Modeling Emissions of High Global Warming Potential Gases

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Outline

- Introduction
- Emission Inventory Methodologies
- Results (U.S. Emissions)
- Additional Applications
- Summary

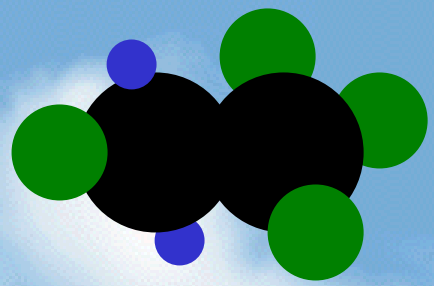
Introduction

- High Global Warming Potential (GWP) Gases
  - What Are They?
  - Where Are They Produced / Used?
  - Why Are They Important?

High-GWP "F-Gases"

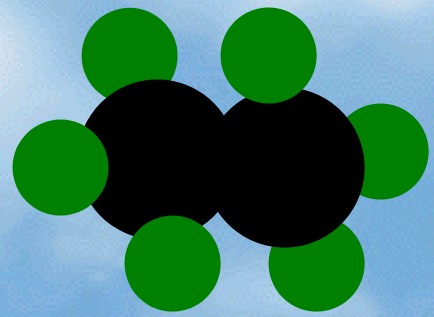
- Hydrofluorocarbons (HFCs)

HFC-134a =

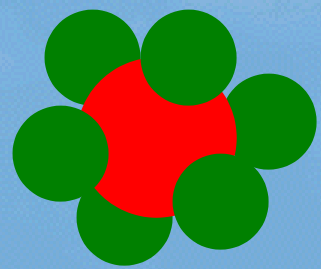


- Perfluorocarbons (PFCs)

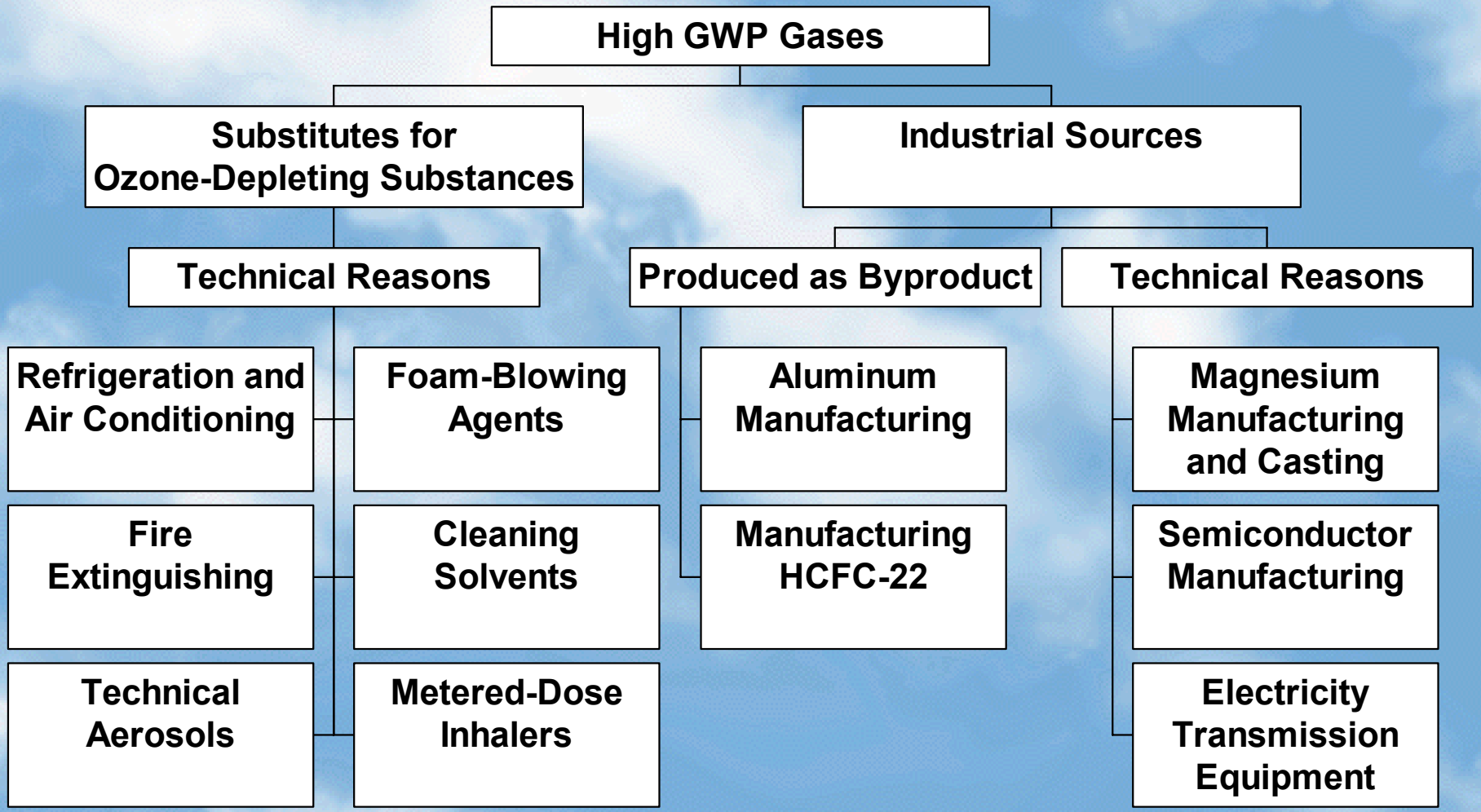
C_2F_6 = PFC-116 =



- Sulfur Hexafluoride (SF_6)



How Are High-GWP Gases Used?



Ozone-Depleting Substances

- CFCs, HCFCs, Halons, Methyl Chloroform, Carbon Tetrachloride, Methyl Bromide, etc.
- Deplete the Stratospheric Ozone Layer
- Are Greenhouse Gases but GWP set to 0
- Production Controlled International *Montreal Protocol* and National Laws (e.g., *US Clean Air Act* and *EC 2000/2037*)
- Various Alternatives, including High-GWP Fluorinated Gases (mainly HFCs)

Examples of High-GWP Gases

	Atmospheric Lifetime (years)	100-year Global Warming Potential
CO_2	varies (>50)	1
HFC-32	5.6	650
HFC-134a	14.6	1,300
HFC-143a	48.3	3,800
CF_4	50,000	6,500
HFC-23	264	11,700
SF_6	3,200	23,900

High-GWP Fluorinated Gases

- Why Important?
  - Critical industries
  - Environmentally important
  - Universal emissions (national, state, entity)
  - Fast growth, high potential growth (so early action can yield high payoffs)
  - Long atmospheric lifetimes
  - Many ways to reduce emissions
  - Relatively cheap to abate

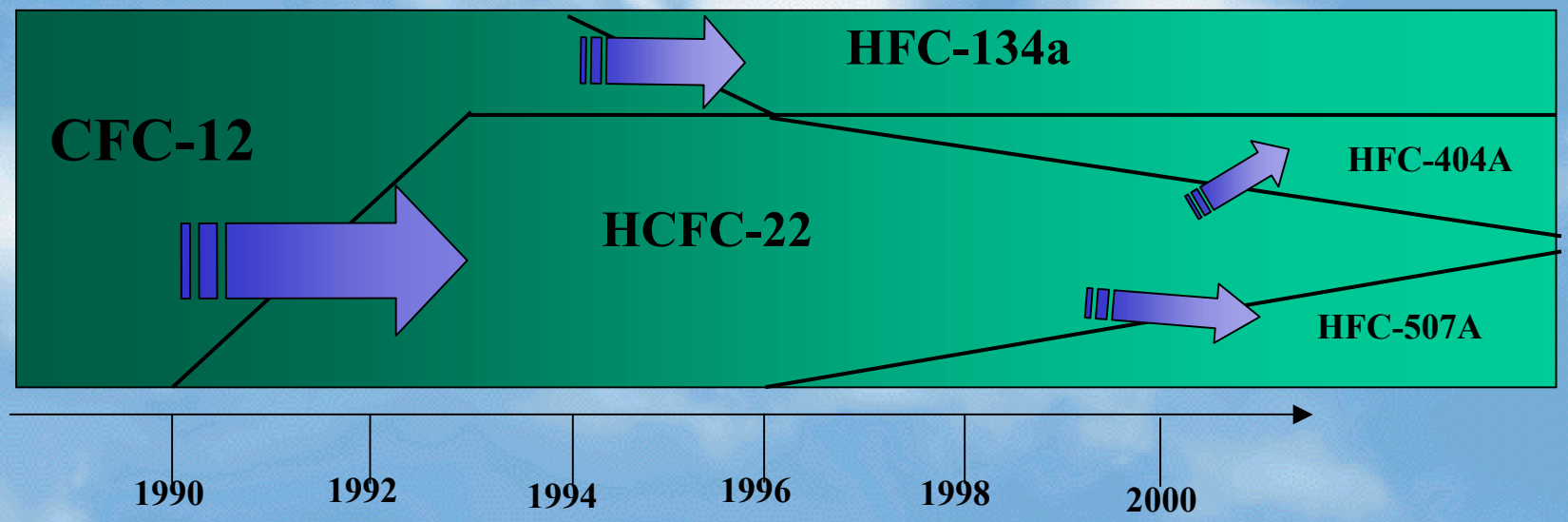
Emission Inventory Methodologies

- U.S. EPA's Vintaging Model
  - Description
  - Sectors and End-Uses
  - Methods for Estimating Emissions
  - Transition from Ozone Depleting Substances

EPA's Vintaging Model

- Yearly Market Data on Over 40 End-Uses:
  - Car ACs, Supermarkets, Appliance Foam …
- Tracks Market as it Transitions from ODSs into HFCs and Other Options
- Emissions: Leaks, Service, Disposal, Use
- Uses Published and CBI Data from Experts, Industry, Trade Associations
- Incorporates Technology Improvements
- Correlated with Top-Down Data

Example Market Transition



Top-Down vs. Bottom-Up

- Radiative Forcing / Global Warming
- Atmospheric Concentrations
- Emissions
- Chemical Sales
- Sectors (New / Service)
- End-Uses
- Individual Units/Sales
  - Gas used in new product / application
  - Emission rates

Partial List of Sectors and End-Uses

- Refrigeration/AC
  - Car ACs
  - Chillers
  - Supermarkets
  - Food Transport & Storage
  - Appliances
  - Central AC, Window Units
  - Commercial AC
  - Heat Pumps / PTACs
- Solvents
  - Electronics, Metal, & Precision Cleaning
- Fire Extinguishing
  - Streaming & Flooding
- Aerosols
  - Consumer & MDIs
- Foams
  - Many by type and application

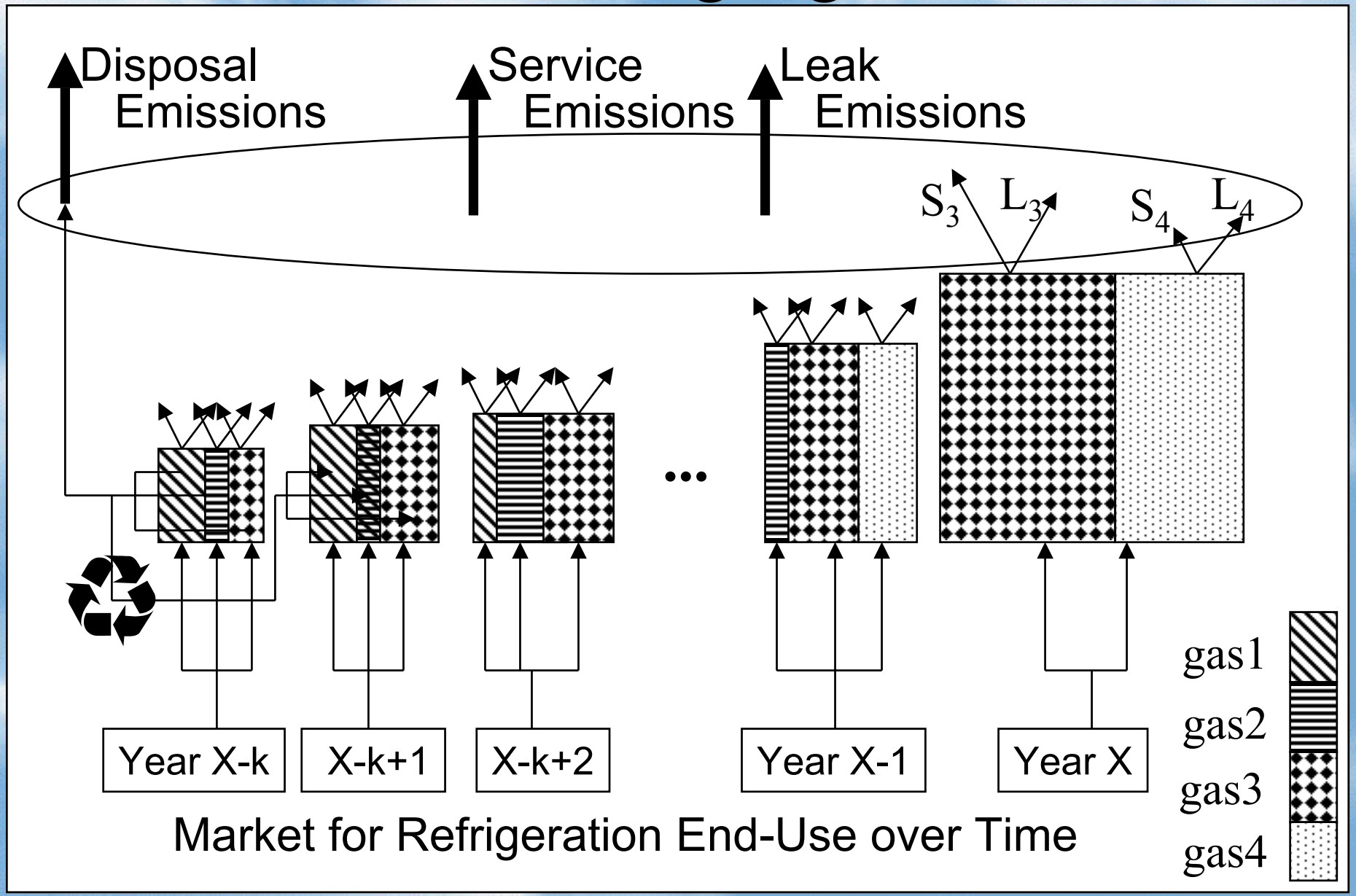
Vintaging Model Emission Profiles

- Ref/AC: emissions from leaks, servicing, disposal

$$E_{2010} = \{(leaks + service) * \sum_{1996}^{2010} Q_{past\_years}\} + \{disposal * Q_{1996}\}$$

  - Q is quantity of gas added in a given year
- Transition:
  - Car ACs (1992-1994)
  - Supermarkets (~1995)
  - Home ACs (~2007)
  - Nearly 100% HFCs

EPA's Vintaging Model



Market for Refrigeration End-Use over Time

Vintaging Model Emission Profiles

- Fire Extinguishing: leaks/releases each year; assume average leak rate over average lifetime.

$$E_{2010} = (average\_leak\_rate) * \sum_{1996}^{2010} Q_{past\_years}$$

- Transition:
  - Streaming Agents (~1995)
    - mostly non-HFC/PFC
  - Flooding Agents (~1994)
    - mostly HFCs & PFCs

Vintaging Model Emission Profiles

- Foams (open): immediate emission
- Foams (closed): manufacturing, use, disposal

$$E_{2010} = \sum_{1996}^{2010} EF_{past\_years} * Q_{past\_years}$$

  - EF is the year-dependent emission factor
- Transition:
  - Varies by type
  - HFCs (2003-2010)
    - minor use ~1993
  - Some hydrocarbons

Vintaging Model Emission Profiles

- Aerosols/MDIs: immediate emissions

$$E_{2010} = Q_{2010}$$

- Transition:
  - CFCs banned 1977
  - Most use HCs, pumps, etc.
  - Some HFCs in 1990s
  - MDIs: HFCs in late 1990s

Vintaging Model Emission Profiles

- Solvents: percentage leaked during first year (rest is recycled or disposed)

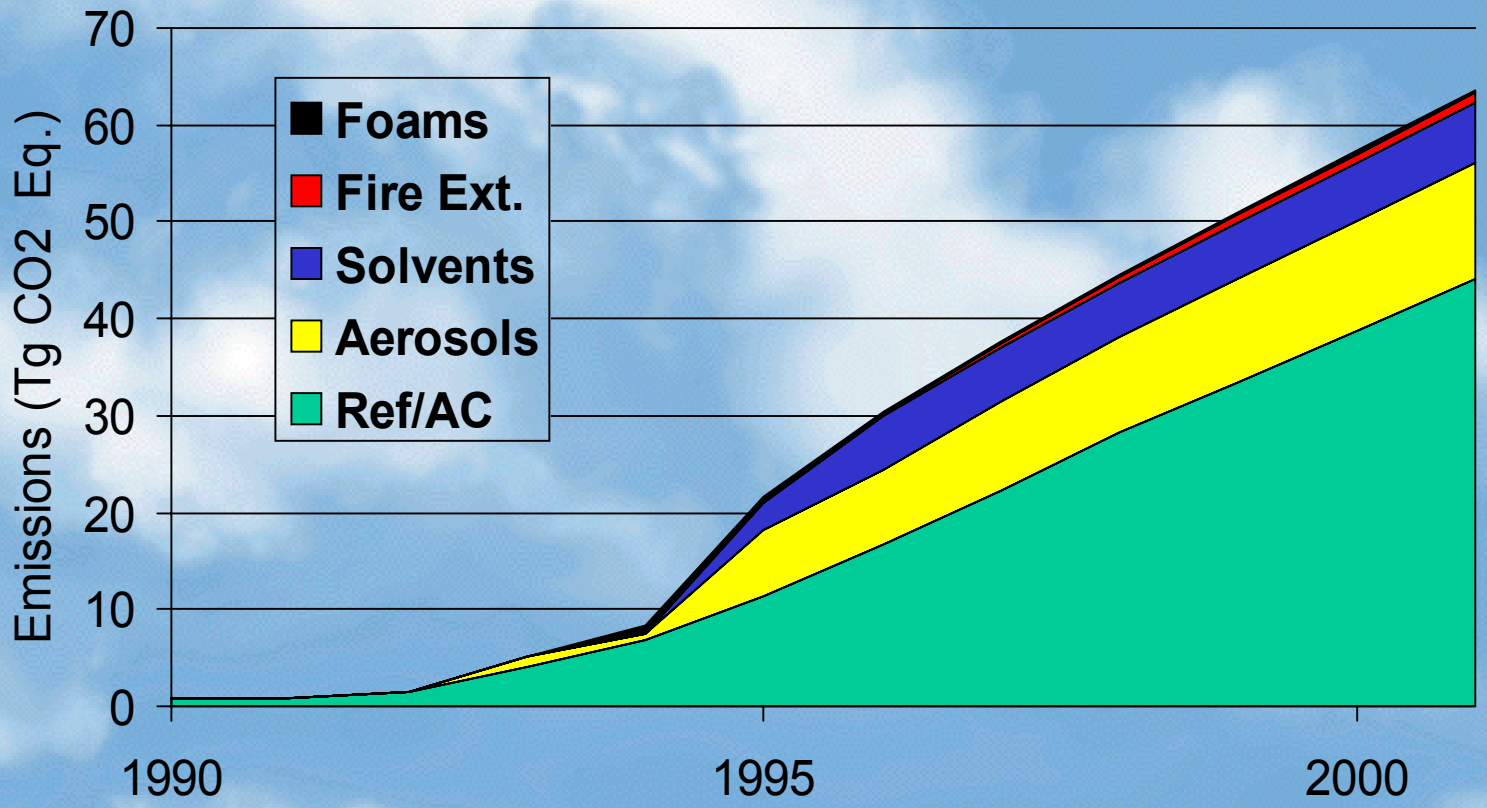
$$E_{2010} = leak\_rate * Q_{2010}$$

- Transition:
  - Many "Not-In-Kind" (~1992)
  - Some HFCs, PFCs (~1995)

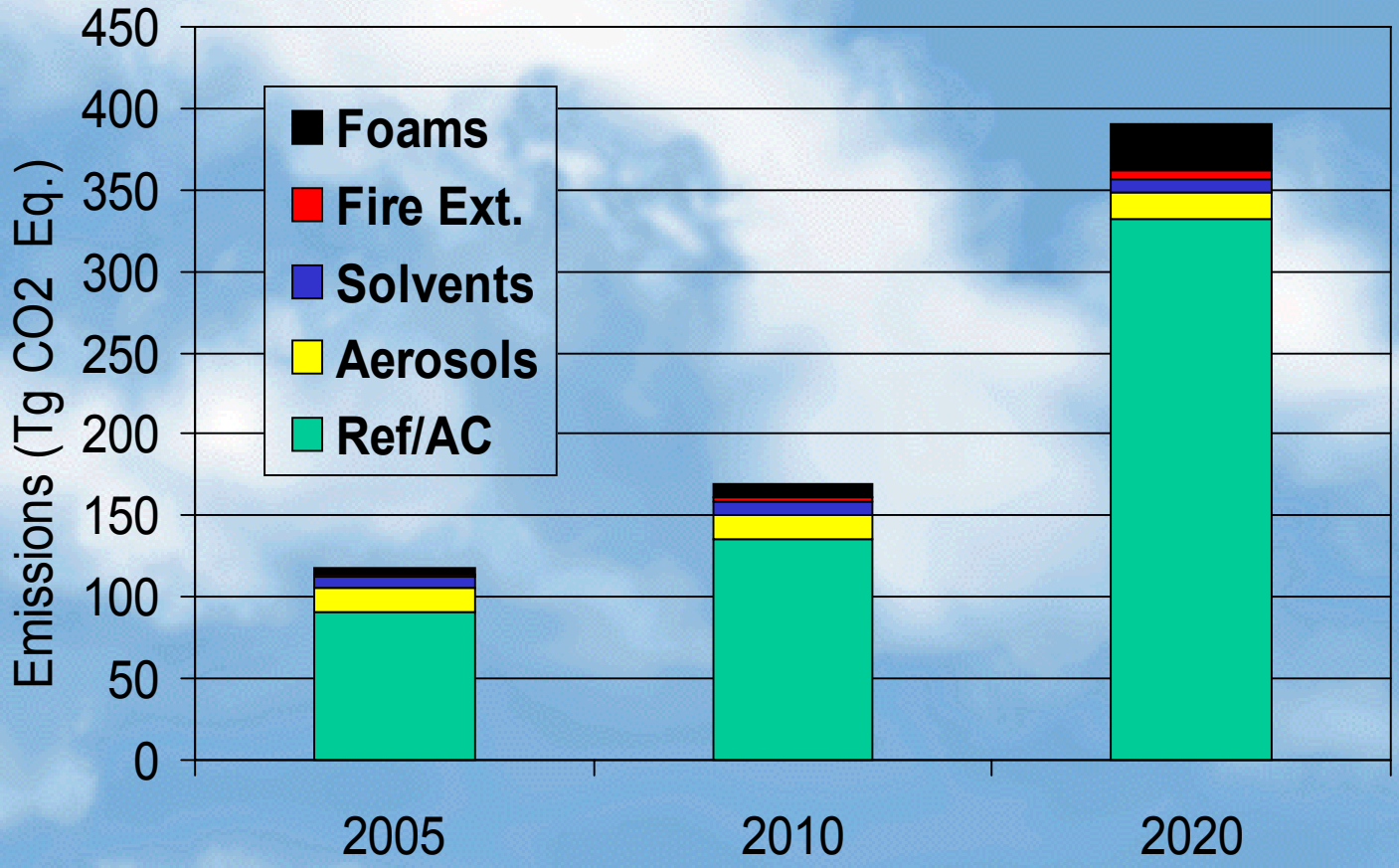
Results

- U.S. Emissions
  - Past Inventories
  - Future Projections

U.S. Historical Emissions



Projection of U.S. Emissions



Additional Applications

- State, Regional and International Emission Inventories and Projections
- Identify Highly-Emissive End-Uses
- Examine Different Futures (what ifs?)
- Analyze Emission Savings vs. Costs
  - emission trading strategies

City/State Inventories

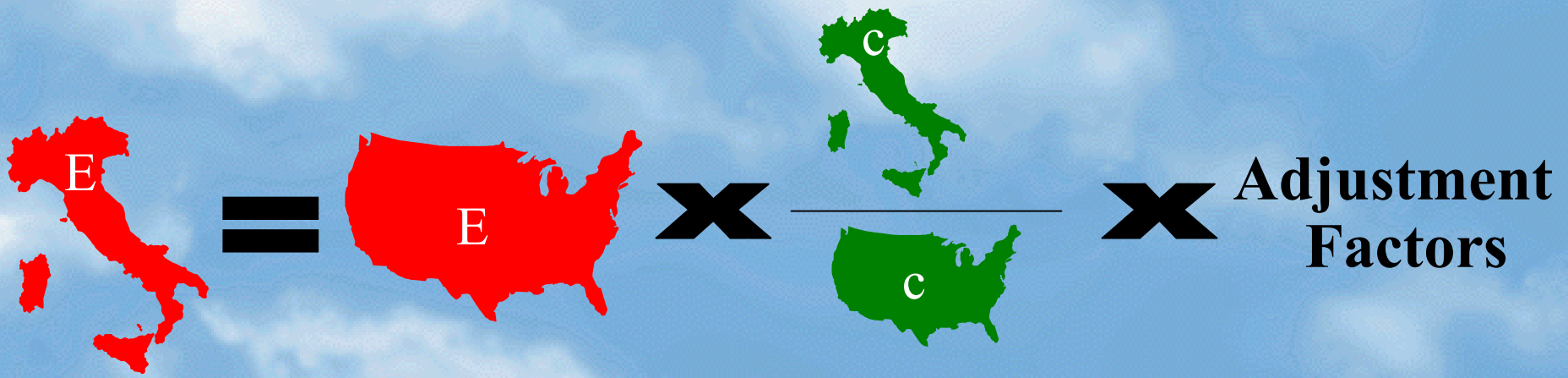
- Bottom-Up Data May Not Be Available
- Apportion U.S. Emissions by Population
  - Generally consumer uses
  - ODS phaseout regulations apply nation-wide
  - Products are sold world-wide
- Further Refinements Possible
  - Penetration of air-conditioning (climate)
  - Foam production or solvent using industry

Company/Entity Inventories

- Perform Inventory of Chemical Use
- Track Chemical In/Out
  - Some companies may keep their own inventory of chemicals
  - Most rely on outside service contractors (e.g., maintenance of Ref/AC equipment)
- Decide on Applicability
  - Example: AC emissions from employee cars

International Inventories

- Generate Country-Specific Vintaging Models Where Detailed Sector-Level Data Are Available (Fire, Foams, Car ACs)
- Otherwise $E_C = E_{US} \times ODS_C/ODS_{US} \times AFs$



E = Emissions C = ODS consumption

Regional Differences from U.S.

- Distribution of ODS Use by Sector
- Patterns Seen in Transition from ODSs (e.g., use of hydrocarbons vs. HFCs)
- Timing of Transition from ODSs
- Historical and Future Economic Growth (mimics market penetrations)
- Regulations and Handling Practices (e.g., recovery/recycling)

Summary

- HFCs and PFCs Used as Substitutes for Ozone-Depleting Substances
- Emissions Rising Sharply and Universally with ODS Phaseout and Economic Growth
- EPA Vintaging Model Uses Detailed Bottom-Up Method for National Inventory
- Applicable for Other Inventories & Analyses
- Many Cheap Emission Reduction Options

Thank You

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