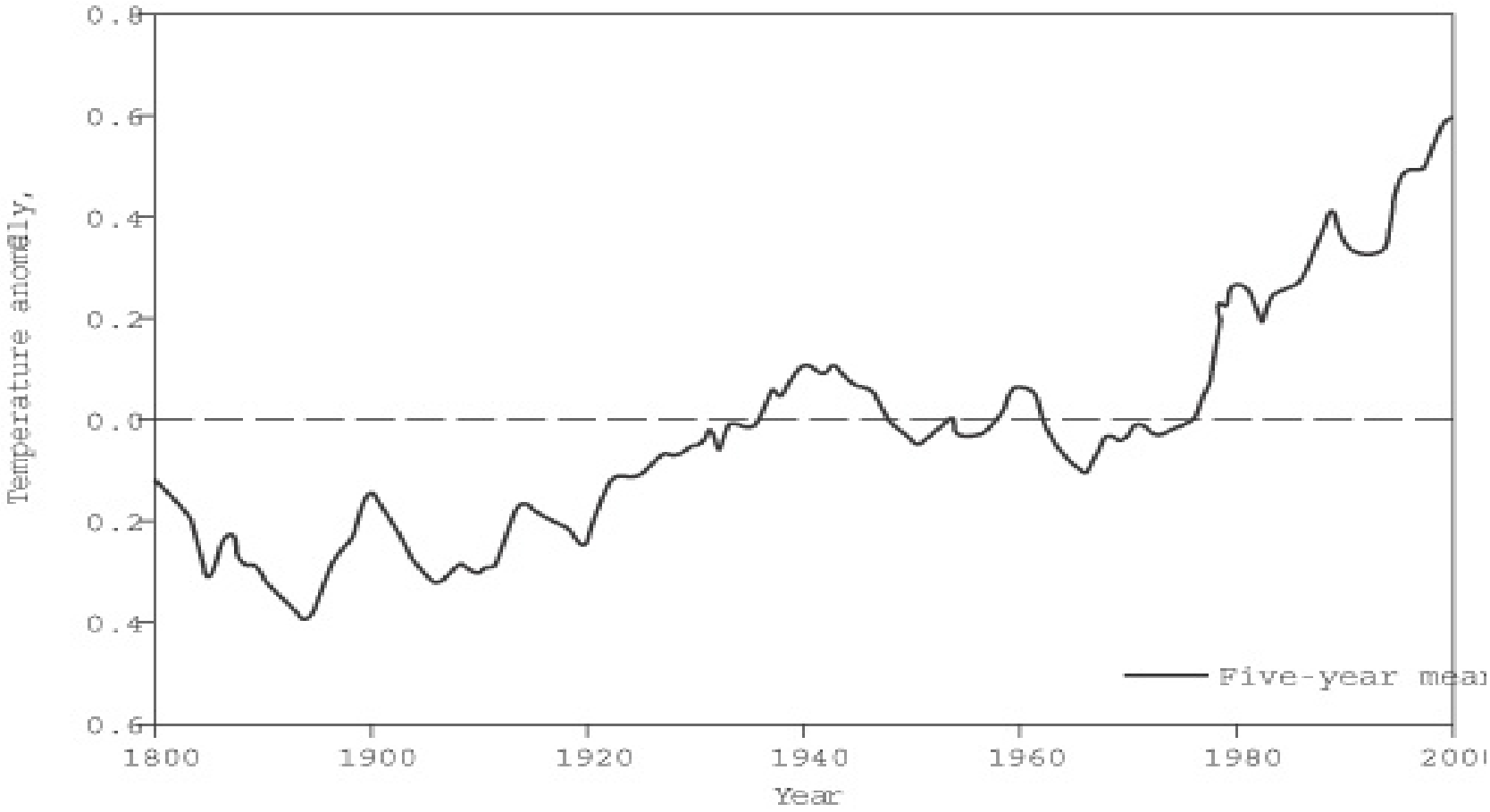
- **Montreal Protocol** on Substances That Deplete the Ozone Layer
  - An international treaty agreed on September 16, 1987
  - Became effective in January 1989
  - Eight revisions: 1990, 1991, 1992, 1993, 1995, 1997, 1999, and 2007
  - Complete phase-out of CFCs

Substitutes for CFCs

- CFC substitutes: hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs)
  - HCFCs are more reactive than CFCs in the troposphere → only small amount reaches the stratosphere (but still has some ozone depletion potential)
  - HFCs do not contain chlorine atoms → no ozone depletion potential
  - Problem: HCFCs and HFCs are greenhouse gases

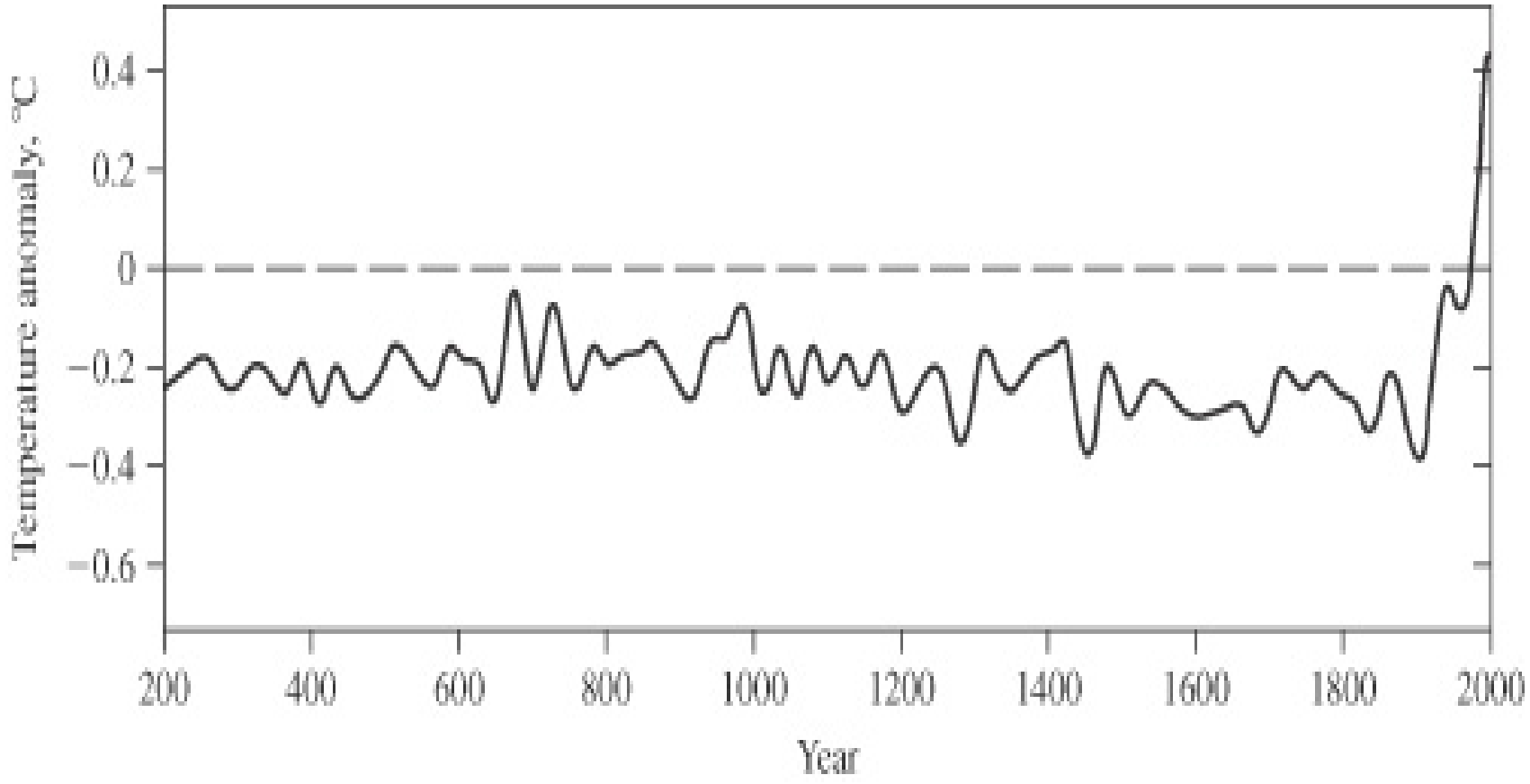
    → Using HCFCs or HFCs is not a permanent solution!

Global warming – an ongoing phenomenon

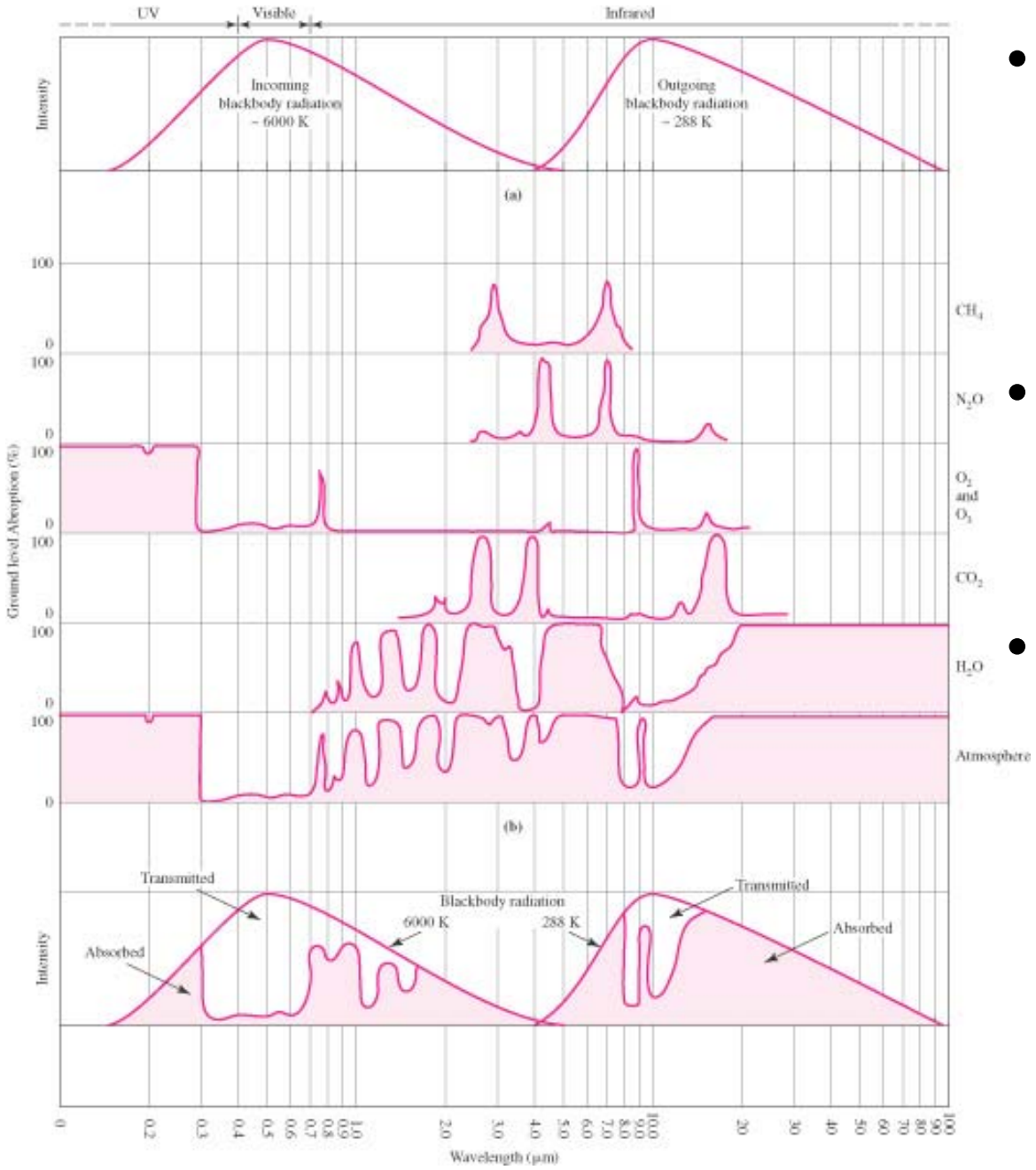


The temperature of the globe is really increasing!

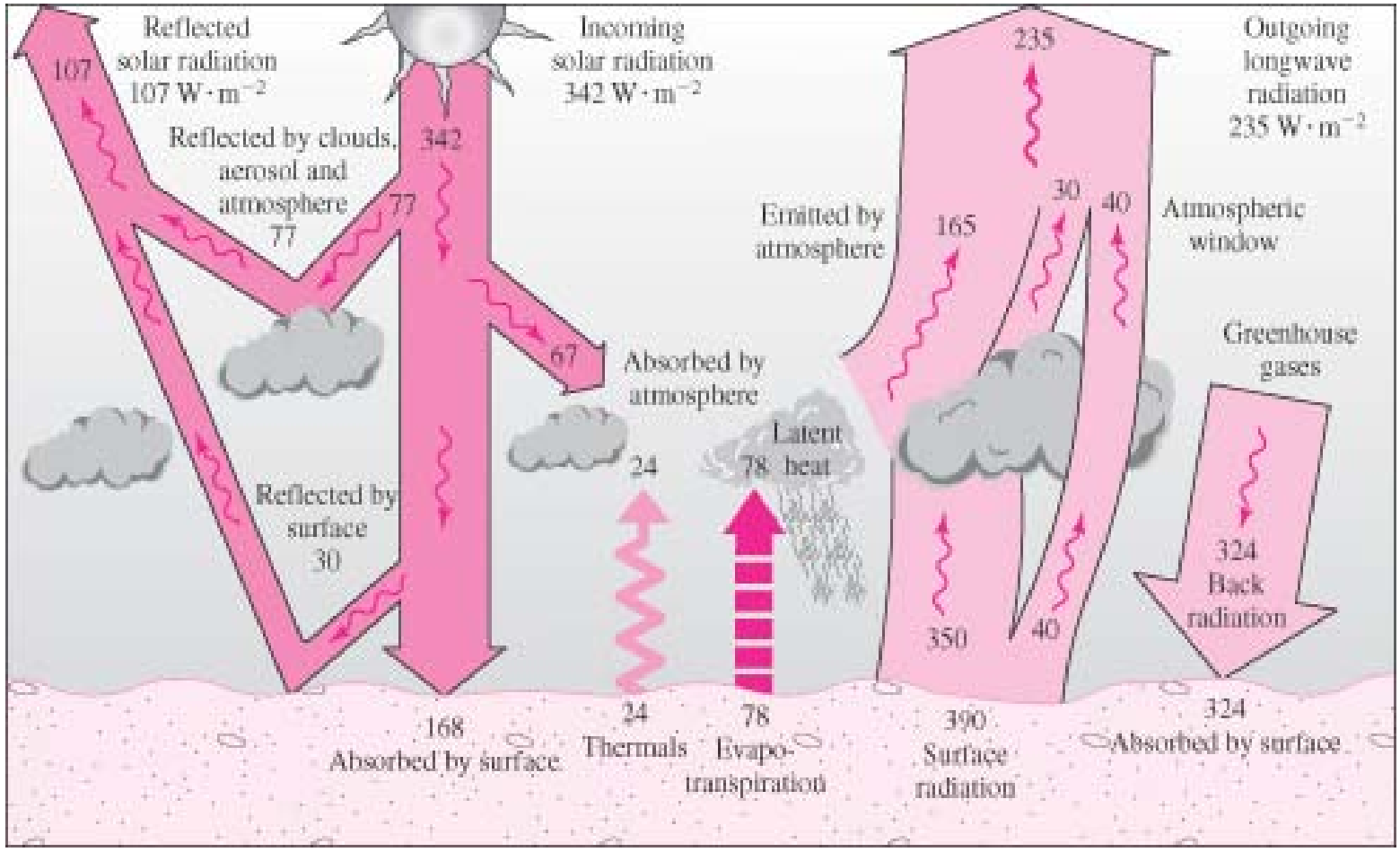
Global warming – an ongoing phenomenon



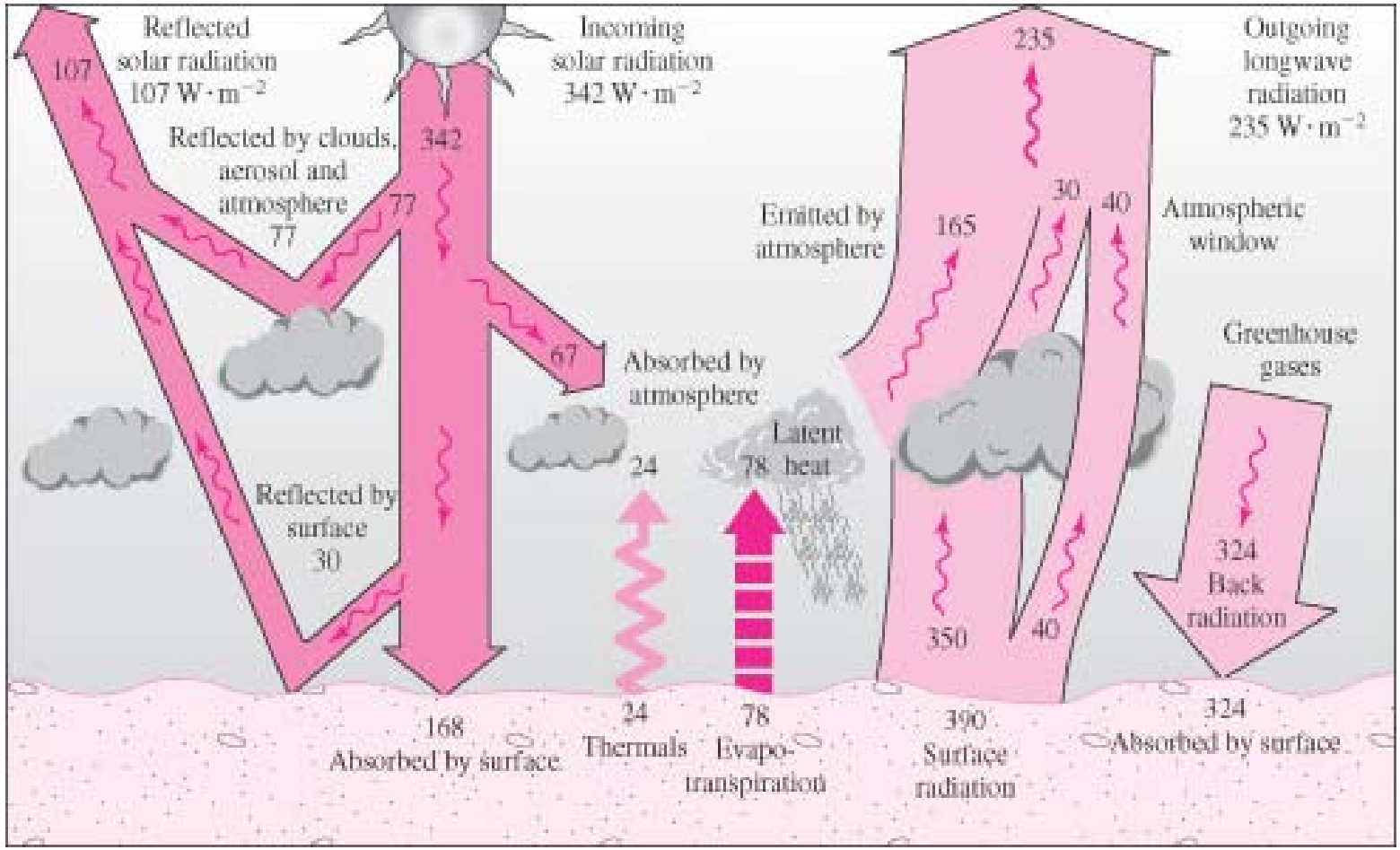
The “hockey stick” graph



- The earth receives short-wave radiation from the Sun
- The Earth's surface emits long-wave radiation
- Some molecules absorb the long-wave radiation → prevent energy to be released out of the Earth



- The greenhouse gases (GHGs) work like the glass on a greenhouse or a blanket
- Maintain the Earth's temperature good for life (without GHGs, the Earth's temperature will be around -17°C)



- 30% increase in the atmospheric CO_2 concentration since 1750
- The increased levels of greenhouse gases changes the radiation balance: greater back radiation → higher surface temperature

Greenhouse gases (GHGs)

- Various GHGs exist, many of them have much higher global warming potential than CO_2
- CO_2 is major because of high atmospheric concentration (but many others (ex: CH_4, N_2O, CFCs) are also of significant concern)

Chemicals	**Lifetime (year)**	**Global warming potential (kg CO_2/kg chemical)**
Carbon dioxide (CO_2)	30-200	1
Methane (CH_4)	12	62
Nitrous oxide (N_2O)	114	275
CFC-12 (CF_2Cl_2)	100	10200
HCFC-22 (CHF_2Cl)	12	4800
Tetrafluoromethane (CF_4)	50000	3900
Sulfur hexafluoride (SF_6)	3200	15100

Efforts to reduce GHG emissions

- Kyoto Protocol
  - Adopted on December 11, 1997
  - Became effective in 2005
  - Targets to reduce GHG emissions in developed countries by 5% compared to 1990 levels during the first commitment period (2008-2012)
  - U.S. did not ratify the protocol

Efforts to reduce GHG emissions

- Kyoto Protocol - amendment
  - Doha amendment (2012)
    - Reduce GHG emissions by 25-40% compared to 1990 levels during the second commitment period (2013-2020)
    - Major CO_2-producing countries (U.S., China, and India) denied to ratify
    - Only 37 countries including EU, Australia, and the Switzerland participated
    - EU has not ratified the amendment yet
    - Korea was not included in Kyoto protocol, but “voluntarily” promised to reduce the GHG emissions

Efforts to reduce GHG emissions

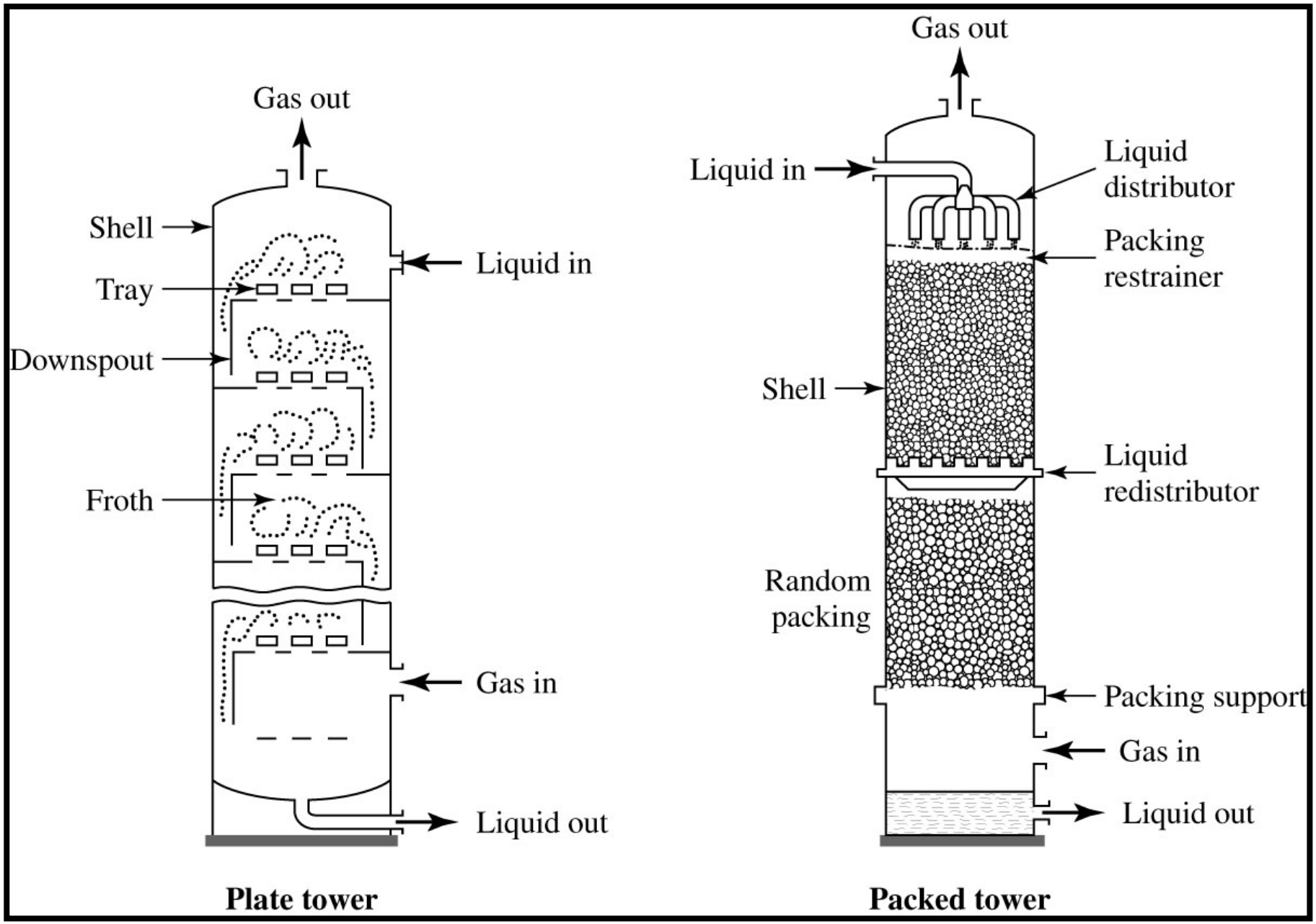
- Paris Agreement (2015)
  - For reduction of GHG emissions after 2020
    - Kyoto Protocol ends in 2020
  - Bottom-up approach (cf: Kyoto Protocol: top-down)
  - Each member country should submit the “Nationally Determined Contributions (NDC)”
  - The NDC should be: “ambitious”, “represent a progression over time”, and “set with the view to achieving the purpose of this Agreement”
  - Korea: submitted the NDC as “achieving the GHG emission in 2030 below 37% of the 2030 BAU value”

**BAU: Business As Usual*

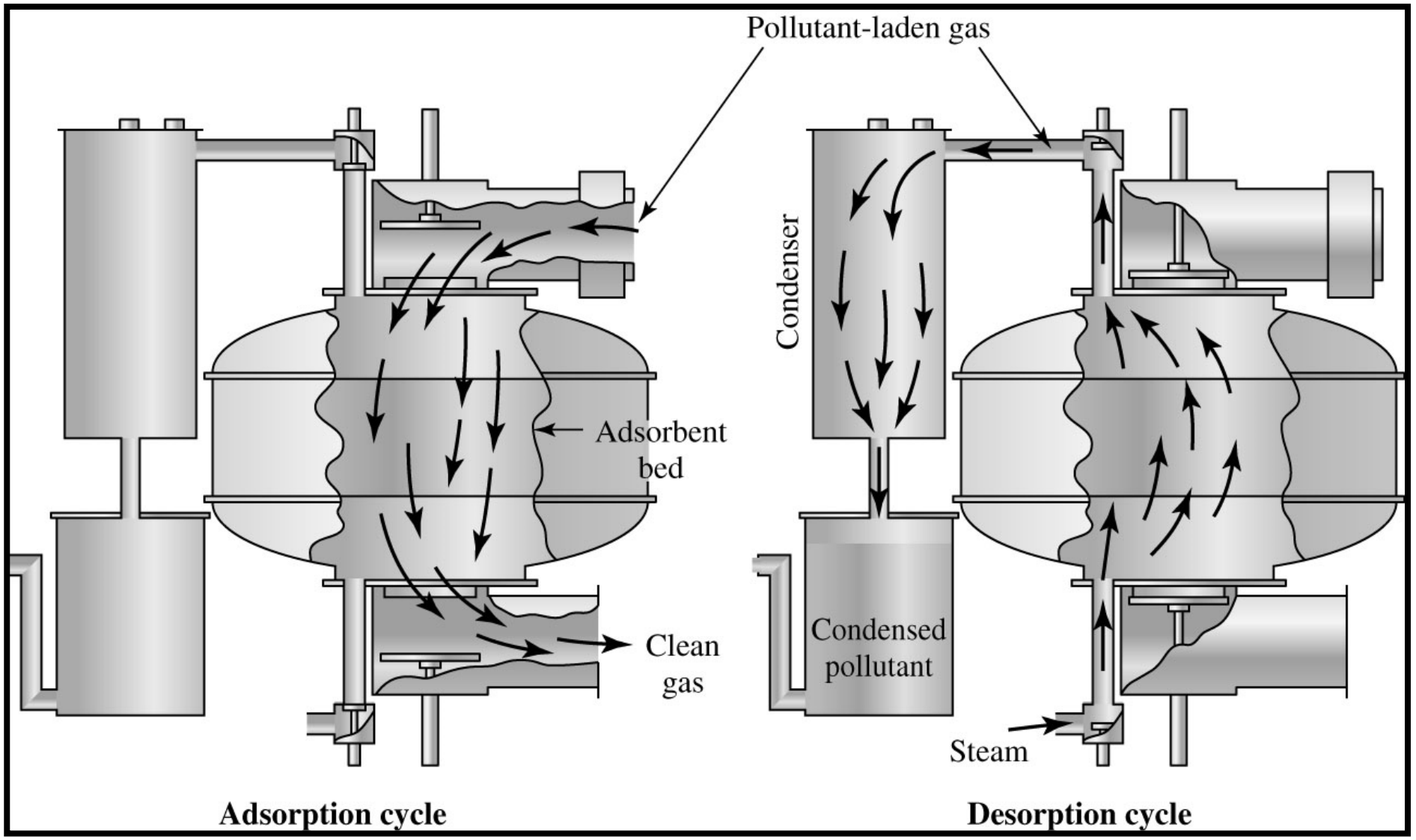
Air pollution control – gaseous pollutants

Common approaches for stationary sources

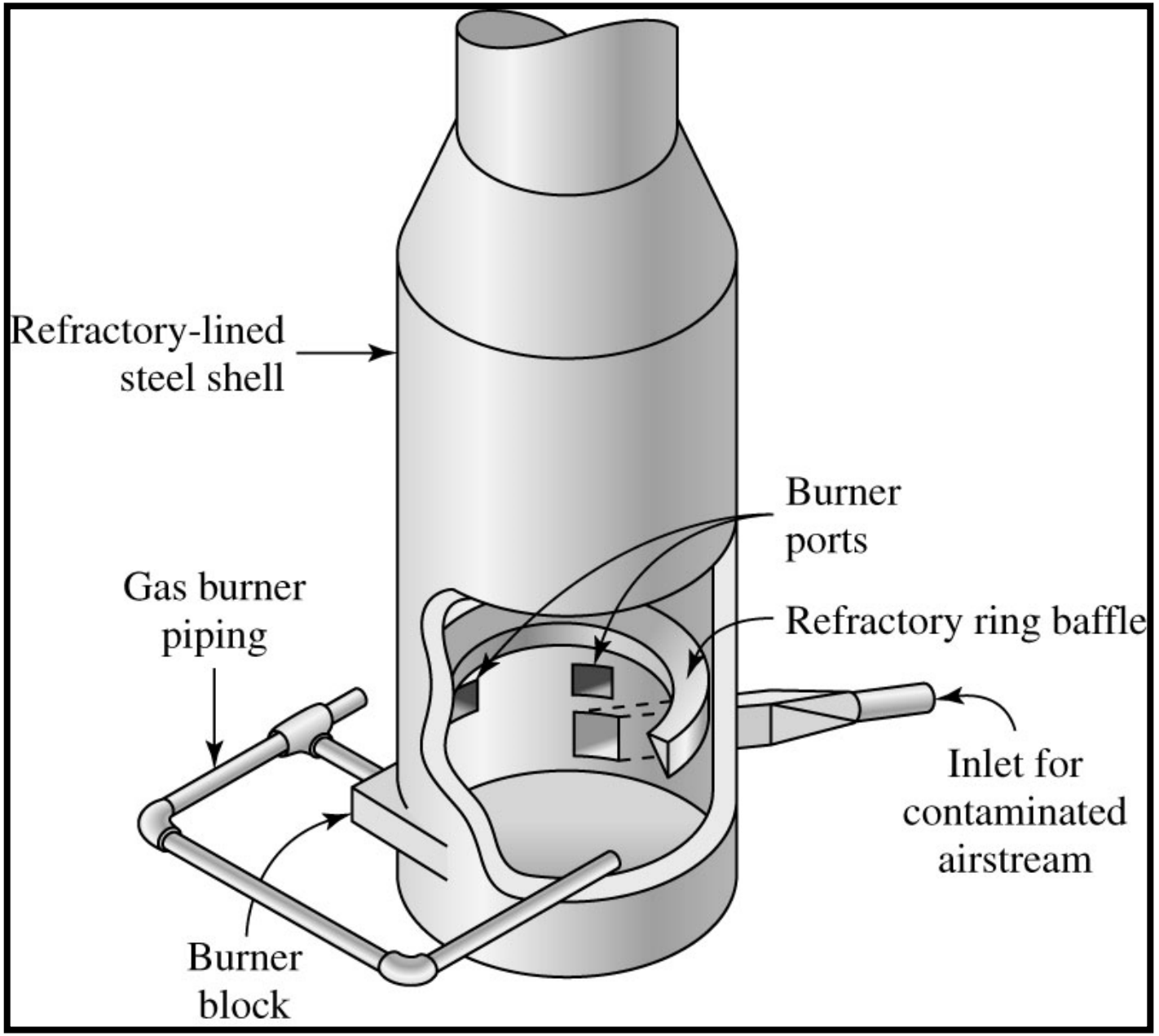
- **Absorption**
  - Dissolution of pollutant gas into a liquid
  - If water is used, only applicable to gases having high water solubility such as NH_3, Cl_2, and SO_2
- **Adsorption**
  - Binding of pollutant gas to a solid
  - Common adsorbents: activated carbon, zeolites, silica gel, and activated aluminum oxide
- **Combustion**
  - Applicable when the pollutant gas can be oxidized to inert gas such as CO_2
  - Can be applied to CO and organic pollutants



Absorption processes



Adsorption processes



Combustion process: direct incinerator

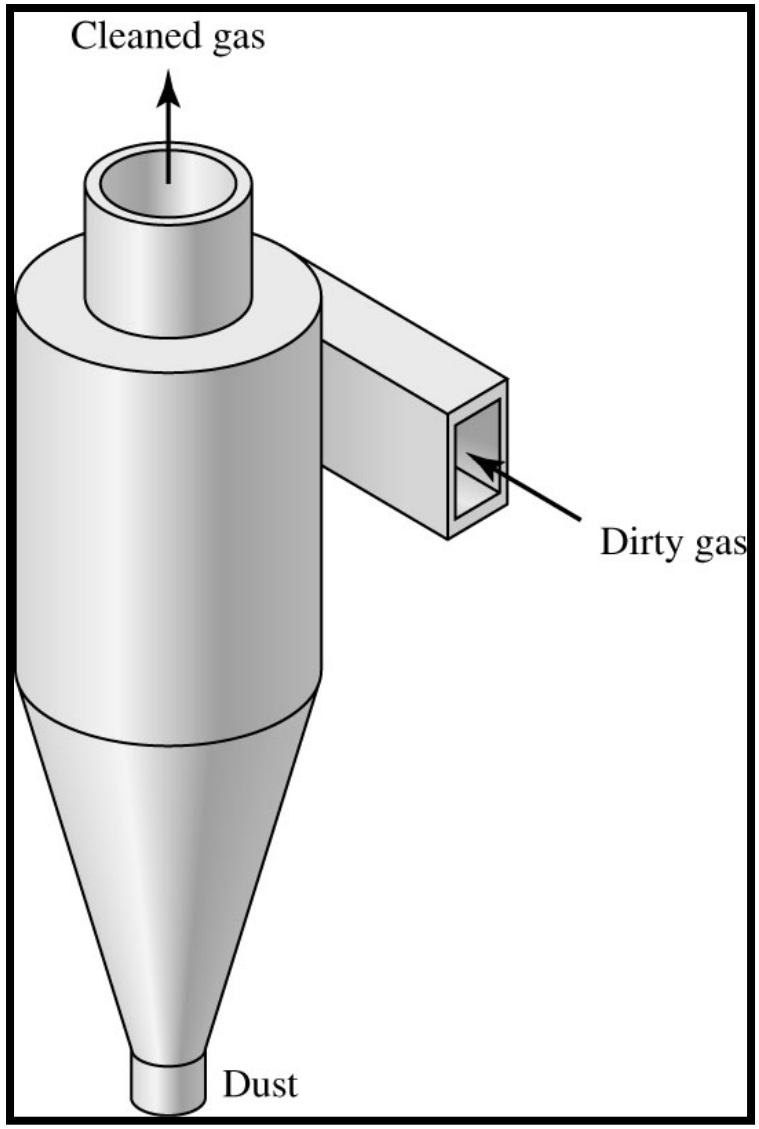
Air pollution control – gaseous pollutants

Common approaches for stationary sources

- **Cyclones**
- **Filters**
- **Liquid scrubbing**
- **Electrostatic precipitation (ESP)**

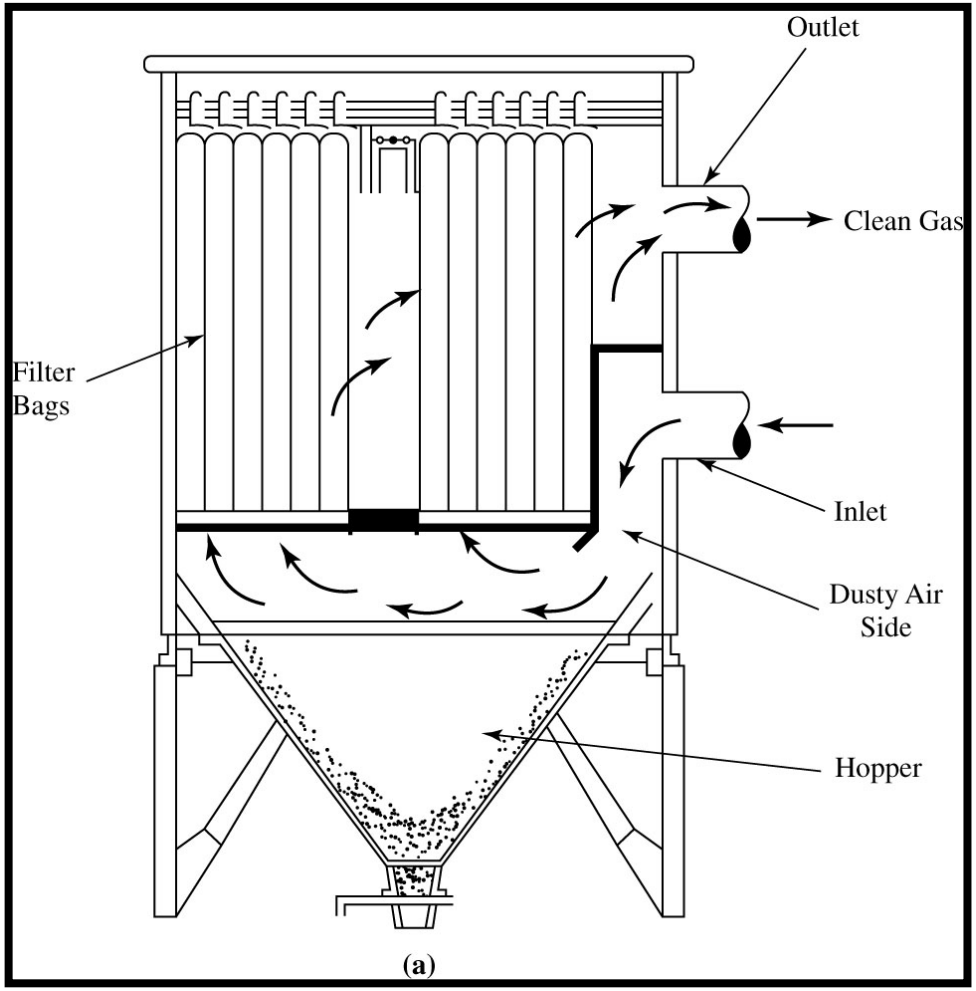
Air pollution control – particulates

- Cyclones: good for large particles (>10 µm)



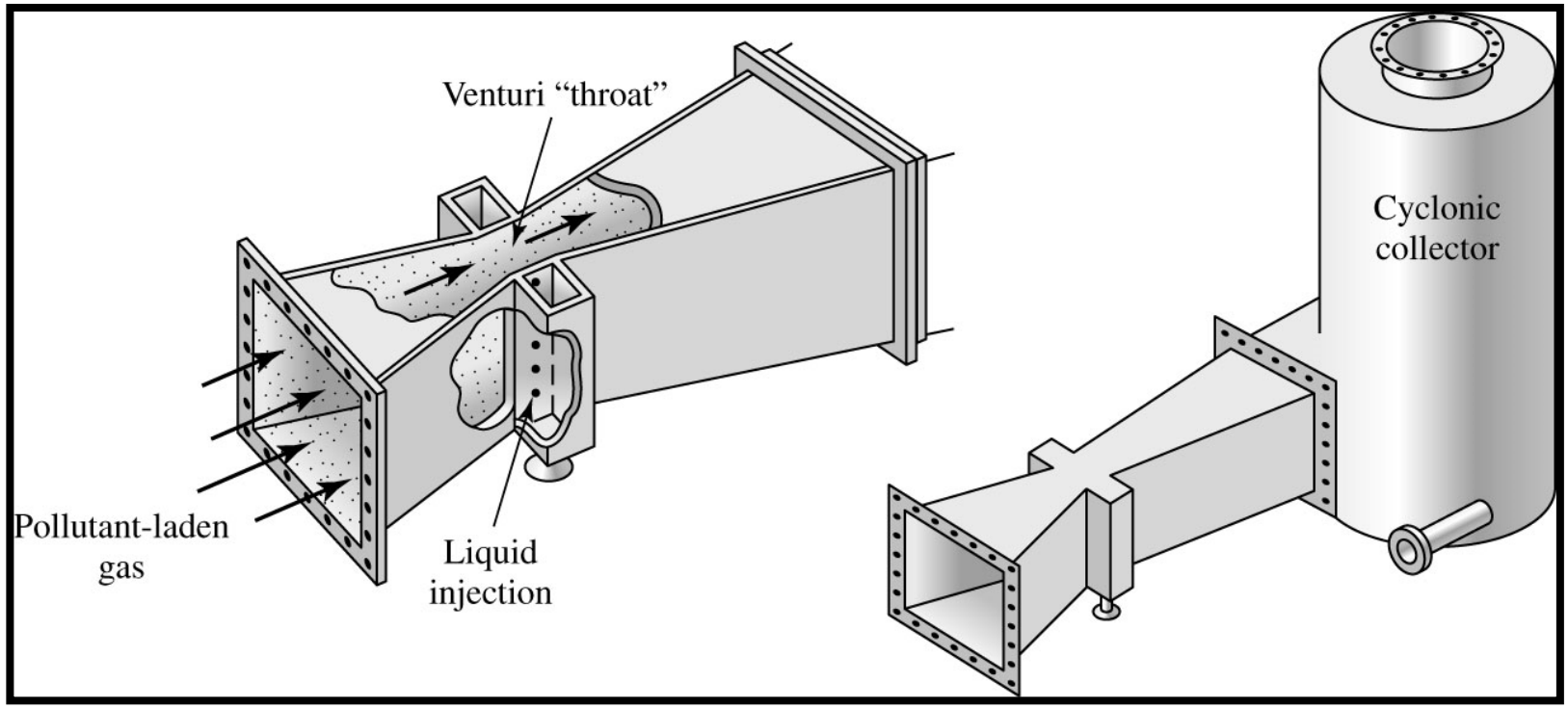
Air pollution control – particulates

- Filter: good for small particles (<5 µm)



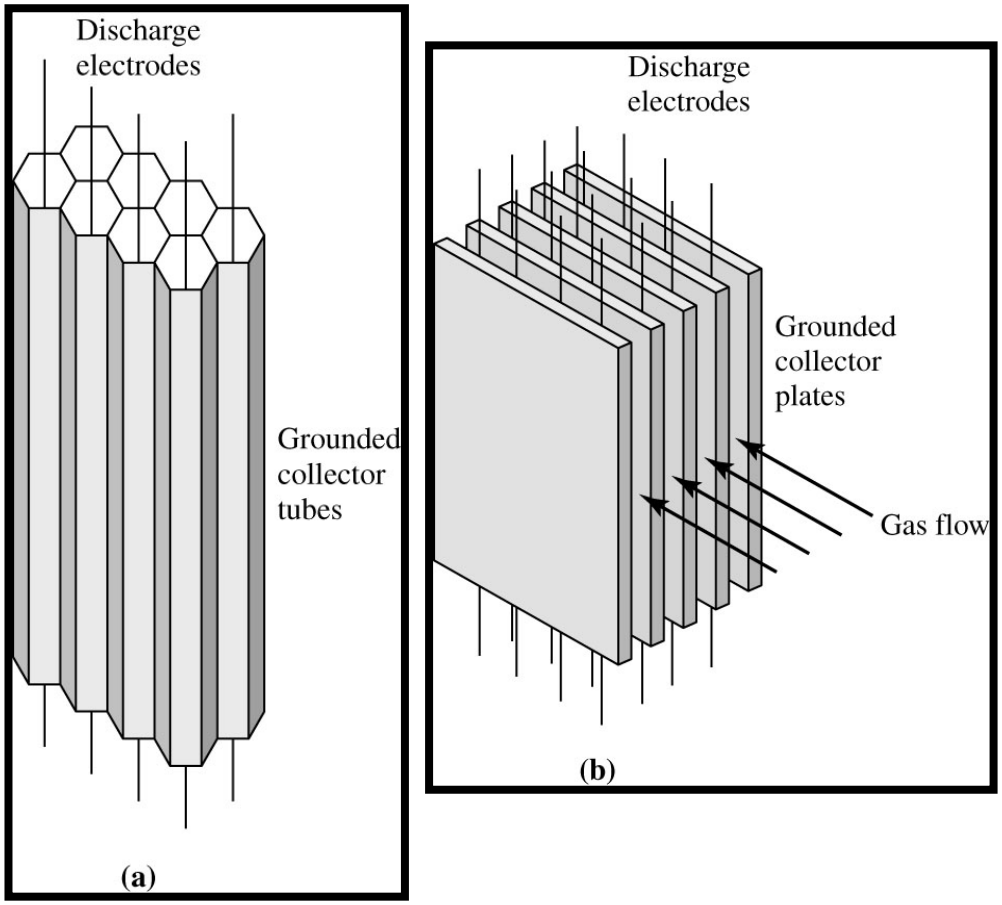
Air pollution control – particulates

- Liquid scrubbing: good for wet, corrosive, or very hot particulates



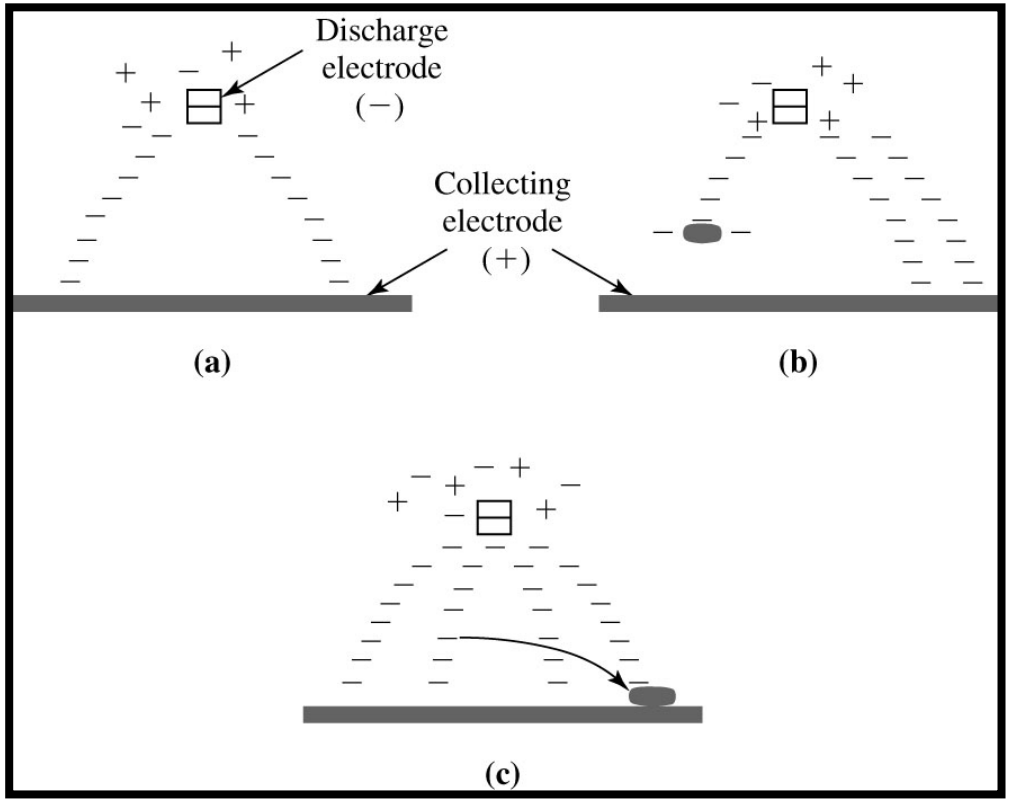
Air pollution control – particulates

- Electrostatic precipitation: high-efficiency, dry collection of particles from hot gas streams



Air pollution control – particulates

- Electrostatic precipitation



Reading assignment

Textbook Ch 12 p. 600-615, 631-640