U.S. Experience: Compiling ODS Substitutes

April/May 2024

U.S. Environmental Protection Agency

Outline

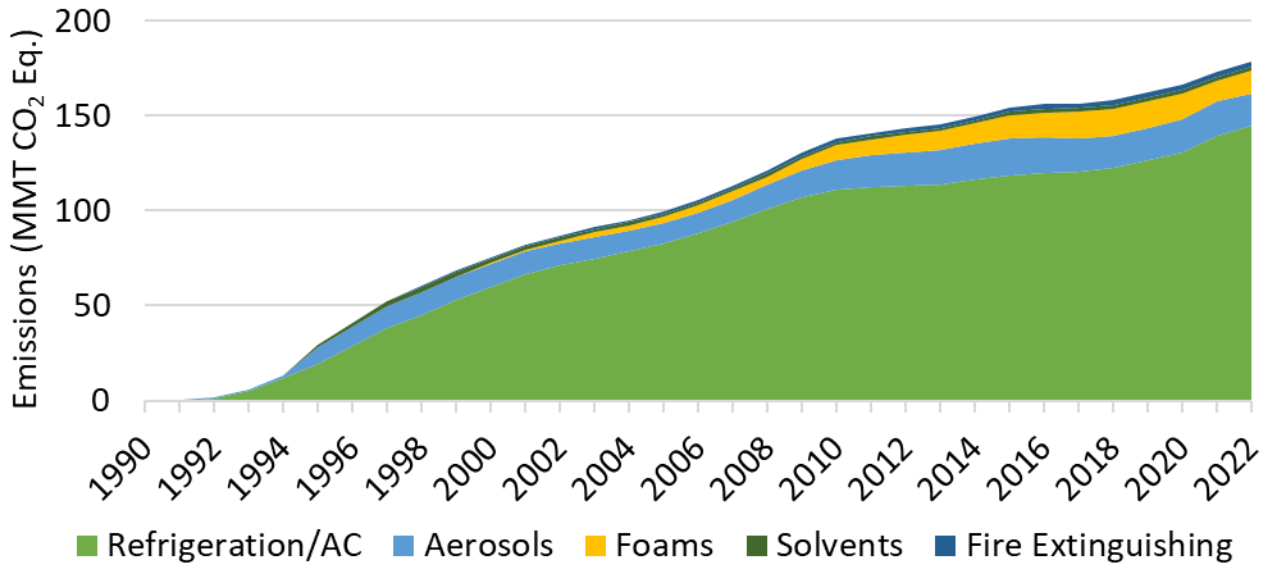
- Institutional Arrangements
- Emissions and Trends
- Methods and Data Sources
- Estimate Improvements
- Common Reporting Tables
- Data Collection Suggestions
  - Example: Motor Vehicle Air Conditioning
- Contact Information

Institutional Arrangements

- Roles in Compilation
  - EPA: Overall Technical Lead and Coordination
  - Technical team (ICF) supports EPA lead in estimate preparation and uncertainty analysis
- Data Collection
  - Vintaging Model (VM): EPA model supported by ICF
    - Tracks types of equipment and practices ("end-uses") of ODS and substitutes across six sectors in the United States.

Summary of Emissions and Trends

- In 2022, emissions from substitutes of ozone depleting substances (ODS Subs) totaled 178.1 MMT CO_2 Eq., which is:
  - 46.5% of emissions from the Industrial Processes and Product Use Sector
  - 2.8% of total GHG emissions in the United States

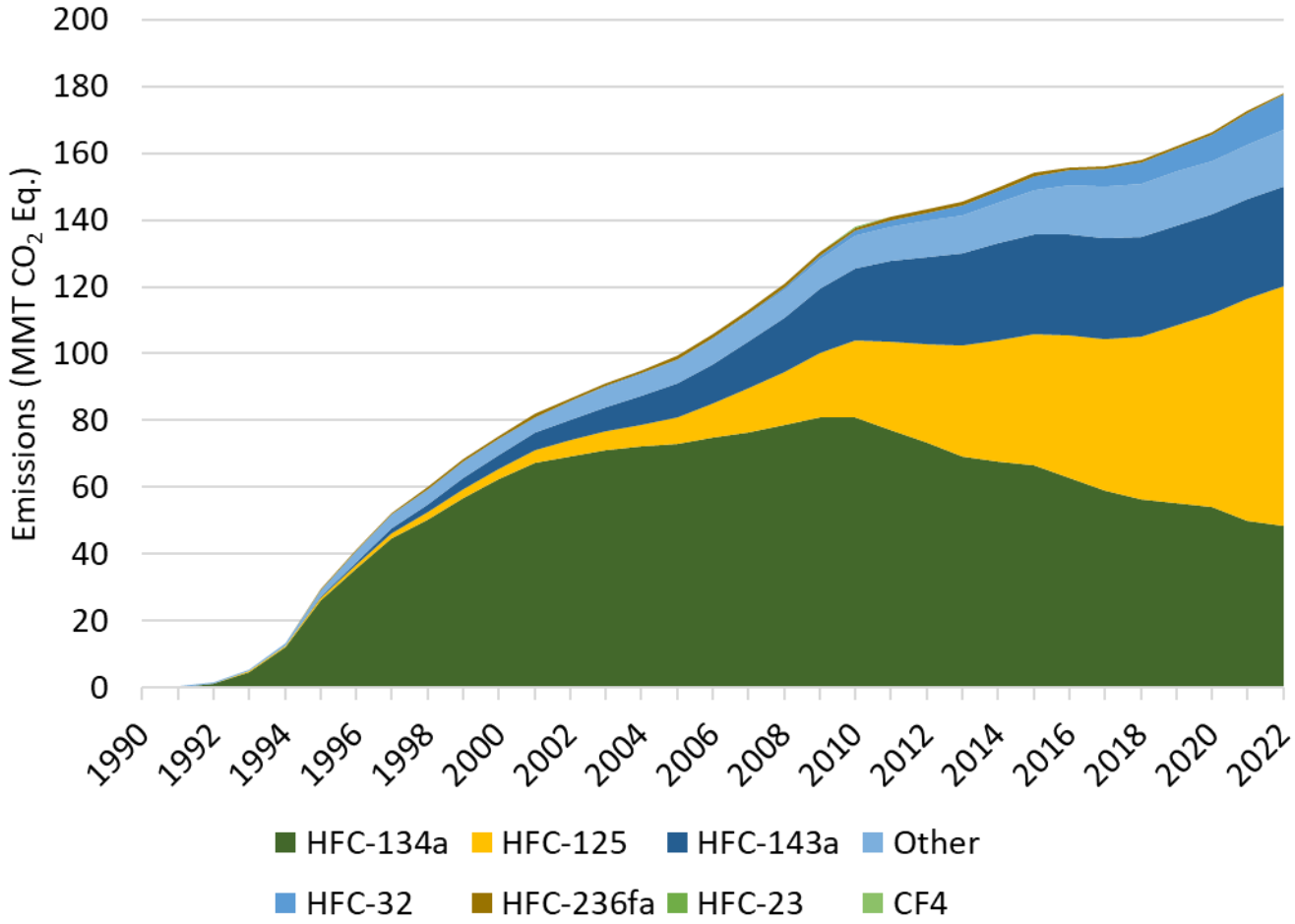


2022 Emissions (MMT CO_2 Eq):

Refrigeration/AC: 144.6
Aerosols: 17.0
Foams: 11.7
Solvents: 2.1
Fire Suppression: 2.6

Summary of Emissions and Trends

- Largest emissions (in CO_2eq) from HFC-125, HFC-134a, HFC-143a
- Others includes HFC-152a, HFC-227ea, HFC-245fa, HFC-365mfc, HFC-4310mee, and HCFO-1233zd(E), HFO-1234yf, HFO-1234ze(E), HFO-1336mzz(Z), C_4F_{10}, and PFC/PFPEs
  - Grouped together to not reveal Confidential Business Information (CBI)



Summary of Methods and Data Sources

- Using a Tier 2 method in accordance with the IPCC methodological decision tree, a detailed Vintaging Model (VM) of ODS and ODS Substitute-containing equipment and products is used to estimate the actual emissions of various ODS substitutes, including HFCs, PFCs, and CO_2. The VM:
  - Estimates annual chemical emissions from industrial sectors that have used ODS in their products across **80** independently modeled end-uses
  - Tracks chemical from when first produced and placed into equipment or product ("consumption") until finally recycled or released to atmosphere ("emissions")
  - The model requires information on the market growth for each of the end-uses, a history of the market transition from ODS to alternatives, and the characteristics of each end-use such as market size or charge sizes and loss rates
  - Synthesizes data from variety of sources (some CBI):
    - EPA's ODS Tracking System
    - EPA's Greenhouse Gas Reporting Program
    - Published documents from the Montreal Protocol's Technology and Economic Assessment Panel
    - Input and review from trade associations and individual companies

Summary of Methods and Data Sources

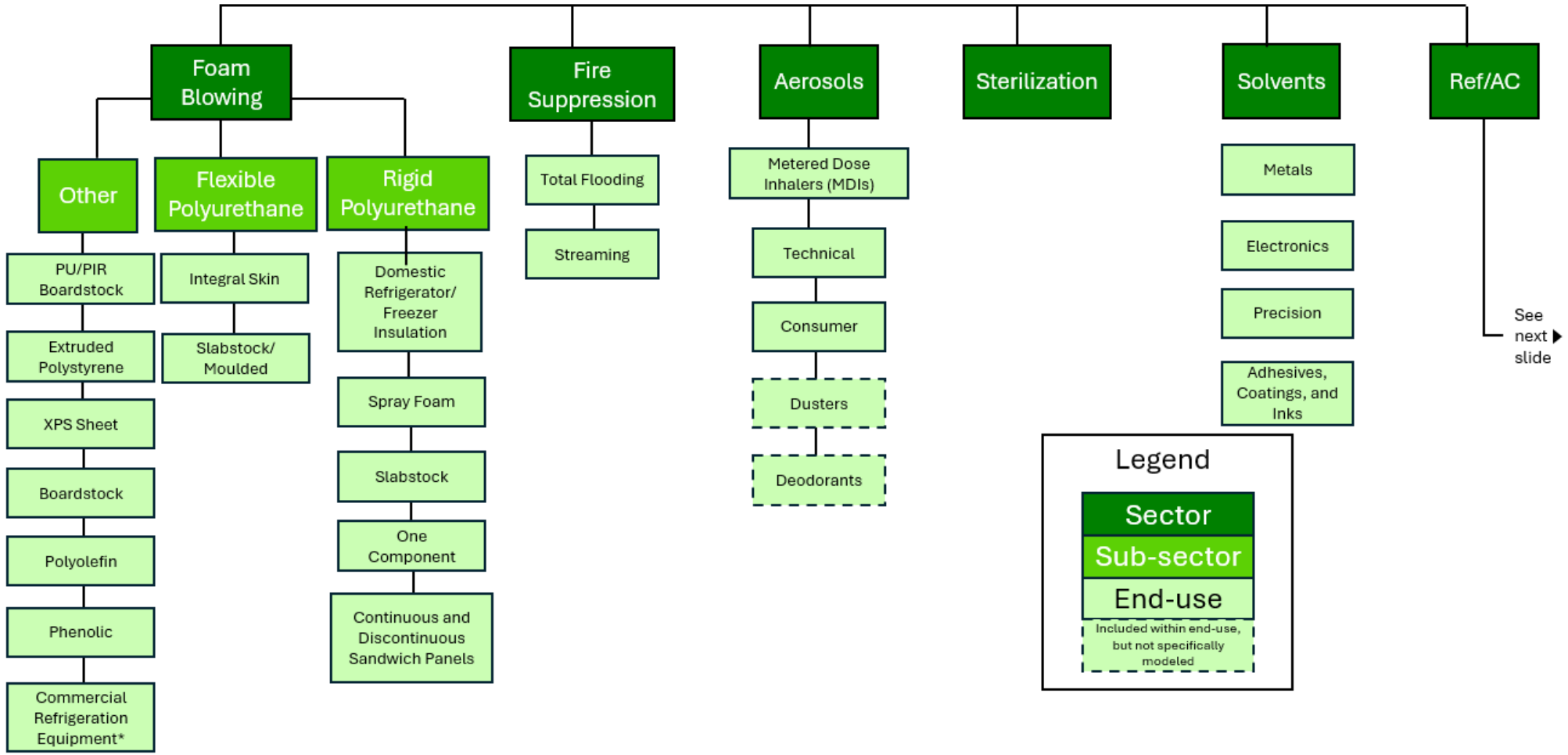
Specifically, the Vintaging Model applies the Tier 2 methodology to estimate the use and emissions of ODS alternatives by taking the following steps:

1. *Gather historical data*. The Vintaging Model is populated with information on each end-use, taken from published sources and industry experts.

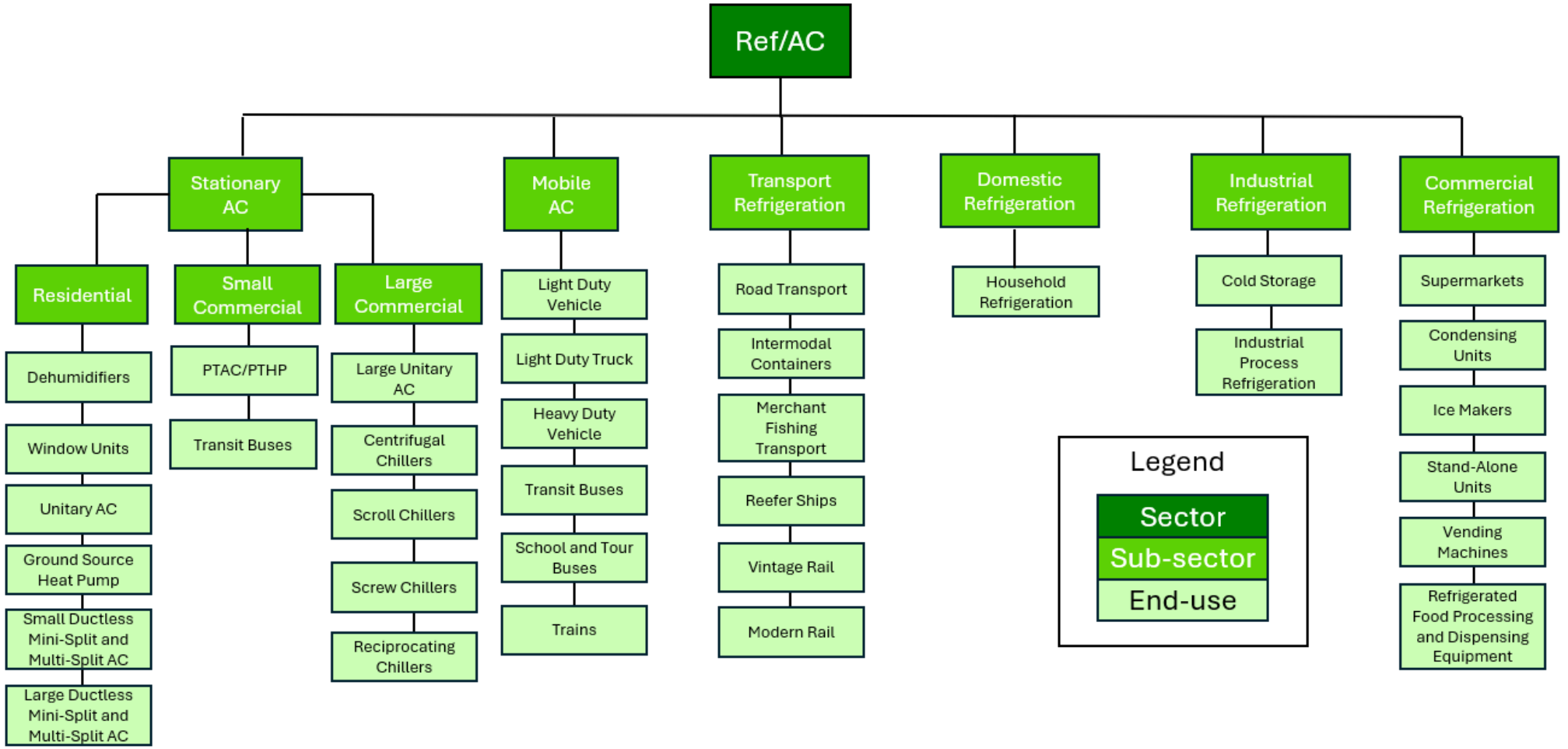
2. *Simulate the implementation of new, non-ODS technologies*. The Vintaging Model uses detailed characterizations of the existing uses of the ODS, as well as data on how the substitutes are replacing the ODS, to simulate the implementation of new technologies that enter the market in compliance with ODS phase-out policies. As part of this simulation, the ODS substitutes are introduced in each of the end-uses over time as seen historically and as needed to comply with the ODS phase-out and other regulations.

3. *Estimate emissions of the ODS substitutes*. The chemical use is estimated from the amount of substitutes that are required each year for the manufacture, installation, use, or servicing of products. The emissions are estimated from the emission profile for each vintage of equipment or product in each end-use. By aggregating the emissions from each vintage, a time profile of emissions from each end-use is developed.

VM Sector and End-Use Flow Chart



VM Sector and End-Use Flow Chart (contd.)



Refrigeration and Air Conditioning

- Annual emissions from leaks and servicing
- Disposal emissions at equipment end-of-life

$$E_{2022} = \{(leaks + service) * \sum_{2002}^{2022} Q_{past\_years}\} + \{disposal * Q_{2002}\}$$

Q is quantity of gas added in a given year

- Emission factors for top 5 emitting end-uses (VM/IPCC)
  - Car ACs: 10-23%/10-20%, Disposal: 50%/75-100%
  - Supermarkets: 9-25%/10-35%, Disposal: 20%/65-100%
  - Refrigerated Transport: 11-17%/15-50%, Disposal: 20-65%/65-100%
  - Home ACs: 7%/1-10%, Disposal: 65%/16-100%
  - Chillers: 3-12%/2-15%, Disposal: 20%/5-100%
- Key gases: R-410A, R-404A, HFC-134a, HFO-1234yf

Foam Blowing

- Blowing agents in open cell foams are released immediately
- Blowing agent emissions occur during manufacturing, use, disposal, and post-disposal of closed cell foams

$$E_{2022} = \sum_{1990}^{2022} EF_{past\_years} * Q_{past\_years}$$

EF is the year-dependent emission factor

- Emission factors (VM/IPCC)
  - Extruded Polystyrene (XPS):
    - Manufacturing: 25-50%/25%; Annual: 1-25%/0.75%
  - Commercial Refrigeration:
    - Manufacturing: 4%/4-7%; Annual: 0.25%/0.25-0.5%
- Key gases: HFC-245fa, HFC-134a

Fire Suppression

- Average leak rate assumed over average lifetime of extinguisher
- Multi-year stockpiling for halon and HCFC-based agents

$$E_{2022} = (average\_leak\_rate) * \sum_{1990}^{2022} Q_{past\_years}$$

- Emission factors (VM/IPCC)
  - Streaming: 3.5%/2-6%
  - Flooding: 2.5%/1-3%

- Key gases: HFC-227ea, HFC-236fa

AEROSOLS

- Aerosol propellant assumed to be completely released within same year of entering the market

$$E_{2022} = Q_{2022}$$

- Emission Factors (VM/IPCC)
  - 100%/50%+50% (year 1 + year 2)

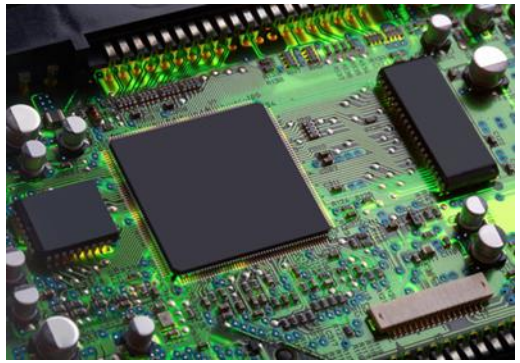
- Key gases: HFC-152a, HFC-134a

SOLVENTS

- Solvents assumed to be released within year of entering the market leaked with a small amount (10%) assumed to be entrained in sludge or waste and disposed of through destruction

$$E_{2022} = leak\_rate * Q_{2022}$$

- Emission Factors (VM/IPCC)
  - 90%/50% + 50%



- Key gases: HFC-4310mee

Common Reporting Table

- The Common Reporting Tables (CRT) summarize the information that is used to estimate total emissions for each product use and gas, including:
  - Emissions from Manufacturing
    - Amount filled into new manufactured products
    - Product manufacturing emission factor
  - Emissions from Stocks
    - Amount in operating systems
    - Product life emission factor
  - Emissions from Disposal
    - Amount remaining in products at decommissioning
    - Disposal loss emission factor

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Gas *(please specify)* *One row per substance*	ACTIVITY DATA *Amount*			IMPLIED EMISSION FACTORS (1)			EMISSIONS (2)			RECOVERY (3,4)
		Filled into new manufactured products	In operating systems (average annual stocks)	Remaining in products at decommissioning	Product manufacturing factor	Product life factor	Disposal loss factor	From manufacturing	From stocks	From disposal	
		(t)			%			(t)			
2.F. Product uses as substitutes for ODS											
2.F.1. Refrigeration and air-conditioning											
2.F.1.a. Commercial refrigeration	e.g. HFC-134a, 365mfc, HFC-43-10mee										

Common Reporting Table

- The Vintaging Model produces the output needed to fill in the CRT categories using the methodology described above, including first-fill, leak, service, and disposal emissions, new chemical demand, and equipment stocks.
- **EPA uses a "Linker Tool" to organize VM output into the categories recognized for CRT:**
  - ***Example for HFC-134a in Commercial Refrigeration***

VM Data Output (MT)		CRT Categories (MT)	
Stocks By Chem	20,922.41	Amount of fluid in operating systems	20,922.41
New Chemical Demand by Chem	2,240.23	Amount of fluid filled in new manufactured products	2,240.23
Disp. Emissions by Chem	254.16	Actual emissions from disposal	254.16
Disp. Recovery by Chem	353.60	Amount of fluid remained in products at decommissioning	607.76
Leak Emissions by Chem	2,801.12	Actual emissions from stocks	3,578.89
Service Emissions by Chem	777.78		
First Fill Emissions by Chem	32.00	Actual emissions from manufacturing	32.00

UID	Brief Data Point	CRF Sector	Sector	Gas	Full Data Point	
B5DB4730-6D0A-428A-A963-DFDF9938	Actual emissions	Refrigeration/AC	Commercial Refrigeration	134	Actual emissions from manufacturing	32.00
9F58103F-B76C-4A38-BBE3-F476F5A6	Actual emissions	Refrigeration/AC	Commercial Refrigeration	134	Actual emissions from stocks	3,578.89
B78EE117-607B-4934-9B29-0603FEA9	Actual emissions	Refrigeration/AC	Commercial Refrigeration	134	Actual emissions from disposal	254.16
DE4520B7-7E61-4A42-BF73-0CC6E9C	Amount of fluid	Refrigeration/AC	Commercial Refrigeration	134	Amount of fluid filled in new manufactured products	2,240.23
0E4B95C4-F5FE-4BAA-9D8A-26874A9	Amount of fluid	Refrigeration/AC	Commercial Refrigeration	134	Amount of fluid in operating systems	20,922.41
68FDA9D4-C628-43D0-9529-EE9D762	Amount of fluid	Refrigeration/AC	Commercial Refrigeration	134	Amount of fluid remained in products at decommissioning	607.75

Common Reporting Table

- Output from the Linker Tool then populates the CRT Reporter Input Template (xlsx) and is uploaded to generate output table

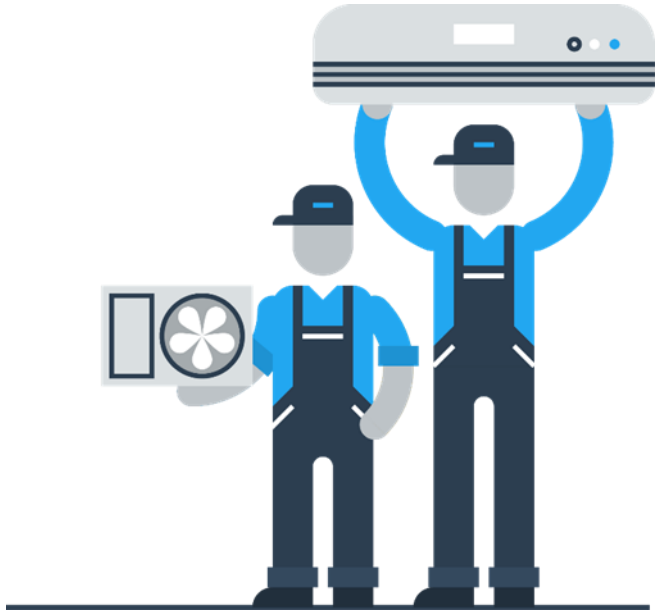
TABLE 2(II).B-H SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES AND PRODUCT USE
Sources of fluorinated substances
(Sheet 2 of 2)

Inventory 2022
Submission 2024 v1
UNITED STATES OF AMERICA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Gas *(please specify)*	ACTIVITY DATA			IMPLIED EMISSION FACTORS[1]			EMISSIONS[2]			
		Amount									
	One row per substance	Filled into new manufactured products	In operating systems (average annual stocks)	Remaining in products at decommissioning	Product manufacturing factor	Product life factor	Disposal loss factor	From manufacturing	From stocks	From disposal	Recovery[3]
		(t)			%			(t)			
F. Product uses as substitutes for ODS											
1. Refrigeration and airconditioning											
Commercial refrigeration											
HFC-23	HFC-23										
HFC-32	HFC-32	1034.84	7835.66	19.19	1.49	20.48	39.60	15.45	1605.00	7.60	NA
HFC-41	HFC-41										
HFC-43-10mee	HFC-43-10mee										
HFC-125	HFC-125	2009.89	31517.33	852.20	1.50	19.93	18.68	30.11	6282.84	159.21	NA
HFC-134	HFC-134										
HFC-134a	HFC-134a	2240.23	20922.41	607.75	1.43	17.11	41.82	32.00	3578.89	254.16	NA
HFC-143	HFC-143										
HFC-143a	HFC-143a	179.23	19165.80	923.08	0.72	18.80	18.54	1.29	3603.63	171.18	NA
HFC-152	HFC-152										

Continuous Improvement of Estimates

- VM under continuous maintenance to improve market assumptions and emission estimates
- Updating stock, refrigerant use, and leak rates for school, tour, and transit buses
- Updating stock for cold storage warehouses to align with refrigerated storage space estimates published biannually from the United States Department of Agriculture (USDA)
- Review of flooding agent fire suppression market transitions to align more closely with real world activities



Data Collection Suggestions

- ODS Substitute emissions can be estimated using a top-down or bottom-up approach, depending on data availability.
- Different types of data can be used to estimate an installed base of equipment/products and/or chemical from which annual emissions can be estimated
- Application or sub-application profile information
  - Country-specific preferred
    - Manufacturer product specification data sheets
  - IPCC Defaults
  - UNEP HFC technical factsheets

Data Collection Suggestions

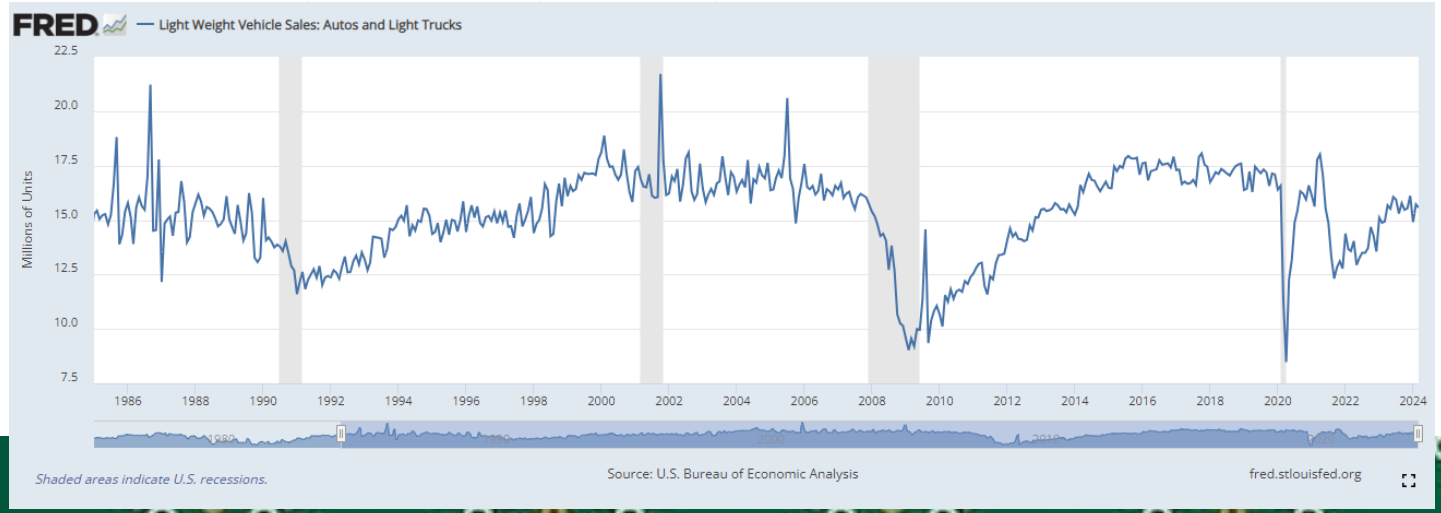
- Top-down approach using chemical sales on a substance-by-substance basis
    - Could be Confidential Business Information (CBI) concerns with chemical producers and/or importers
  - Apply composite emission factor for the application or sub-application
  - Certain chemicals can be used across multiple applications with different emission factors

Data Collection Suggestions

- Bottom-up using equipment or product sales
  - Sales data must be adjusted for imports/exports
  - Growth rate and lifetime assumptions needed to develop installed base
- Bottom-up using other country-specific data
  - Country-specific data that could be used to estimate HFC emissions could include:
    - Number of residential, commercial, and industrial buildings
    - Vehicle registrations
    - Population data
  - Use country-specific data to estimate number of different types of equipment or products per building type (e.g., RAC system, foam) or person (e.g., MDI)

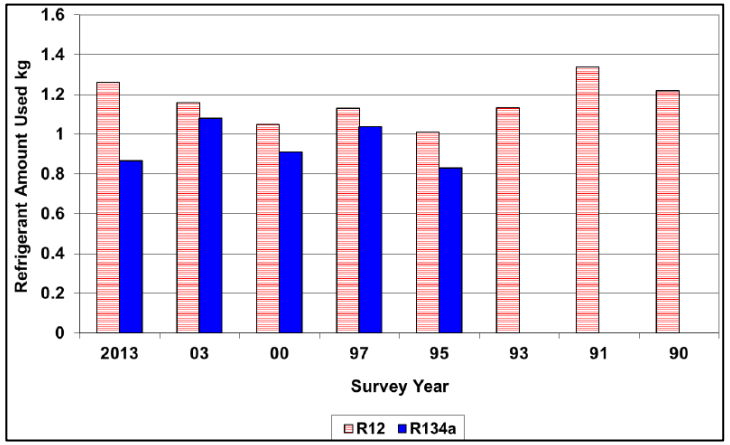
Example: Motor Vehicle AC

- The Vintaging Model has two light-duty motor vehicle air conditioning (MVAC) end-uses—light duty cars (LDC) and light duty trucks (LDT).
- The modeled number of vehicles “on the road” or active in the United States is based on a variety of sources:
  - 1985 to current is based on published automobile sales (WardsAuto, U.S. Bureau of Economic Analysis);
  - Future growth rates are based on Energy Information Administration (EIA) Annual Energy Outlook
- From 1985 to 2002, it is assumed that the percentage of vehicles equipped with an AC system rose from 85.3% to 98.6%. Starting in 2003 and for all future years, it is assumed that 99% of new light-duty vehicles have an AC system.
- LD passenger vehicle AC systems (in the United States) are assumed to be in use for exactly 16 years, based on analysis of WardsAuto data and in agreement with other sources (e.g., study from California Air Resources Board).



EXAMPLE: MOTOR VEHICLE AC

- Weighted average refrigerant charge sizes are based on motor vehicle sales data and charge size data, by make, model, and year from industry reports and confirmed by peer review:
  - Mobile Air Conditioning Society (MACS) Worldwide *Air Conditioning Specifications Domestic and Import Cars, APVs, Vans and Light Trucks: 1990 through 1998,*
  - *A/C & Cooling System Specifications: 1996-2007,*
  - Average vehicle charge sizes reported to the Minnesota Pollution Control Agency (MPCA)
- Leak rates based on industry reports and confirmed by peer review:
  - *Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025*
  - Leak rate data reported to MPCA



Refrigerant	Vintage	Charge Size (kg)	First Fill Loss (% of charge)	Annual Loss (% of charge)		End of Life Loss (% of charge)
				Leakage	Servicing	
CFC-12	1985-1993	1.0-1.1	0.5%	18%	23%	50%
HFC-134a	1992*-2020	0.56-1.1	0.2%	3.7%-18%⁺	2.7%-19%^	40%-45%
HFO-1234yf	2012-on	0.56-0.79	0.2%	3.7%	2.7%	40%

* LDCs begin transition in 1992, LDTs begin in 1993.

⁺ High end leak rate (i.e., 18%) is for MVACs produced between 1992 through 2001 and low end (i.e., 3.7%) represents systems manufactured after 2005.

^ High end servicing emission rate (i.e., 19%) is for MVACs produced between 1992 through 2001 and low end (i.e., 3.1% and 2.7%) represents systems manufactured after 2002 and 2008, respectively.

Contact Information

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