IPCC Methodology for Estimation of Emissions of Fluorinated Greenhouse Gases from Products

Presentation On Training Seminar on QA/QC Procedures in Industrial Processes

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Outline of Presentation

- Introduction
- Methodology in general
- IPCC 1996 Guidelines
- IPCC 2006 Guidelines
  - Aerosols and solvents
  - Foam blowing agents
  - Refrigeration and air conditioning
  - Fire protection
  - SF_6 from products

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Fluorinated Greenhouse Gases

- Synthetic greenhouse gases covered by UNFCCC / Kyoto (and perhaps Montreal-protocol in the future)
- Most have high global warming potentials
- Some are very long lived (PFCs and SF_6). HFCs typically have a lifetime of a few years
- **HFCs: Used as substitute for ozone-depleting substances (ODS) in refrigeration and other products**
- PFCs: Also substitute, but main source is industrial production processes (not covered here)
- SF_6: Used as an isolator in electric power industry and in some other applications
- Global emissions are increasing rapidly

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HFCs (and PFCs) as Substitutes for ODS

- Main application is refrigeration and air-conditioning
- Also used in fire suppression, aerosols, solvents, foam etc.
- Used as pure substances or blends
- Emissions from:
  - Production (by-product, fugitive)
  - During use (intended, leakage)
  - At decommissioning / end-of-life
- HFCs are traded products (no formation in processes) , so **potential** emissions might be rather easy to predict
- Development of long-lived banks complicates the calculation of **actual** emissions

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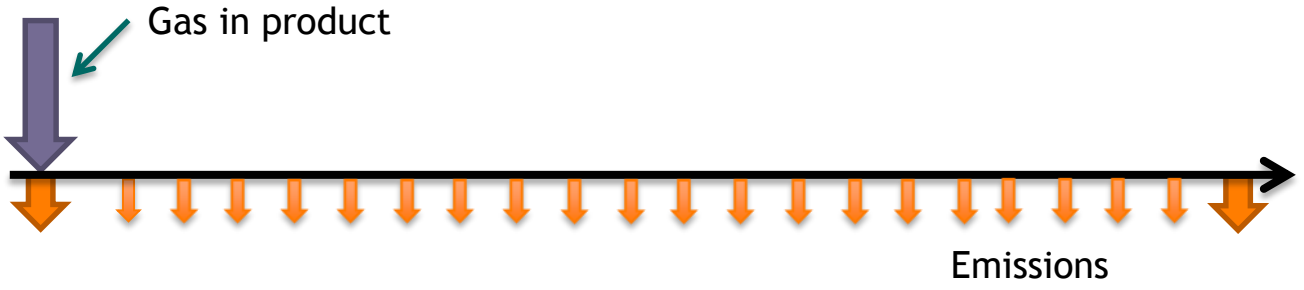
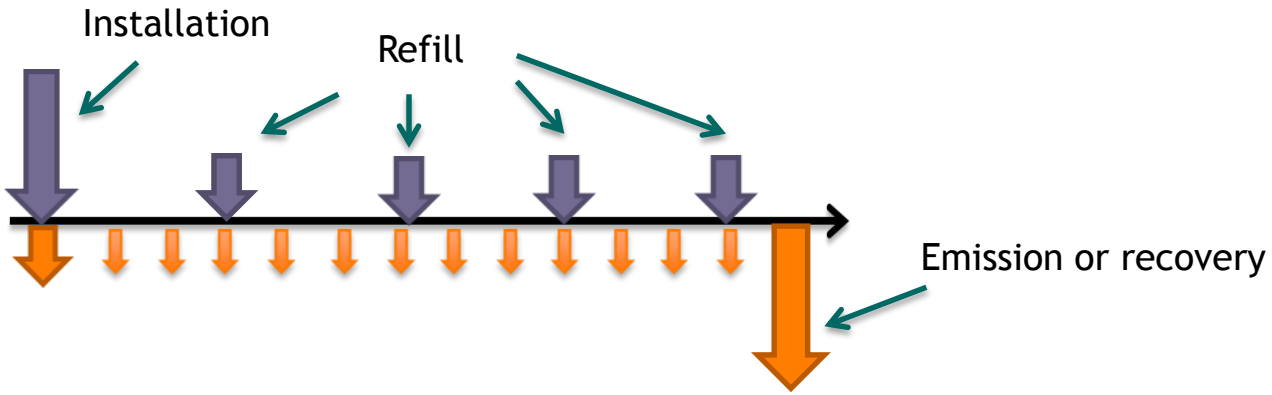
HFC – Time Lag

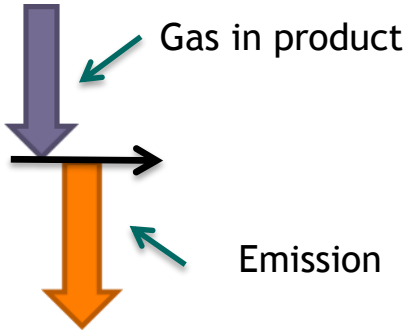
Closed cell foam:



Commercial Refrigeration:



Aerosols:



Time:

Added to bank:

Extracted from bank:

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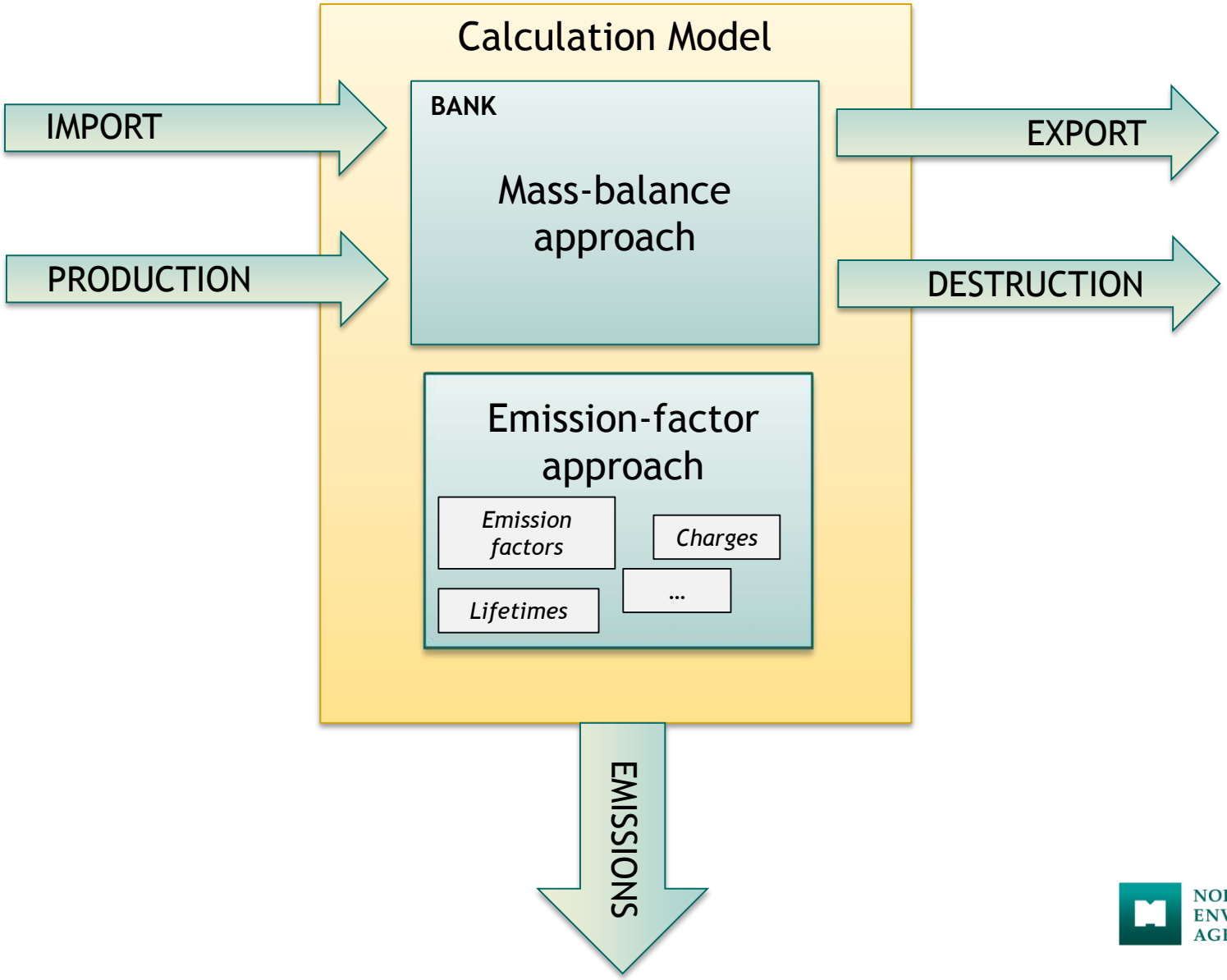
HFC - Methodology



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IPCC 1996 Guidelines

- Used up till 2012
- Tier 1methodology:
  - Potential emissions (time lag not taken into account)
  - Tier 1a: Emissions = import in bulk (- export in bulk)
  - Tier 1b: Includes also gas in products
- Tier 2 methodology:
  - Calculates actual emissions for each individual chemical
  - Based on data on the flow of each gas on a sector or sub-sector level
  - Emissions estimated from consumption and emission characteristics of equipment and processes

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IPCC 2006 Guidelines

- In use from 2012
- Application areas:
  - Refrigeration and air conditioning
  - Fire suppression
  - Aerosols
  - Solvents
  - Foam
  - Other
- Tier 1: Actual emissions on application level
- Tier 2: Actual emissions on sub-application level

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Aerosols and solvents

- Prompt emissions (100% of chemical is emitted within 2 years)
- Activity data needed is quantity of each chemical sold as solvent in a particular year

Emissions = Sale this year (t)* 0.5 (EF)
+ Sale previous year (t) * 0.5 (EF)
(- quantity destroyed previous year)

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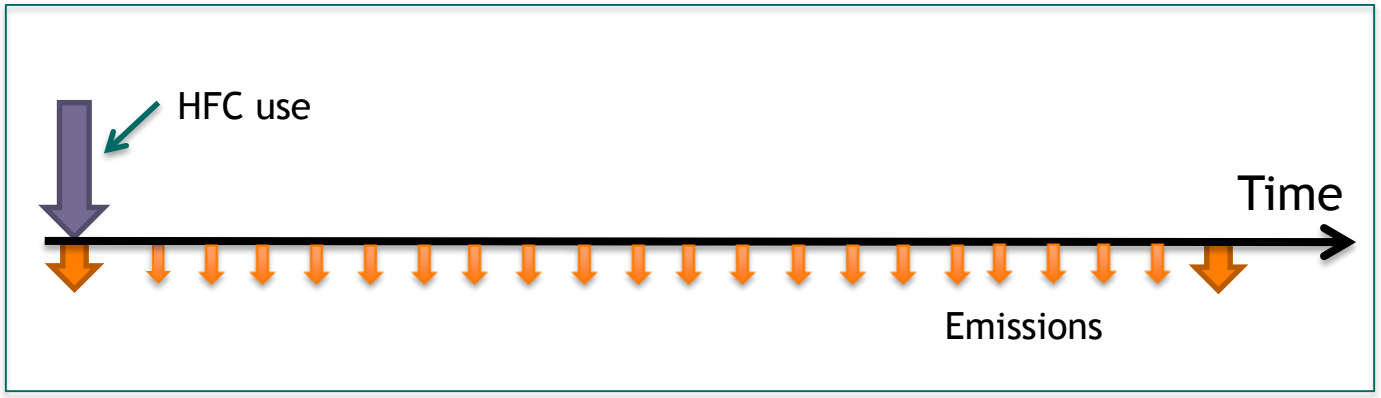
Foam Blowing Agents

- Open cell foams: All HFCs are released immediately

Emissions =	HFC used in manufacturing (t)

- Closed cell foams: Emissions during manufacturing, in-use phase and end-of life

Emissions =		Total HFC used in manufacturing (t) * First year loss (EF)
	+	HFK in foam in use (Bank, t) * annual loss (EF)
	+	End-of-life loss (t)
	-	Recovery and destruction (t)



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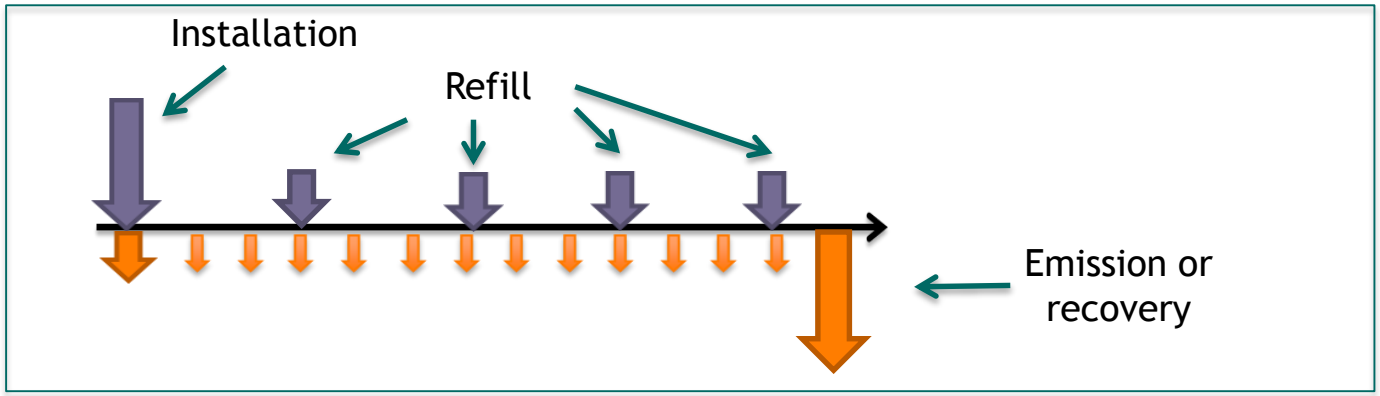
Refrigeration and Air Conditioning

- Emissions during installation, use (leakage) and decomissioning
- Sub-applications:
  - Domestic refrigeration
  - Commercial refrigeration
  - Industrial processes
  - Transport refrigeration
  - Stationary air-conditioning
  - Mobile air-conditioning



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Tier 1a/b Method (on Application level)

- Only applicable if this sector is not a key category
- Assumes 15% leakage rate (weighted average across all sub-applications)
- Assumes 15 years equipment lifetime
- Some other assumptions also built into model
- Data needed:
  - Sale of specific refrigerant
  - Year of introduction of refrigerant
  - Growth rate in sales of new equipment
  - Import / export of equipment
- Back-calculates development of banks
- Models transition from new to mature market

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Tier 1 Refrigeration
Argentina - HFC-143a

HFC-143a

Current Year	2005

Use in current year - 2005 (tonnes)	Data Used Here
Production of HFC-143a	800
Imports in current Year	200
Exports in current year	0
Total new agent to domestic market	*1000*

Year of Introduction of HFC-143a	1998
Growth Rate in New Equipment Sales	3.0%

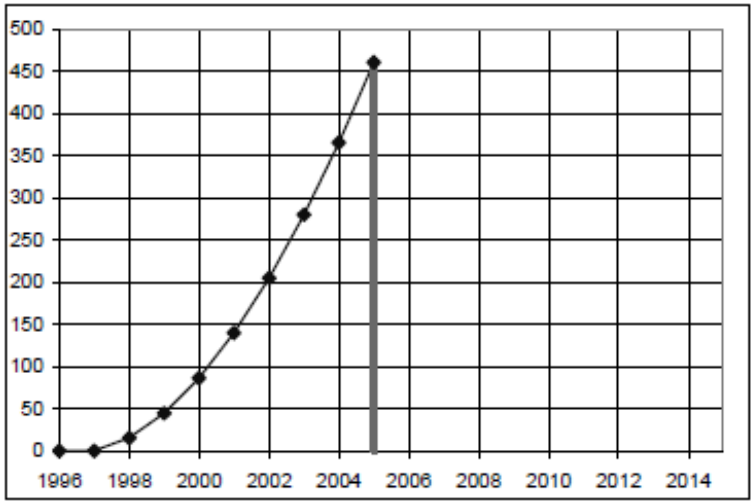
Tier 1 Defaults	
Assumed Equipment Lifetime (years)	15
Emission Factor from installed base	15%
% of HFC-143a destroyed at End-of-Life	0%

Summary

Country: Argentina
Agent: HFC-143a
Year: 2005

Emission: 460.7 tonnes

In Bank: 3071.1 tonnes



Estimated data for earlier years	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Production	0	0	81	167	259	355	458	566	680	800
Agent in Exports	0	0	0	0	0	0	0	0	0	0
Agent in Imports	0	0	20	42	65	89	114	141	170	200
Total New Agent in Domestic Equipment	0	0	102	209	323	444	572	707	850	1000
Agent in Retired Equipment	0	0	0	0	0	0	0	0	0	0
Destruction of agent in retired equipment	0	0	0	0	0	0	0	0	0	0
Release of agent from retired equipment	0	0	0	0	0	0	0	0	0	0
Bank	0	0	102	296	575	933	1365	1867	2437	3071
Emission	0	0	15	44	86	140	205	280	365	461

Tier 2 Method

- Calculation on sub-application level
- Data needed for sub-applications:
  - Refrigerant choice (type(s) of HFC)
  - Typical refrigerant charge
  - Equipment lifetime
  - Emission factor during operation (leakage rate)
  - Emission factor at servicing
  - Emission factor at end-of-life (depends on recovery)
- Derives the total stock of equipment for each sub-application -> refrigerant banks

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Tier 2b Mass-balance Approach

- Particularly applicable to refrigeration and AC, but can lead to underestimates when equipment stocks are growing
- Quantity of gas used for refilling is used as a proxy for emissions, since emissions (leakage) from equipment is assumed to be replaced by new gas
- Adjust for gas used in new equipment (no emissions)
- Adjust for decomisioning (emissions or recovery)

Emissions =		Annual sales of new refrigerant (t)
	-	Total charge of new equipment (Bank, t)
	+	Original total Charge of retiring equipment (t)
	-	Amount of intentional destruction (t)

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Tier 2a Emission-Factor Approach

- Emissions from each sub-application at year t calculated separately for:
  - Management of containers
  - Charging of refrigerant
  - Annual emissions from equipment banks (leakage and servicing)
  - Emissions at end of life

Emissions =		Emission containers (t)
	+	Emission charging new (t)
	+	Emission lifetime (t)
	+	Emission end-of-life (t)

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TABLE 7.9
ESTIMATES[1] FOR CHARGE, LIFETIME AND EMISSION FACTORS FOR REFRIGERATION AND AIR-CONDITIONING SYSTEMS

Sub-application	Charge (kg)	Lifetimes (years)[2]	Emission Factors (% of initial charge/year)[3]		End-of-Life Emission (%)	
Factor in Equation	**(M)**	**(d)**	**(k)**	**(x)**	**($\eta_{rec,d}$)**	**(p)**
			Initial Emission	**Operation Emission**	**Recovery Efficiency[4]**	**Initial Charge Remaining**
Domestic Refrigeration	$0.05 \le M \le 0.5$	$12 \le d \le 20$	$0.2 \le k \le 1$	$0.1 \le x \le 0.5$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Stand-alone Commercial Applications	$0.2 \le M \le 6$	$10 \le d \le 15$	$0.5 \le k \le 3$	$1 \le x \le 15$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Medium & Large Commercial Refrigeration	$50 \le M \le 2000$	$7 \le d \le 15$	$0.5 \le k \le 3$	$10 \le x \le 35$	$0 < \eta_{rec,d} < 70$	$50 < p < 100$
Transport Refrigeration	$3 \le M \le 8$	$6 \le d \le 9$	$0.2 \le k \le 1$	$15 \le x \le 50$	$0 < \eta_{rec,d} < 70$	$0 < p < 50$
Industrial Refrigeration including Food Processing and Cold Storage	$10 \le M \le 10{,}000$	$15 \le d \le 30$	$0.5 \le k \le 3$	$7 \le x \le 25$	$0 < \eta_{rec,d} < 90$	$50 < p < 100$
Chillers	$10 \le M \le 2000$	$15 \le d \le 30$	$0.2 \le k \le 1$	$2 \le x \le 15$	$0 < \eta_{rec,d} < 95$	$80 < p < 100$
Residential and Commercial A/C, including Heat Pumps	$0.5 \le M \le 100$	$10 \le d \le 20$	$0.2 \le k \le 1$	$1 \le x \le 10$	$0 < \eta_{rec,d} < 80$	$0 < p < 80$
Mobile A/C	$0.5 \le M \le 1.5$	$9 \le d \le 16$	$0.2 \le k \le 0.5$	$10 \le x \le 20$[5]	$0 < \eta_{rec,d} < 50$	$0 < p < 50$

[1] Based on information contained in UNEP RTOC Reports (UNEP-RTOC, 1999; UNEP-RTOC, 2003)

[2, 3] Lower value for developed countries and higher value for developing countries

[4] The lower threshold (0%) highlights that there is no recovery in some countries.

[5] Schwarz and Harnisch (2003) estimates leakage rates of 5.3% to 10.6%; these rates apply only to second generation mobile air conditioners installed in European models in 1996 and beyond.

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Tier 2a

Emissions all containers	=	Bulk gas market
	*	emission factor
Emission charging new	=	Amount charged (sub-application)
	*	Emission factor
Emission lifetime	=	Amount banked (sub-application)
	*	Leakage rate (emission factor)
Emission end-of-life	=	Initial charge
	*	Residual charge (%)
	*	(1 – recovery efficiency at disposal)

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Fire Protection

- Emissions calculated from bank and average leakage rate (emission factor)
- Adjustment for recovery release or loss
- Spreadsheat similar to refrigeration tier 1a/b can be used.

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SF_6 from Electric Equipment

- Dealt with in IPCC 2006 Guidelines, Chapter 8
- Calculation principles for Gas insulated switchgear (GIS) similar with those used for refrigeration
- Tier 1: Default emission factors
- Tier 2: Country specific emission factor
- Tier 3: Hybrid method – Emissions by life cycle stage of equipment

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SF_6 – Norwegian Reporting on Installation Level

- **Bank of gas in equipment** (Previous total + New Installations- Decomissioned Installations)
- **Bank of gas in containers** (Previous total + gas purchased +gas recovered – gas filled on equipment – gas delivered for destruction)
- **Data on Import, export, sale and purchase of gas**
- **Mass - balance - approach:** Emissions = refill (and compensate for change in stock, new equipment, decommissioning, production….)
- **Validity of calculation can be checked over time:** Can gas imported be accounted for?

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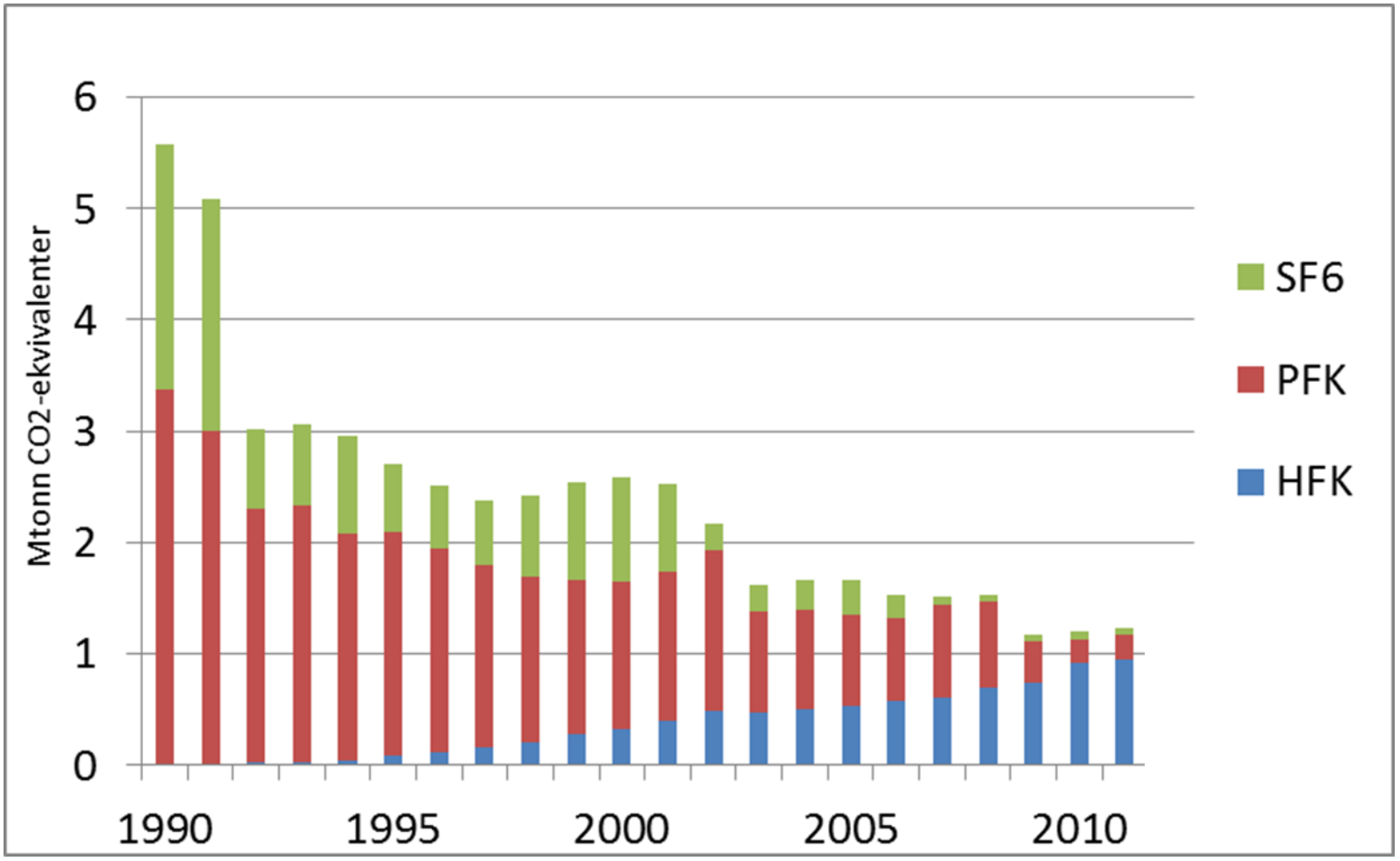
Emissions in Norway - Total



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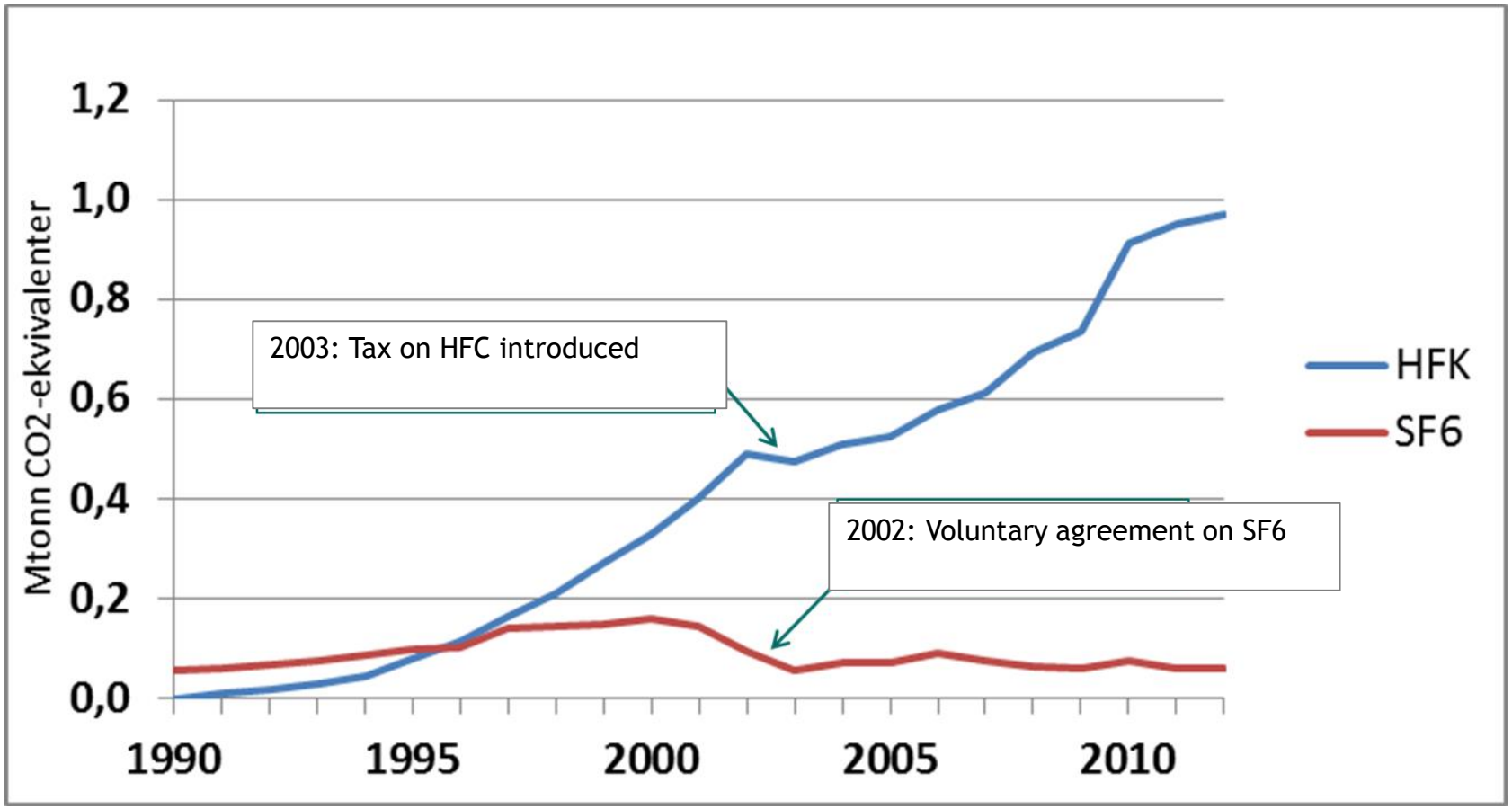
Emissions in Norway – from Products



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Additional Information

- **Report - Emissions from consumption of HFCs, PFCs and SF6 in Norway:** http://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/emissions-from-consumption-of-hfcs-pfcs-and-sf6-in-norway

- **Report - Emissions of HFCs and PFCs from product use in Norway:** http://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/emissions-of-hfcs-and-pfcs-from-product-use-in-norway

- **Report – The Norwegian Emission Inventory 2013:** http://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/the-norwegian-emission-inventory-2013

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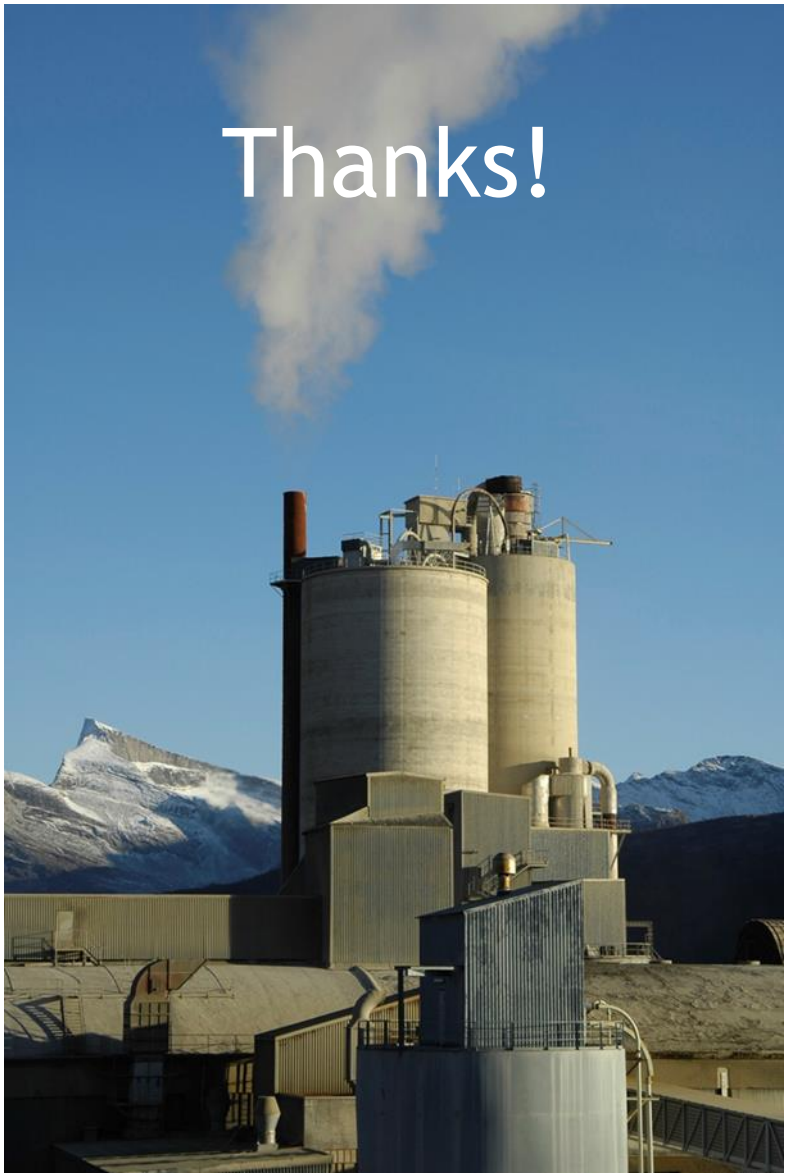
Thanks!



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