An Inventory for Greenhouse Gas Emissions and Impacts in California from Insulating and Buoyancy Foams

California Air Resources Board Contract 07-312

Technical Seminar

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Background (1)

- The AB 32 Scoping Plan identified foam insulation containing high-global warming potential (GWP) greenhouse gases as a sector of interest for possible mitigation efforts, as summarized in the Scoping Plan measure for Foam Recovery and Destruction
- Sources of high-GWP foam insulation include building insulation, appliances such as refrigerator-freezers and water heaters, transport refrigerated units (TRUs or “reefers”), and miscellaneous uses such as marine buoyancy
- Typically, the high-GWP GHGs within the foam are released when the product reaches its useful end-of-life or thereafter when it becomes a waste material
- Historically, insulating foam has been manufactured using foam blowing agents (also called foam expansion agents) that are high-GWP GHGs, which include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs)

Background (2)

- Foam expansion agents typically have global warming potentials thousands of times greater than carbon dioxide
- In addition to being high-GWP greenhouse gases, CFCs and HCFCs are also ozone-depleting substances (ODSs) that destroy the protective stratospheric ozone layer
- The California Climate Action Team initially examined hydrofluorocarbon (HFC) reduction strategies, but also realized that greater GHG reductions would be possible if Ozone Depleting Substances (ODSs) were additionally considered
- While not included in the Kyoto Protocol, nor in AB 32, ODSs have a large and ongoing impact because large banks of these chemicals still exist in the building stock and elsewhere
- These banks will eventually be emitted into the atmosphere during use or at end-of-life or thereafter if not properly recovered and destroyed

Background (3)

- The central proposition behind this project is that it could make environmental sense from a climate policy perspective to mitigate emissions by:-

  a. reducing current reliance on high-global warming potential (GWP) blowing agents
  b. separating and diverting ozone-depleting substance (ODS) and hydro fluorocarbon (HFC) containing foams out of the waste stream to be processed in ways that avoid ozone depletion and greenhouse gas emissions

  …….and that it is practicable to do so

- The inventory and assessment of potential mitigation strategies are designed to help confirm or dismiss this proposition prior to a more in depth assessment of policy options

- The outputs from this project will assist the California Air Resources Board in developing and implementing strategies that contribute to the State of California reaching its goal of carbon dioxide-equivalent (CO_2-eq.) greenhouse gas (GHG) emission reductions to 1990 levels by 2020

Project Objectives

- Characterize foam blowing agent banks according to product/application
- Characterize current foam production, use, and end-of-life fate according to the main foam using sectors
- Characterize ODS phase-out, replacement, and not-in-kind technology trends according to product/application
- Develop an emissions model based on collected blowing agent, foam and phase-out data to indicate emissions now and in 2020 under business-as-usual (BAU) and other scenarios
- Prepare reports including discussions and analyses, as well as a bank and emissions model based on a life cycle assessment showing BAU and the impacts of potential control strategies in 2020

Project Overview

- The project methodology involved:

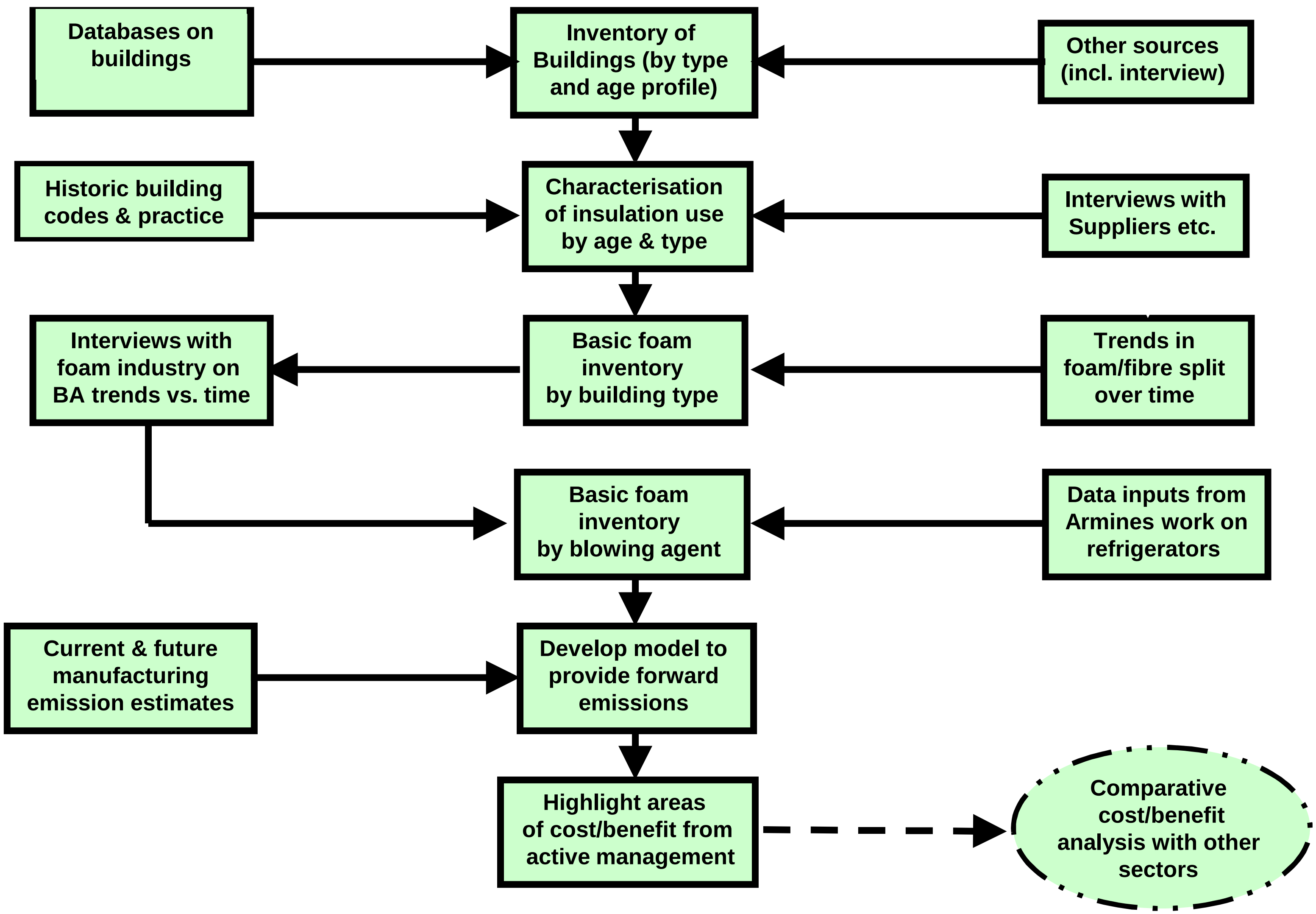
  a. the study of the existing literature
  b. the development of a research plan
  c. the development of tools and materials to be used in the survey process
  d. a extensive survey process
  e. the analysis of results
  f. the development of the spreadsheet based blowing agent banks and emissions model

- Surveying of 302 organizations responsible for the production, installation, use, and end-of-life management of foams that contain ODSs or HFCs

- Development of a foam banks and emissions model characterizing the distribution of foams and their greenhouse gas containing blowing agents across different end-use sectors and the foam life-cycle

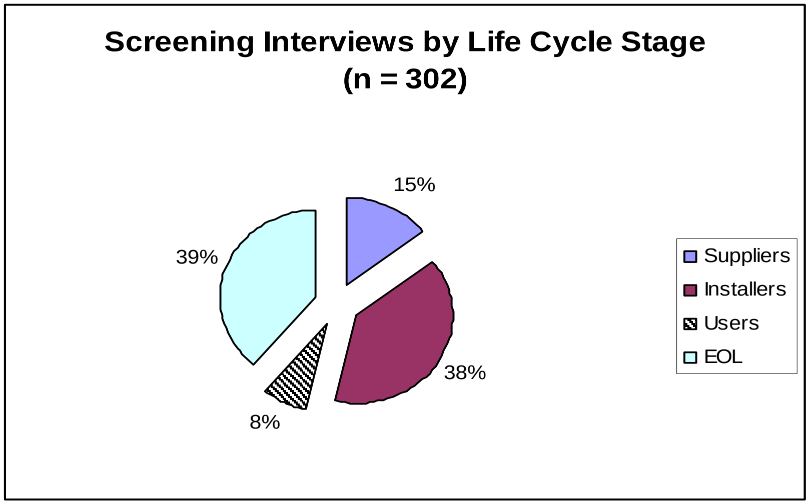
- Identification of potential greenhouse gas mitigation options and their climate impact in 2020

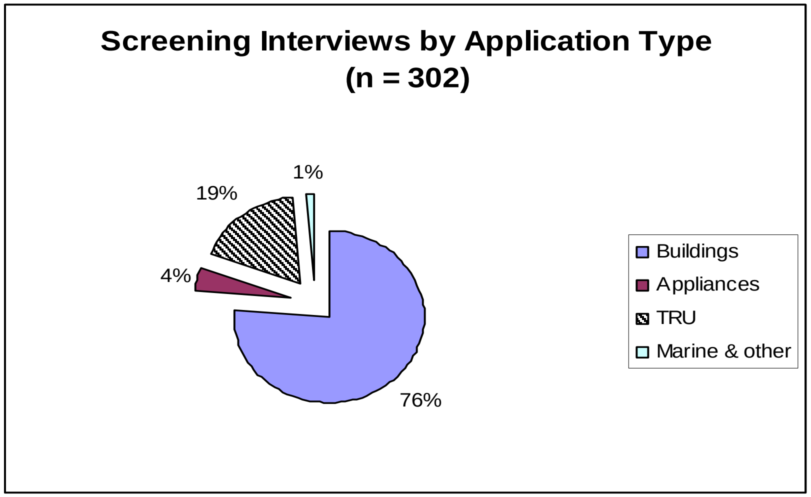
Summary of Project Process



Interviews & Data Analysis (1)

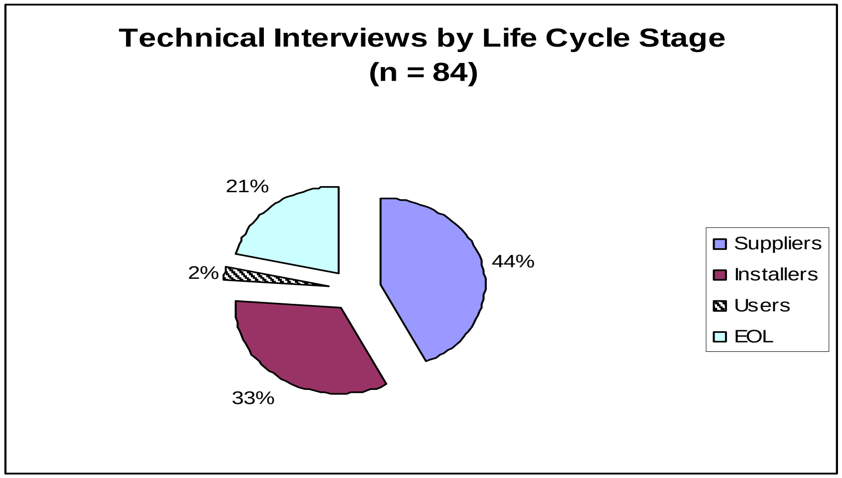
- Comprehensive survey/interview process
- Provided bottom-up data inputs to the project
- 302 screening interviews
- Main LCA focus was on Installers and End-of-Life
- Main Applications focus was on Buildings and TRU

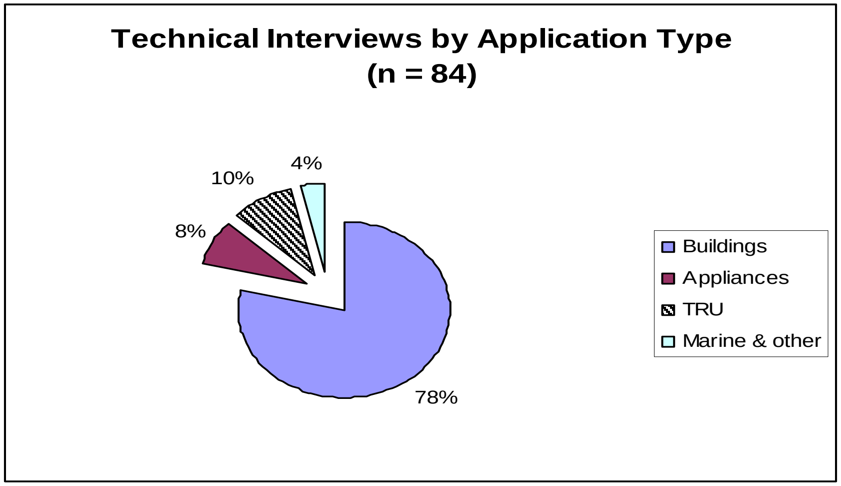




Interviews & Data Analysis (2)

- 84 technical interviews
- From screening interviews & delivery team own networks
- More depth on Life Cycle aspects of supply, installation and end-of-life management
- In-depth review of Applications to filled data gaps





ODS/GHG Bank & Emissions Modelling

Preliminary Model

- ODS/HFC/HC volumes in metric tons
- Segmentation per main application
- Segmentation by banks
- Segmentation by emissions

Full Model

- Disaggregated stock, foam and blowing agent volumes
- Distribution by blowing agent species
- Distribution by product type
- Up to date set of values for leakage rates across the foam life cycle
- Assist in ascertaining GHG emissions in terms of CO_2 -eq. from BAU and the potential control strategies

In-State Foam Production (1)

Extruded Polystyrene (XPS)	Expanded Polystyrene (EPS)
•One known producer operated between 1960 and 2009 using over 35,500 tons of blowing agents •With around 25% XPS market share in the buildings application, this plant would have met practically all of California's demand between 1960 and 2009	•Expanded polystyrene was not considered by this project •This type of foam is generally used for packaging applications and has never used ozone depleting substances or HFCs as blowing agents



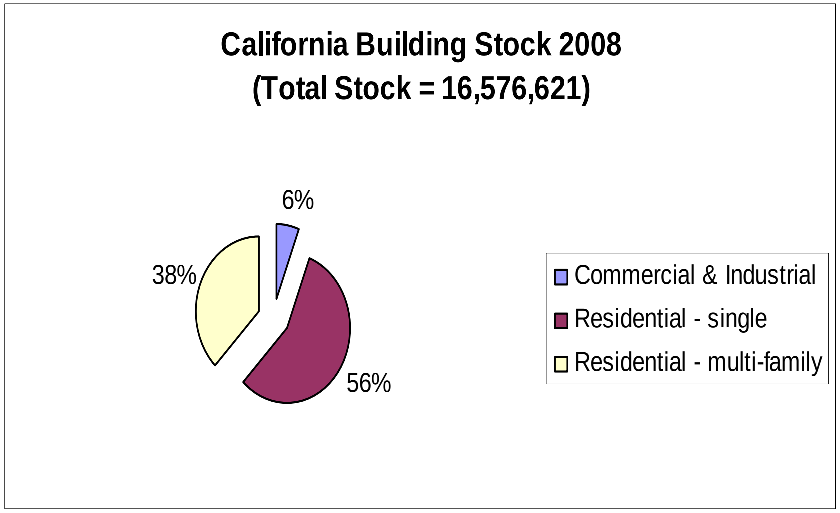

In-State Foam Production (2)

Polyurethane (PUR/PIR)

•No record of collective foam volume produced across a multiple product mix, but emissions would be relatively small	•PUR Spray foam is using HFC-245fa and PUR panels use pentane blends. They all changed from HCFC-141b around 2005
•There are two PU panel producers in California and there are at least 20 spray-foam contractors, together producing an estimated 9,800 tons of PUR/PIR foam/year – most of which is boardstock or pour-in-place (PIP) foam	•Polyisocyanurate (PIR) formulations have historically used CFC-11, before switching to HCFC-141b and then eventually converted to hydrocarbons about 10 years ago

Building Stock Data

- Detailed buildings stock data for residential, non-residential and commercial buildings from a variety of sources
- Building stock, stock turnover, stock additions and vintage data have been integrated and further developed in Caleb's banks and emissions model
- There were over 16 million buildings in California in 2008, of which the majority was residential single-family dwellings

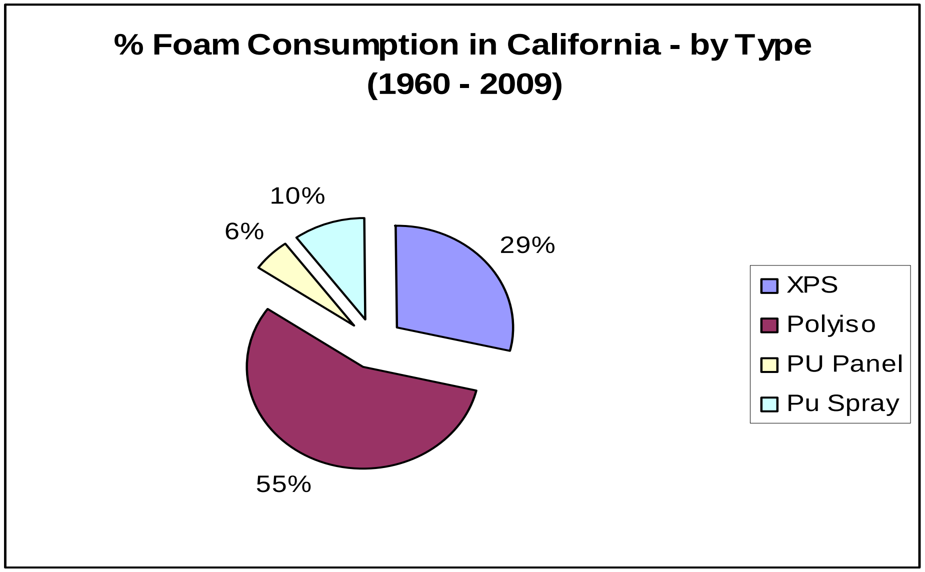


2008 CALEB ESTIMATE OF BUILDING STOCK (NUMBER OF BUILDINGS)

Building Use	Existing Stock	New Starts	Demolition	Revised Stock
Single Family Homes	9,179,595	224,798	91,796	9,312,597
Multi Family Homes	6,100,700	237,743	61,007	6,277,436
Commercial	944,436	61,041	18,889	986,588
Total	***16,224,730***	***523,583***	***171,692***	***16,576,621***

Foam in Buildings

- A variety of foam types are used in building insulation. The relative market shares are driven by building code changes as well as wider supply, demand and cost factors
- The figure shows a Caleb estimate of the average percent share of total insulation foam consumption for the period 1960 to 2009 for new building and refurbishment
- In 2008, foam insulation in buildings was split roughly equally across the main building uses



CALEB ESTIMATES OF FOAM VOLUME IN BUILDINGS (m3)

Building Use	Foam in Buildings	New Foam	Refurbishment Foam	Decommissioned Foam	Foam in Buildings - Revised
Single Family Homes	9,802,172	513,816	20,982	162,726	10,499,696
Multi Family Homes	12,763,393	905,673	23,240	161,976	13,854,282
Commercial	12,338,548	985,537	30,488	120,298	13,474,871
Total	***34,904,113***	***2,405,026***	***74,710***	***445,000***	***37,828,849***

Buildings Related Blowing Agent Use & Substitutions (1)

- Major US building insulation producing companies, such as Atlas Roofing, Firestone, RMAX, and Johns Manville have shifted from HCFC-141b to using pentane
- Pentane is less costly than HFC-245fa and, given the high GWP of these substances, pentane is environmentally more sustainable
- Substitution rates are specific to foam types and Caleb has summarized the changes over time, as can be seen in the tables

BUILDINGS: - SUMMARY OF POLYISO B.A SUBSTITUTIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	100%	0%	0%	0%
1993	75%	25%	0%	0%
1994	50%	50%	0%	0%
1995	25%	75%	0%	0%
1996	0%	100%	0%	0%
1997	0%	100%	0%	0%
1998	0%	100%	0%	0%
1999	0%	100%	0%	0%
2000	0%	95%	5%	0%
2001	0%	80%	10%	10%
2002	0%	70%	20%	10%
2003	0%	30%	10%	60%
2004	0%	15%	5%	80%
2005	0%	0%	5%	95%
2006	0%	0%	5%	95%
2007	0%	0%	5%	95%
2008	0%	0%	5%	95%
2009	0%	0%	5%	95%
2010	0%	0%	5%	95%

BUILDINGS: - SUMMARY OF XPS B.A SUBSTITUTIONS

YEAR	CFC 12	HCFC 142b	HCFC 22	HFC 134a
1992	100%	0%	0%	0%
1993	75%	16%	9%	0%
1994	50%	33%	18%	0%
1995	25%	49%	26%	0%
1996	0%	65%	35%	0%
1997	0%	65%	35%	0%
1998	0%	65%	35%	0%
1999	0%	65%	35%	0%
2000	0%	65%	35%	0%
2001	0%	65%	35%	0%
2002	0%	65%	35%	0%
2003	0%	65%	35%	0%
2004	0%	65%	35%	0%
2005	0%	65%	35%	0%
2006	0%	65%	35%	0%
2007	0%	65%	35%	0%
2008	0%	49%	26%	25%
2009	0%	16%	9%	75%
2010	0%	0%	0%	100%

Buildings Related Blowing Agent Use & Substitutions (2)

- For thermal insulation applications (the majority of rigid foam use), mineral fiber alternatives (e.g., glass fiber [fiberglass] and mineral wool) have been, and continue to be, major not-in-kind alternatives
- Their relative benefits and limitations vary substantially, both between products within a category and between applications
- This makes a generic conclusion about preferences impossible

BUILDINGS: - SUMMARY OF PU PANEL B.A SUBSTITUTIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	100%	0%	0%	0%
1993	75%	25%	0%	0%
1994	50%	50%	0%	0%
1995	25%	75%	0%	0%
1996	0%	100%	0%	0%
1997	0%	100%	0%	0%
1998	0%	100%	0%	0%
1999	0%	100%	0%	0%
2000	0%	95%	5%	0%
2001	0%	80%	15%	5%
2002	0%	70%	20%	10%
2003	0%	30%	40%	30%
2004	0%	15%	45%	40%
2005	0%	0%	50%	50%
2006	0%	0%	50%	50%
2007	0%	0%	50%	50%
2008	0%	0%	50%	50%
2009	0%	0%	50%	50%
2010	0%	0%	50%	50%

BUILDINGS: - SUMMARY OF PU SPRAY B.A SUBSTITUTIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	100%	0%	0%	0%
1993	75%	25%	0%	0%
1994	50%	50%	0%	0%
1995	25%	75%	0%	0%
1996	0%	100%	0%	0%
1997	0%	100%	0%	0%
1998	0%	100%	0%	0%
1999	0%	100%	0%	0%
2000	0%	95%	5%	0%
2001	0%	80%	20%	0%
2002	0%	70%	30%	0%
2003	0%	30%	70%	0%
2004	0%	15%	85%	0%
2005	0%	0%	100%	0%
2006	0%	0%	100%	0%
2007	0%	0%	100%	0%
2008	0%	0%	100%	0%
2009	0%	0%	100%	0%
2010	0%	0%	100%	0%

Current End of Life practices – Buildings (1)

- Some foam may end up as municipal solid waste (MSW) delivered to waste-to-energy plants, but C&D waste typically gets separated at waste transfer stations and foams are then land filled
- Foam insulation is not tracked separately in the 2008 Waste Characterization Study (CIWMB 2009a), but is likely to be contained in the ‘Remainder/Composite Plastics’ category (0.23% of C&D waste stream; 7,174 tons/year in four metropolitan areas – or up to 15,130 tons/year state-wide)
- This is broadly consistent with Caleb’s assessment of decommissioned foam, where 445,000 m3 of foam waste per year equates to 15,575 tons

Current End of Life practices - Buildings (2)

- Foam land filling is unlikely to change in the foreseeable future for a variety of reasons including:

  a. land fill space appearing to be readily accessible in most instances
  b. general failure to segregate demolition waste unless there is a specific mandate
  c. appearing to be the least cost option ($39 – $60/ton)
  d. the complexities of separating foams from other C&D waste fractions

- Caleb estimates that 92% of demolition foams are land filled, with 8% being diverted to open shredders for extraction of metals prior to waste foam being land filled

Alternative End of Life practices - Buildings

What drives waste diversion from land fills?

Intrinsic economic value	Mandated recovery	Leverage through Carbon Market (?)
 		 

- CAR – the Climate Action Reserve – will consider credits from direct foam incineration (waste to energy, or WTE) where the identity of the blowing agent is clear and the concentration has been established

- The cost and practicalities of diversion would be more problematic, particularly within the context of relatively low landfill disposal costs

- Carbon credits would have to be sufficiently high (and stable) to stimulate recovery and destruction in the face of the significant costs that are involved

Appliances Stock Data

- Domestic refrigerators/ freezers is the largest appliances group
- The Commercial Appliances stock data covers equipment located in large 'shed type' stores
- Appliances in other commercial premises (restaurants, hotels, cafés etc.) are grouped within the refrigerated vending machine or domestic appliances definitions

2008 APPLIANCES STOCK ESTIMATES & 2020 APPLIANCES STOCK PROJECTIONS

Appliances Stock	Existing Stock	New Additions	Decommissioned	Revised Stock
2008 Estimates				
Refrigerators/Freezers	22,142,686	2,129,442	973,422	23,298,706
Commercial Appliances	7,802	556	450	7,908
Refrigerated Vending Machines	527,641	38,055	32,779	532,917
Water Heaters	16,138,571	1,062,559	916,794	16,284,336
2020 Projections				
Refrigerators/Freezers	35,892,347	2,966,083	1,925,868	36,932,562
Commercial Appliances	8,208	595	485	8,318
Refrigerated Vending Machines	594,559	42,882	36,936	600,505
Water Heaters	15,883,665	1,096,485	1,178,230	15,801,920

Foam in Appliances

- Caleb determined the foam content (in m^3) in the existing 2007 stock and projected 2019 stock
- Caleb estimates a revised volume for the total foam banked in appliances in 2008 and project a revised volume in 2020

CALEB 2008 ESTIMATES & 2020 PROJECTIONS OF FOAM VOLUME IN APPLIANCES (m^3)

Appliances Type	In-Appliance Foam	New Foam	Decommissioned Foam	revised in-Appliance Foam
2008 Estimates				
Domestic Refrigerators	7,689,229	946,955	205,441	8,430,743
Domestic Freezers	3,253,289	367,158	108,169	3,512,278
Commercial Refrigeration	546,134	38,917	31,487	553,564
Refrigerated Vending Machines	175,422	16,695	7,215	184,902
Water Heaters	1,203,505	113,199	49,917	1,266,787
Total	***12,867,579***	***1,482,924***	***402,229***	***13,948,274***
2020 Projections				
Domestic Refrigerators	15,935,335	1,319,006	830,564	16,423,777
Domestic Freezers	6,164,247	511,411	307,757	6,367,902
Commercial Refrigeration	574,537	41,660	33,970	582,227
Refrigerated Vending Machines	260,208	18,812	15,581	263,439
Water Heaters	1,710,156	121,543	109,529	1,722,170
Total	***24,644,483***	***2,012,433***	***1,297,400***	***25,359,515***

Appliance Related Blowing Agent Use & Substitutions (1)

- For many years, the almost universal blowing agent used in refrigerator-freezers was CFC-11
- The phase-out of ozone depleting substances (ODS) in the USA was assisted by the Significant New Alternatives Program (SNAP) initiative
- During 1994, most manufacturers of refrigerator-freezers in the U.S. converted to foams using HCFC-141b

DOMESTIC REFRIGERATOR/FREEZER BLOWING AGENT SUBSTITUTIONS

Sales Year	Disposal Year	Percent of Units Disposed Annually by Blowing Agent			
		HFC-134a	HCFC-141b	HFC-245fa	HC
1996	2010	2%	98%	0%	0%
1997	2011	3%	97%	0%	0%
1998	2012	4%	96%	0%	0%
1999	2013	5%	95%	0%	0%
2000	2014	6%	94%	0%	0%
2001	2015	7%	75%	18%	0%
2002	2016	4%	45%	47%	4%
2003	2017	0%	21%	70%	9%
2004	2018	0%	0%	87%	13%
2005	2019	0%	0%	83%	17%
2006	2020	0%	0%	82%	18%
2007	2021	0%	0%	82%	18%
2008	2022	0%	0%	81%	19%
2009	2023	0%	0%	80%	20%
2010	2024	0%	0%	79%	21%
2011	2025	0%	0%	79%	21%
2012	2026	0%	0%	78%	22%
2013	2027	0%	0%	77%	23%
2014	2028	0%	0%	76%	24%
2015	2029	0%	0%	76%	24%
2016	2030	0%	0%	75%	25%

Source: Association of Home Appliance Manufacturers, (AHAM), 2010

Appliance Related Blowing Agent Use & Substitutions (2)

- HCFCs were identified as the best transition blowing agent on a path leading to the total phase-out of all ozone depleting substances with emphasis on improved energy efficiency

- These HCFC conversions were considered interim solutions until energy-efficient zero ODS options could be developed and implemented. Additionally, the HCFC substitutes were still potent greenhouse gases, although less so than CFC-11

- More recently, HFCs have been used as the foam blowing agent in appliance insulation

COMMERCIAL APPLIANCES: - B.A. SUBSTITUTIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	**100%**	0%	0%	0.00%
1993	**75%**	**25%**	0%	0.00%
1994	**50%**	**50%**	0%	0.00%
1995	0%	**100%**	0%	0.00%
1996	0%	**100%**	0%	0.00%
1997	0%	**100%**	0%	0.00%
1998	0%	**100%**	0%	0.00%
1999	0%	**100%**	0%	0.00%
2000	0%	**95%**	**5%**	0.00%
2001	0%	**80%**	**20%**	0.00%
2002	0%	**70%**	**30%**	0.00%
2003	0%	**30%**	**70%**	0.00%
2004	0%	**15%**	**85%**	0.00%
2005	0%	0%	**100%**	0.00%
2006	0%	0%	**100%**	0.00%
2007	0%	0%	**100%**	0.00%
2008	0%	0%	**100%**	0.00%
2009	0%	0%	**100%**	0.00%
2010	0%	0%	**100%**	0.00%
2011	0%	0%	**100%**	0.00%
2012	0%	0%	**100%**	0.00%
2013	0%	0%	**100%**	0.00%
2014	0%	0%	**100%**	0.00%
2015	0%	0%	**100%**	0.00%
2016	0%	0%	**100%**	0.00%
2017	0%	0%	**100%**	0.00%
2018	0%	0%	**100%**	0.00%
2019	0%	0%	**100%**	0.00%
2020	0%	0%	**100%**	0.00%

VENDING MACHINES: - B.A. SUBSTITUTIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	**100%**	0%	0%	0%
1993	**75%**	**25%**	0%	0%
1994	**50%**	**50%**	0%	0%
1995	0%	**100%**	0%	0%
1996	0%	**100%**	0%	0%
1997	0%	**100%**	0%	0%
1998	0%	**100%**	0%	0%
1999	0%	**100%**	0%	0%
2000	0%	**95%**	**5%**	0%
2001	0%	**80%**	**20%**	0%
2002	0%	**70%**	**30%**	0%
2003	0%	**30%**	**70%**	0%
2004	0%	**15%**	**85%**	0%
2005	0%	0%	**100%**	0%
2006	0%	0%	**100%**	0%
2007	0%	0%	**100%**	0%
2008	0%	0%	**100%**	0%
2009	0%	0%	**100%**	0%
2010	0%	0%	**100%**	0%
2011	0%	0%	**100%**	0%
2012	0%	0%	**100%**	0%
2013	0%	0%	**100%**	0%
2014	0%	0%	**100%**	0%
2015	0%	0%	**100%**	0%
2016	0%	0%	**100%**	0%
2017	0%	0%	**100%**	0%
2018	0%	0%	**100%**	0%
2019	0%	0%	**100%**	0%
2020	0%	0%	**100%**	0%

Appliance Related Blowing Agent Use & Substitutions (3)

- The current trend is for hydrocarbons (HCs) to replace HFCs
- Hydrocarbons are not ozone-depleting, and typically have low GWPs which results in a 97% reduction in the GHG impact from appliance insulation
- In Appliances no proven not-in-kind technologies are available at present that can meet all the requirements. Vacuum insulation panels are being used in limited but increasing quantities

WATER HEATERS: - SUMMARY OF B.A. SUBSTITUIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	100%	0%	0%	0%
1993	75%	25%	0%	0%
1994	50%	50%	0%	0%
1995	0%	100%	0%	0%
1996	0%	100%	0%	0%
1997	0%	100%	0%	0%
1998	0%	100%	0%	0%
1999	0%	100%	0%	0%
2000	0%	95%	0%	5%
2001	0%	80%	5%	15%
2002	0%	70%	5%	25%
2003	0%	30%	10%	60%
2004	0%	15%	10%	75%
2005	0%	0%	10%	90%
2006	0%	0%	10%	90%
2007	0%	0%	10%	90%
2008	0%	0%	10%	90%
2009	0%	0%	10%	90%
2010	0%	0%	10%	90%
2011	0%	0%	10%	90%
2012	0%	0%	10%	90%
2013	0%	0%	10%	90%
2014	0%	0%	10%	90%
2015	0%	0%	10%	90%
2016	0%	0%	10%	90%
2017	0%	0%	10%	90%
2018	0%	0%	10%	90%
2019	0%	0%	10%	90%
2020	0%	0%	10%	90%

Current End of Life practices - Appliances

- Major appliances are covered by the Certified Appliance Recycling (CAR) program
- Most waste foam is land filled, with the exception of the foam recovered from appliances recycled through utility programs – accounting for 14% of disposed units
- The re-use rate is approximately 39%
- The single largest pathway shows recycling of appliances without foam recovery

2008 - FATE OF DOMESTIC REFRIGERATORS & FREEZERS AT END-OF LIFE

Year	Stock	Discarded	2nd life	Recycled - foam recovery	Recycled - no foam recovery; residue Disposed
2008	23,398,708	1,020,601	398,034	145,000	477,567
		100.00%	**39.00%**	**14.00%**	**47.00%**

Transport Refrigerated Unit (TRU) Stock Data

- Total in-use TRUs during 2003 to 2009 range from 30,000 to 38,000 units, depending on the fate of the state economy
- Average TRU life-cycle is 15 years and there has been a steady build-up of units over the years
- There may also be a build-up of ‘parked’ TRUs – held at the major ports for disposal in California
- This could not be substantiated by Caleb, and is therefore not included in our analysis

2008 TRU/REEFER POPULATION_

TRU Type	2007 Stock	New Stock	Decomissioned Stock	2008 Stock
Road/Trailer	32,056	4,362	3,206	33,212
Rail	2,167	303	217	2,253
Sea/Reefer	1,189	150	119	1,220
Total	**35,412**	**4,815**	**3,542**	**36,685**

Foam in Transport Refrigerated Units (TRUs)

- Rigid foam is used in refrigerated vans, rail refrigerated units, and ship reefers and also for repair and maintenance of these units
- During the mid 1990s, the market increased at an average rate of 19%/year – especially for refrigerated vans
- Based on TRU stock data, Caleb determined the foam content (in m^3) in the existing 2007 stock (Foam in TRUs)

CALEB ESTIMATES OF FOAM VOLUME IN TRUs (M^3)

TRU Type	Foam in TRUs	New Foam	Decomissioned Foam	Revised Foam in TRUs
Road/Trailer	297,956	27,262	14,164	311,054
Rail	24,329	2,271	1,256	25,344
Sea/Reefers	8,061	675	433	8,303
Total	**330,346**	**30,208**	**15,853**	**344,701**

TRU Related Blowing Agent Use & Substitutions

- Transition to HFCs around 2001/2 and Hydrocarbons in the last few years

TRU/REEFER: - B.A. SUBSTITUTIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	**100%**	0.00%	0.00%	0.00%
1993	**100%**	0.00%	0.00%	0.00%
1994	**80%**	**20.00%**	0.00%	0.00%
1995	**60%**	**40.00%**	0.00%	0.00%
1996	0%	**100.00%**	0.00%	0.00%
1997	0%	**100.00%**	0.00%	0.00%
1998	0%	**100.00%**	0.00%	0.00%
1999	0%	**100.00%**	0.00%	0.00%
2000	0%	**100.00%**	0.00%	0.00%
2001	0%	**80.00%**	**20.00%**	0.00%
2002	0%	**40.00%**	**60.00%**	0.00%
2003	0%	0.00%	**80.00%**	**20.00%**
2004	0%	0.00%	**80.00%**	**20.00%**
2005	0%	0.00%	**80.00%**	**20.00%**
2006	0%	0.00%	**80.00%**	**20.00%**
2007	0%	0.00%	**70.00%**	**30.00%**
2008	0%	0.00%	**60.00%**	**40.00%**
2009	0%	0.00%	**50.00%**	**50.00%**
2010	0%	0.00%	**40.00%**	**60.00%**

Current End of Life practices - TRU

- There is some uncertainty about the quantity of reefers that reach their end-of-life in California
- Approximately 25% experience a ‘second life’ at the point of disposal, and we assume a ‘first life’ lifespan of around 15 years
- Units that reach end of life are recycled in scrap metal yards. In accordance with US Clean Air Act Regulation Sections 608 and 609, refrigerant must be recovered prior to recycling by Certified Technicians
- As enforcement is sometimes difficult, it is uncertain how much refrigerant is recovered and how much is vented to the atmosphere
- Recovery of the blowing agent from the insulating foam from TRUs is not mandatory. The foam is shredded along with the rest of the unit and aggregated with other non ferrous wastes and land filled as Assorted Shredded Residues (ASR)

Marine & Other Applications Stock Data

- The main other applications for foams are in the leisure marine sectors, including leisure boats, canoes and buoyancy aids
- Other short-lived applications include cooler boxes, but these have been made with water blown foam since the 1980s
- A further minor category is non-structural walk-in cold stores

SUMMARY OF MARINE REGISTRATION & OTHER APPLICATION STOCKS

Estimated Product Stock	Existing Stock	New Additions	Decommissioned	Revised Stock
Leisure Boats	635,057	48,471	35,930	647,599
Canoes	207,446	15,899	11,374	211,971
Other -incl. Cooler boxes;buoys	10,944,373	836,179	618,565	11,161,986
Total	**11,786,876**	**900,549**	**665,869**	**12,021,556**

2008 NON STRUCTURAL COLD STORE STOCK

Estimated Product Stock	Existing Stock	New Additions	Decommissioned	Revised Stock
Walk-In Cold Stores	11,048	700	485	11,262

Foam in Marine & Other Applications

- Fiberglass Reinforced Plastics/Glass Reinforced Plastics (FRP/GRP) hull types typically have a structural foam core that contains PU or Polystyrene foam
- Marine applications – recreational boats, buoys, and repair & retrofitting account for 54% of foam use, with coolers estimated to account for the balance
- Non-structural cold stores are a relatively minor segment, and are evaluated separately

2008 - CALEB ESTIMATES OF FOAM VOLUME IN MARINE & OTHER APPLICATIONS (M^3)

Appliance Type	Foam in Equipment	New Foam	Decommissioned Foam	Revised Foam in Equipment
Leisure Boats	444,654	34,622	25,664	453,612
Canoes	23,191	1,817	1,300	23,708
Other - incl. Cooler boxes; buoys	612,958	47,782	35,347	625,393

2008 - CALEB ESTIMATES OF FOAM VOLUME IN NON STRUCTURAL COLD STORES (M^3)

Product Type	Foam in Equipment	New Foam	Decommissioned Foam	Revised Foam in Equipment
Walk-In Cold Stores	105,628	6,996	4,955	107,669

Blowing Agent Use & Substitutions in Marine & Other Applications

- Blowing Agents used for these applications are HCFC-141b for boats and coolers to a broader range (HFC-245fa; H2O/CO_2) for buoys as well as methyl formate, a low-GWP alternative

MARINE & OTHER: - SUMMARY OF B.A. SUBSTITUTIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	**100%**	0.00%	0.00%	0.00%
1993	**100%**	0.00%	0.00%	0.00%
1994	**80%**	**20.00%**	0.00%	0.00%
1995	**60%**	**40.00%**	0.00%	0.00%
1996	0%	**100.00%**	0.00%	0.00%
1997	0%	**100.00%**	0.00%	0.00%
1998	0%	**100.00%**	0.00%	0.00%
1999	0%	**100.00%**	0.00%	0.00%
2000	0%	**100.00%**	0.00%	0.00%
2001	0%	**80.00%**	**20.00%**	0.00%
2002	0%	**40.00%**	**60.00%**	0.00%
2003	0%	0.00%	**80.00%**	**20.00%**
2004	0%	0.00%	**80.00%**	**20.00%**
2005	0%	0.00%	**80.00%**	**20.00%**
2006	0%	0.00%	**80.00%**	**20.00%**
2007	0%	0.00%	**70.00%**	**30.00%**
2008	0%	0.00%	**60.00%**	**40.00%**
2009	0%	0.00%	**50.00%**	**50.00%**
2010	0%	0.00%	**40.00%**	**60.00%**

COLD STORES: - SUMMARY OF B.A. SUBSTITUIONS

YEAR	CFC 11	HCFC 141b	HFC 245fa	HC
1992	**100%**	0%	0%	0%
1993	**100%**	0%	0%	0%
1994	**80%**	**20%**	0%	0%
1995	**60%**	**40%**	0%	0%
1996	0%	**100%**	0%	0%
1997	0%	**100%**	0%	0%
1998	0%	**100%**	0%	0%
1999	0%	**100%**	0%	0%
2000	0%	**100%**	0%	0%
2001	0%	**80%**	**20%**	0%
2002	0%	**40%**	**60%**	0%
2003	0%	0%	**80%**	**20%**
2004	0%	0%	**80%**	**20%**
2005	0%	0%	**80%**	**20%**
2006	0%	0%	**80%**	**20%**
2007	0%	0%	**70%**	**30%**
2008	0%	0%	**60%**	**40%**
2009	0%	0%	**50%**	**50%**
2010	0%	0%	**40%**	**60%**

End of Life Fate – Marine & Other Minor Applications

- There are no specific programs to recover and recycle hulls in California and the retired boats tend to end up at landfill sites following mechanical destruction in auto shredders
- Following the break-up of leisure boats in auto shredders or scrap metal yards, the non-reusable materials, including hull pieces containing PU foam, are land filled as assorted shredder residues – similarly to TRUs
- Caleb assumes that 5% of canoes are discarded per year as proportion of the stock and that 10% of coolers are assumed to be discarded every year. Caleb also assumes that 5% of leisure boats are exported

Model Data Sources & Assumptions

Factor	Units	Buildings	Appliances	TRUs	Marine & Other	Comments
Growth Rate - market	%	1.5 - 5	0.95 - 7.2	0.95 - 5.5	1.5 - 5	Source: Published Rates & Caleb
Growth Rate - Building Insulation	%	0.5	N/A	N/A	N/A	Source: Caleb
Growth Rate - Building Foams	%	1-2	N/A	N/A	N/A	Source: Caleb
Buildings Demolition Rate	%	1-2	N/A	N/A	N/A	1% = Residential; 2% = Commercial; Source: Interviewees
Buildings Refurbishment Rate	%	1-2	N/A	N/A	N/A	1% = Residential; 2% = Commercial; Source: Interviewees
Average foam life time	Years	30	14-15	15	10-30	Sources: CEC & Forintek Corp. (Buildings); Armines & ICF International (Appliances); CARB-ISOR (TRUs); NMMA (Marine)
Average re-use Rate	%	N/A	25	25	N/A	Sources: Armines (Appliances); CARB-ISOR (TRU)
Foam Density	kg/m^3	32-40	30-32	40	30-35	Source: Caleb
Blowing Agent content	%	5-10	7	10	7-10	Source: Caleb
End-of-Life practices						
Export	%	0	25	25	5	Source: Caleb
Re-use	%	0	25	25	0	Sources: Armines (Appliances); CARB-ISOR (TRU)
Direct Landfill	%	92	0	0	0	Source: Interviewees
Open Shredding, then Landfill	%	8	60	75	95	Source: Interviewees
Direct Destruction	%	0	15	0	0	Source: Interviewees

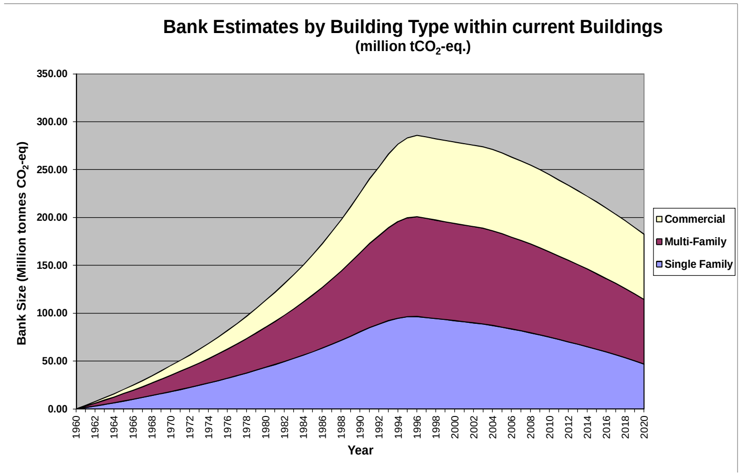
Greenhouse Gas Global Warming Potentials

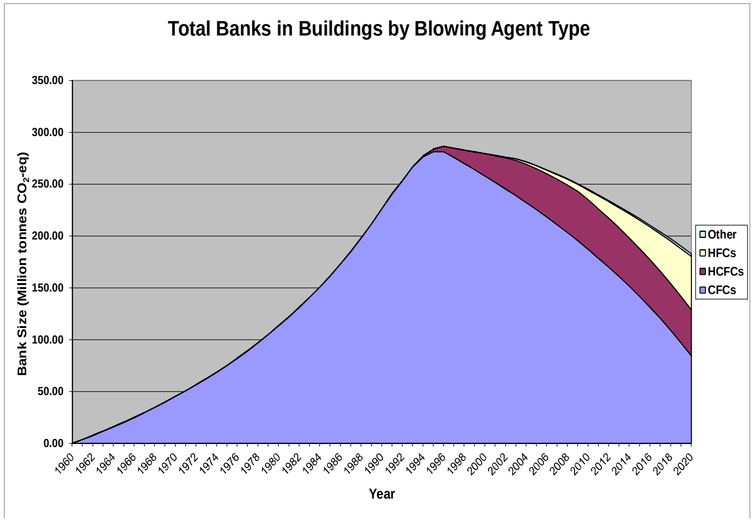
Blowing Agent	GWP SAR (1995)	GWP TAR (2001)	TEAP XX/7 (2009)	Percent Change from 1995 to 2009
CFC-11	3800	4600	4680	23%
CFC-12	8100	10600	10720	32%
HCFC-141b	n/a	700	713	2%
HCFC-142b	1800	2400	2270	26%
HCFC-22	1500	1700	1780	19%
HFC-134a	1300	1300	1410	8%
HFC-152a	140	120	122	-13%
HFC-245fa	n/a	950	1020	7%
Hydrocarbons	n/a	n/a	25	--

- For each foam blowing agent, the GWP values from the Second Assessment Report (SAR) in 1995, the Third Assessment Report (TAR) in 2001 and the 2009 UNEP TEAP Decision XX/7 Report are given
- GWP values increased between 2% - 32% for seven of nine blowing agents, HFC-152a decreased 13%, and hydrocarbons remained the same

Model Data: Buildings related Banks & Emissions (1)

- Banks of high-GWP gases reached a peak of approximately 286 million tCO_2-eq in 1996
- They have reduced by around 40 million tCO_2-eq to date and are expected to reduce by a further 60 million tCO_2-eq by 2020
- Accumulations are equally spread between buildings uses
- The high GWP of CFCs is the primary cause for the reduction in the bank size over the next 10 years
- This rapid decline in the CFC bank within buildings points to the significant opportunity that exists to avoid emissions at end-of-life



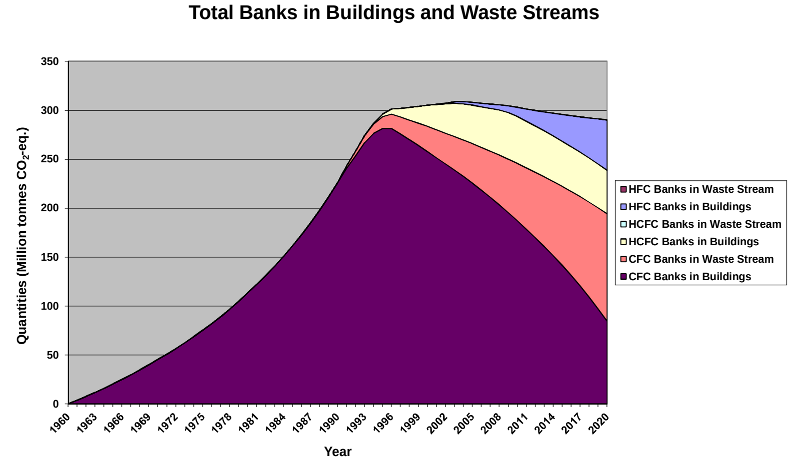


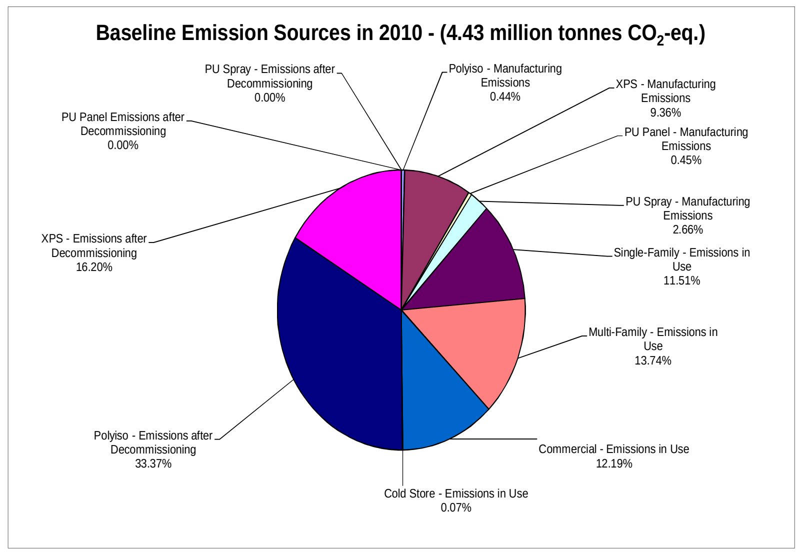
Model Data: Buildings related Banks & Emissions (2)

- In the baseline scenario, not all CFCs will be directly emitted. The figure illustrates the likely accumulation of CFCs already occurring in the waste stream

- CFCs in the waste stream in 2010 are estimated at 59 million tCO_2-eq. and without intervention, banks will reach around 110 million tCO_2-eq. by 2020

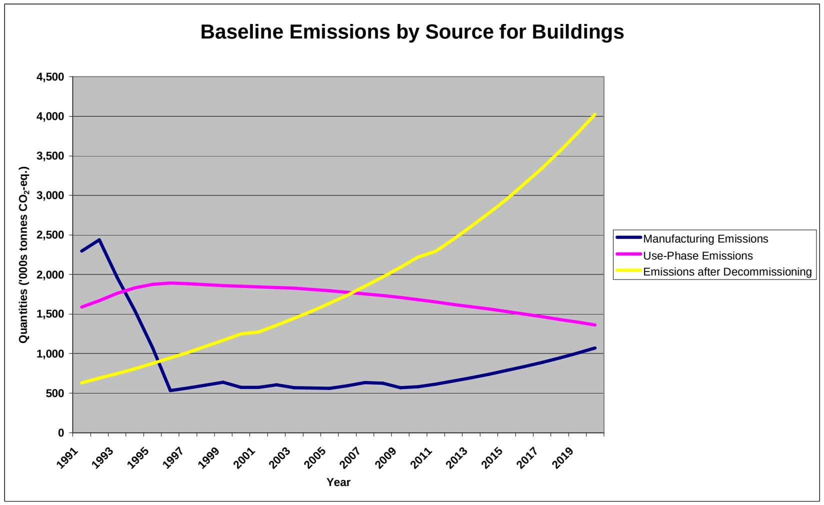
- Caleb estimates the current emissions from the various sources at 4.43 million tCO_2-eq. – split between 0.60 $MMTCO_2E$ from HFCs, and 3.83 $MMTCO_2E$ from ODS

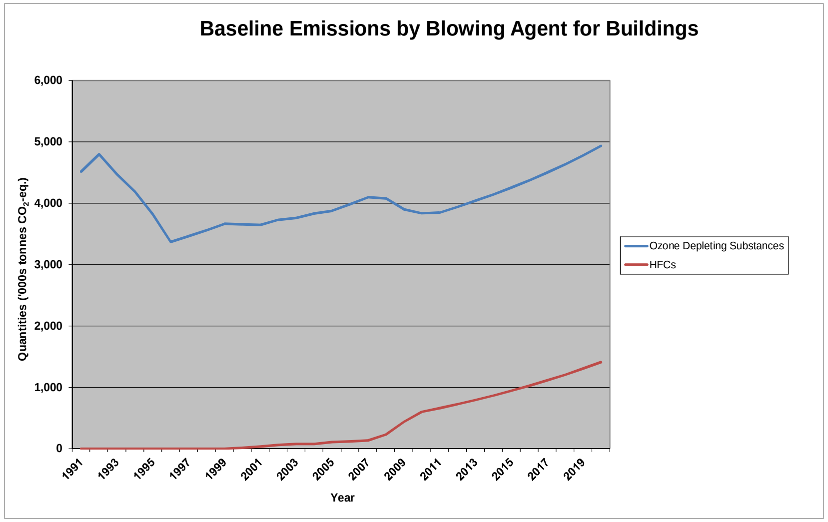




Model Data: Buildings related Banks & Emissions (3)

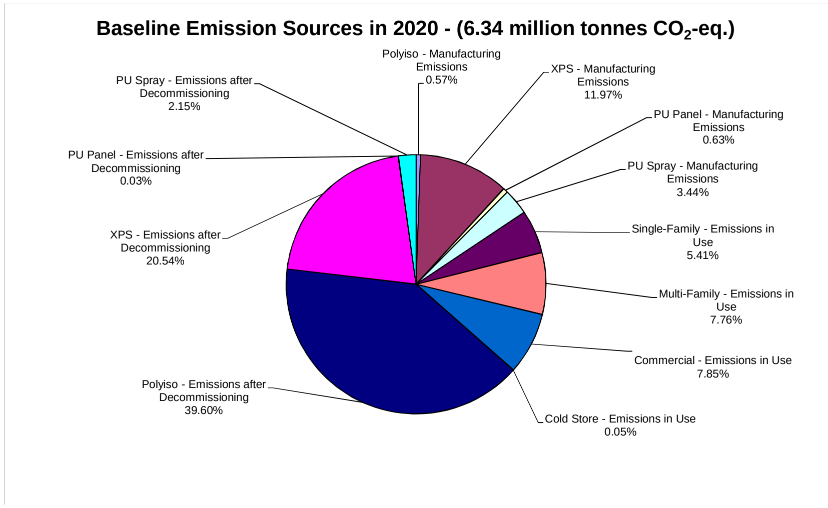
- Blowing agent emission trends from the building sector reveal that, after 2007, the decommissioning stage represents the largest single source of such emissions
- By 2020 they are expected to exceed 4 million tCO_2-eq. annually under the baseline scenario, all of which are associated with ozone depleting substances
- Caleb also expects an increase in the climate impact of manufacturing emissions as higher GWP HFCs replace HCFCs in a number of key applications

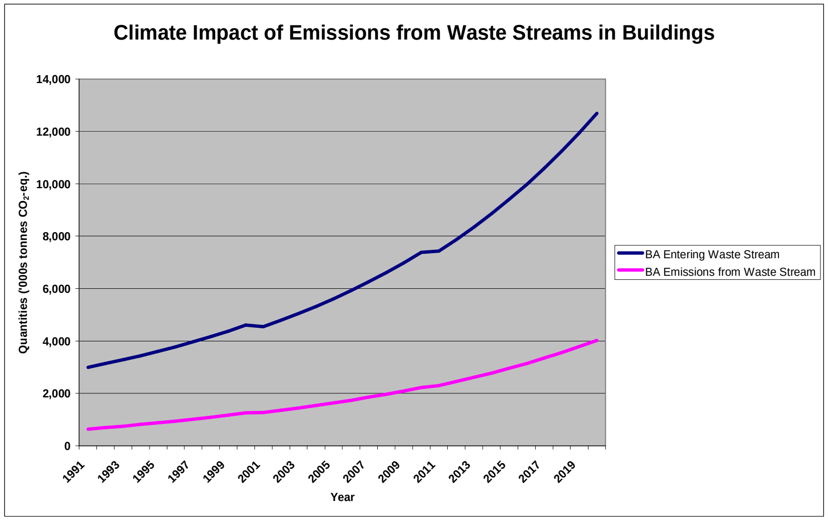




Model Data: Buildings related Banks & Emissions (4)

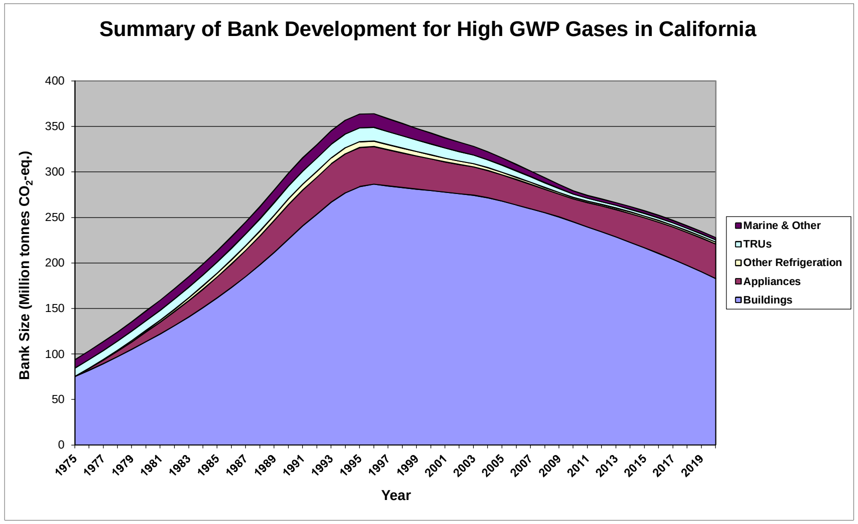
- Total emissions are expected to grow to 6.34 million tCO_2-eq by 2020, or which 1.40 $MMTCO_2E$ are from HFCs, and 4.94 $MMTCO_2E$ from ODS
- Flows into the waste stream are roughly three times as great as the annual emissions arising from them in the period to 2020
- Intervention at the point that foams reach the waste stream could have significantly impact, but many of the avoided emissions will be in the post-2020 period

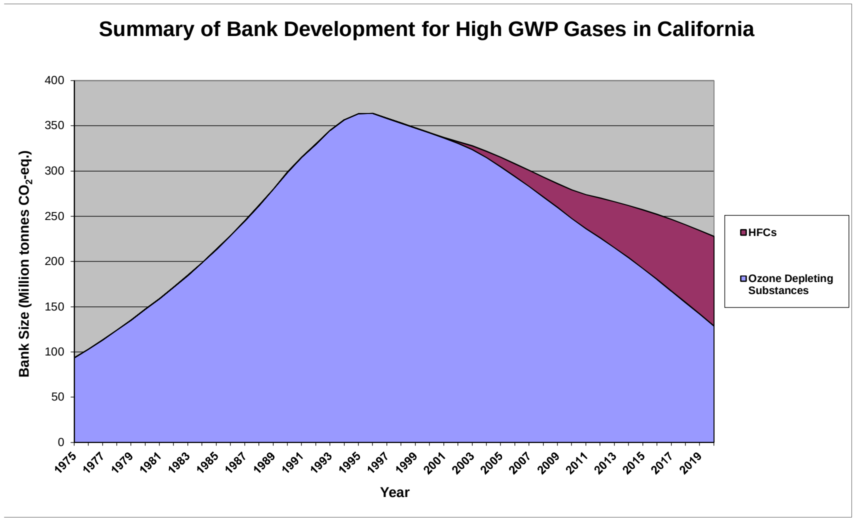




Model Data: Comparison of Buildings with other Foam containing sectors (1)

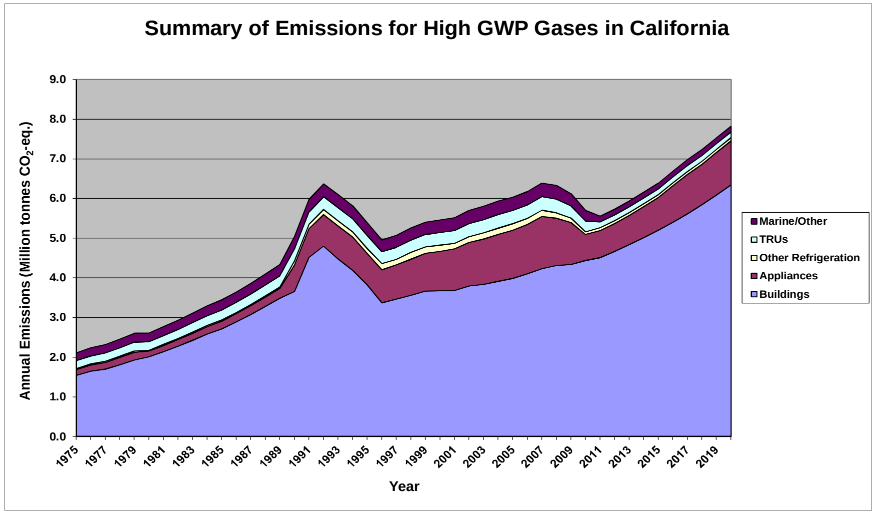
- Buildings constitute the biggest single location for ODS Banks
- The banks of all other sources combined never exceed 25% of the total, but may be more emissive.
- Some banks in the other sectors show rapid decline when compared with buildings
- Domestic appliances represent an exception where the widespread adoption of HFC-245fa as a substitute for HCFC-141b has resulted in a continued growth in bank size since 2005

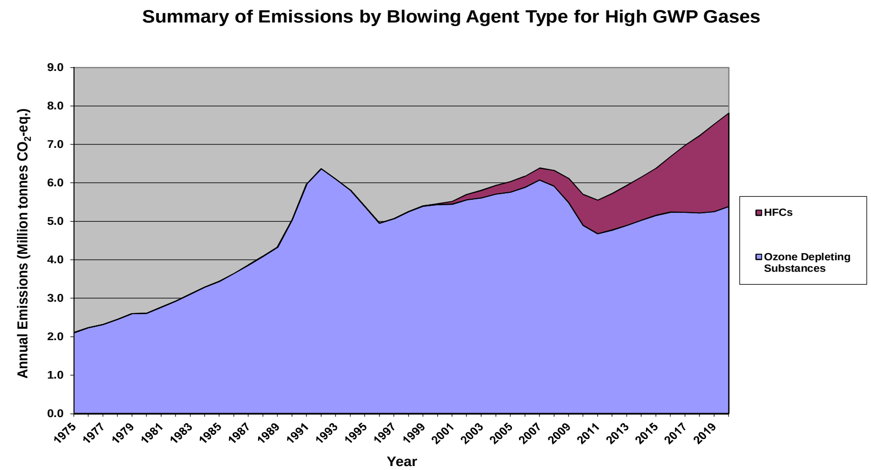




Model Data: Comparison of Buildings with other Foam containing sectors (2)

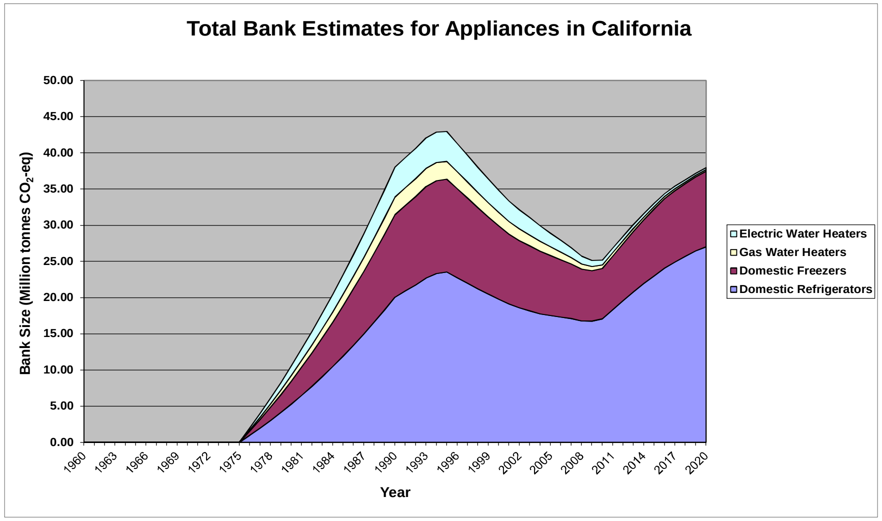
- A similar story exists for emissions, despite the shorter lifetimes associated with many of the products and equipment containing ODS-banks
- At their peak, the emissions from sources other than buildings reach 34% of the total annual emissions
- The buildings sector should be the main focus in policy terms, although there could be some cost-effective win-wins where significant banks of high GWP greenhouse gases still remain in the appliances sectors

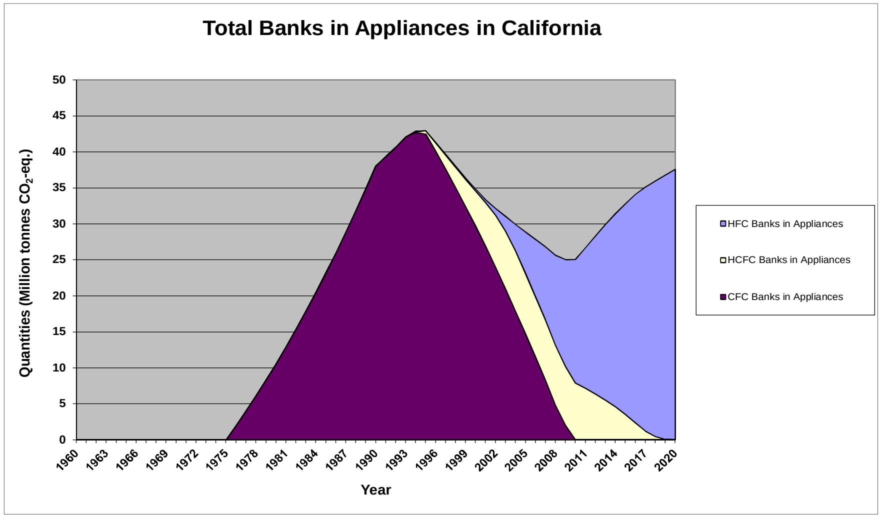




Model Data: Appliance Related Banks and Emissions (1)

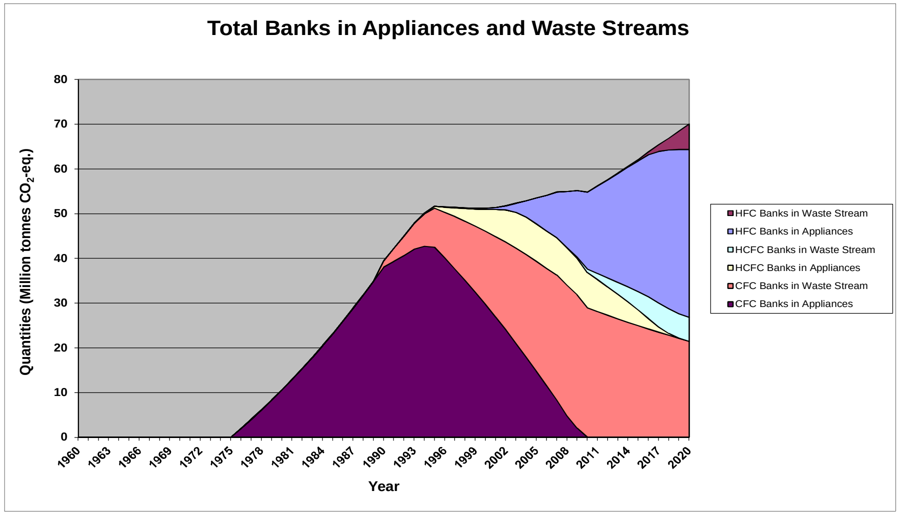
- The bank assessment in the appliance sector is based on the assumption that the average lifetime of these units is 14-15 years
- Both figures illustrate the importance of the uptake of HFCs in the domestic refrigerator and freezer products and also show the impact of previous transitions out of high GWP gases in the water heater sector
- HFCs are the only significant component of the appliances bank by 2020

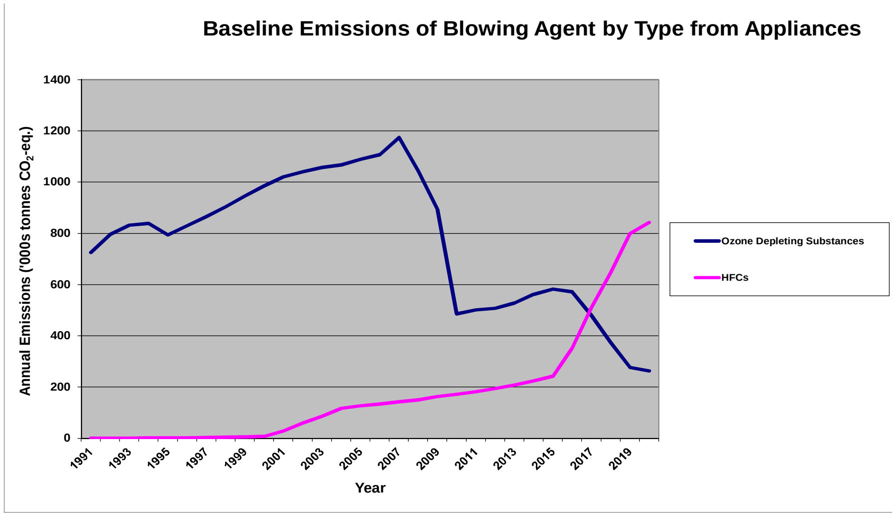




Model Data: Appliance Related Banks and Emissions (2)

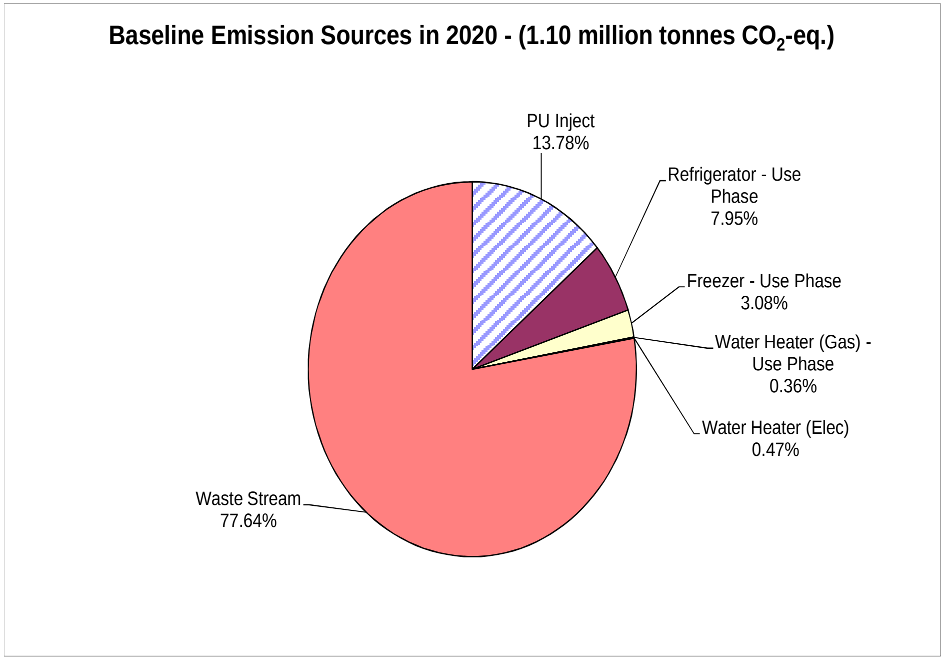
- The quantity of high GWP blowing agents in the waste stream is a greater component than in the buildings sector because of shorter lifetimes in the appliance sector
- Peak emission took place in 2007 at the point where the largest number of CFC-containing refrigerators would have been decommissioned
- From 2010 onward, growth in GHG emissions is due to HFC based appliance manufacture, and the end-of-life processing of appliances through shredders with no foam gas recovery





Model Data: Appliance Related Banks and Emissions (3)

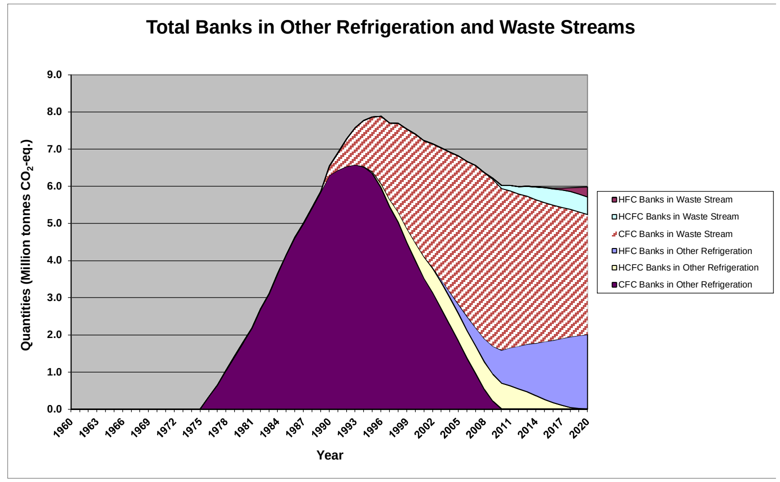
- Baseline emissions from appliances in 2020 are projected at 1.1 million tCO_2-eq from manufacturing, in-use phase, and decommissioning
- Emissions in the period after decommissioning will remain the dominant factor (~75% of total) unless measures are taken to curb them
- In-use losses are predictably low, but the relatively significant share (above 15%) ascribed to manufacturing losses highlights the on-going importance of blowing agent choice in the domestic refrigerator and freezer sector

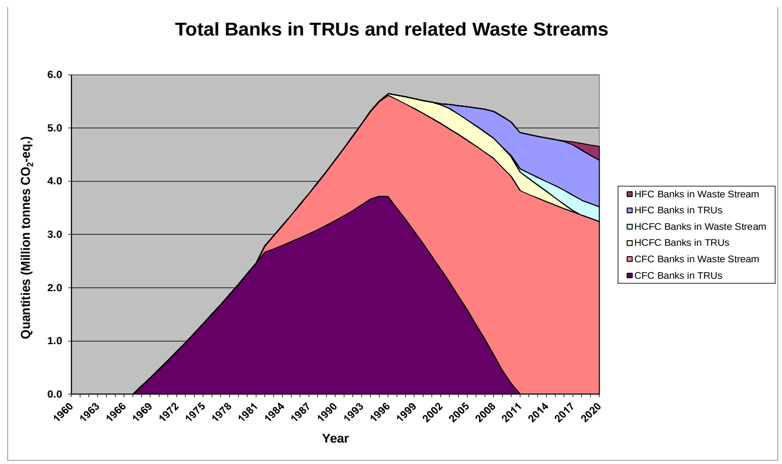


Model Data: Refrigerated Transport, Other Refrigeration, Marine and Other Applications – Banks and Emissions (1)

- In view of their relatively small contribution to both banks and emissions of high GWP gases, these sources are taken together in one section

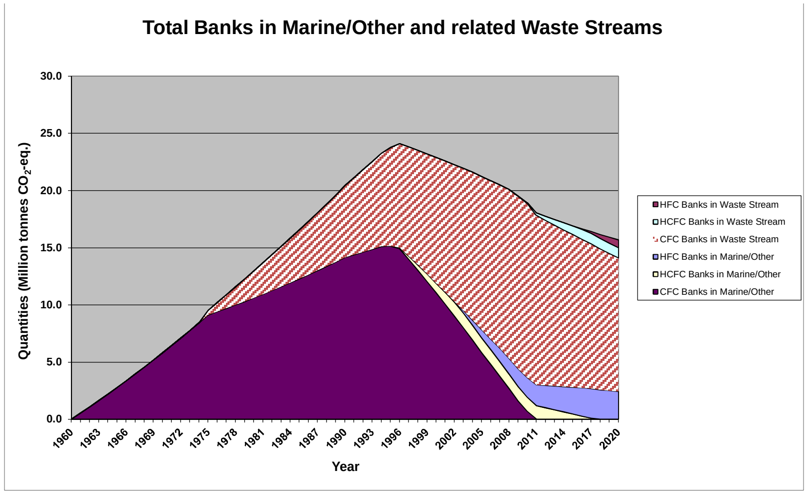
- The combined banks for these sources in 2008 is in the region of 33 million tCO_2-eq., and by 2020 they reduce to 27 million tCO_2-eq.

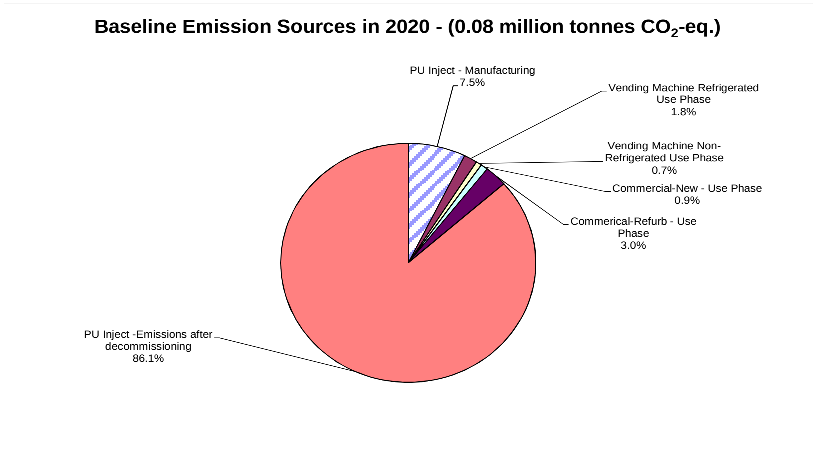




Model Data: Refrigerated Transport, Other Refrigeration, Marine and Other Applications – Banks and Emissions (2)

- Even in 2010, the most significant banks of high GWP gases are already in the waste stream, making these less favorable options for mitigation strategies

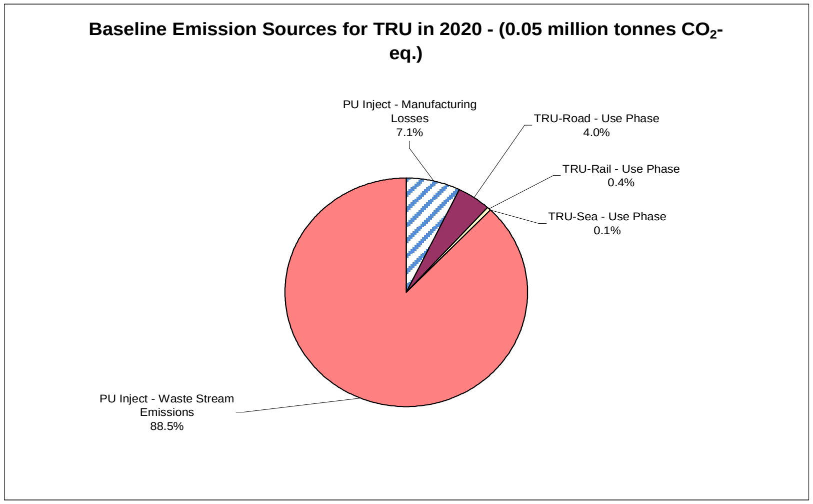


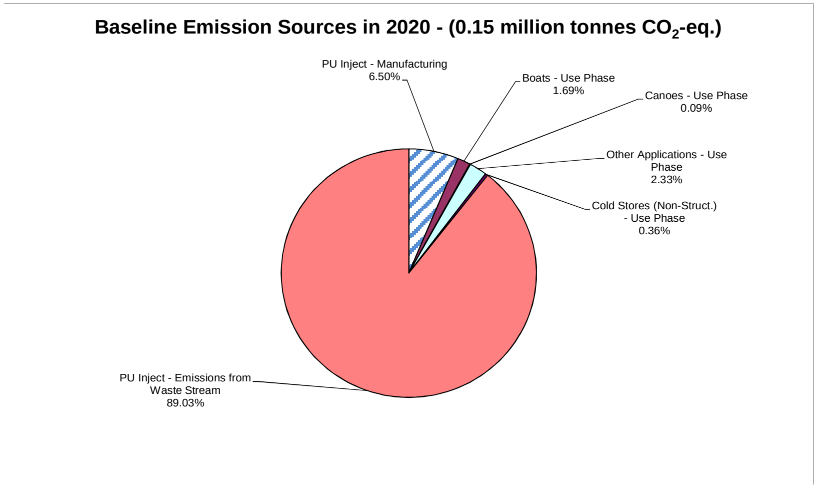


Model Data: Refrigerated Transport, Other Refrigeration, Marine and Other Applications – Banks and Emissions (3)

- The combined emissions from vending machines, commercial refrigeration (*see pie chart previous slide*), TRU and marine sources in 2020 is in the region of 0.3 million tCO_2-eq.

- With respect to emissions, those emanating after decommissioning (e.g., from banks in waste streams) will dominate in all of the applications





Mitigation Options - Background(1)

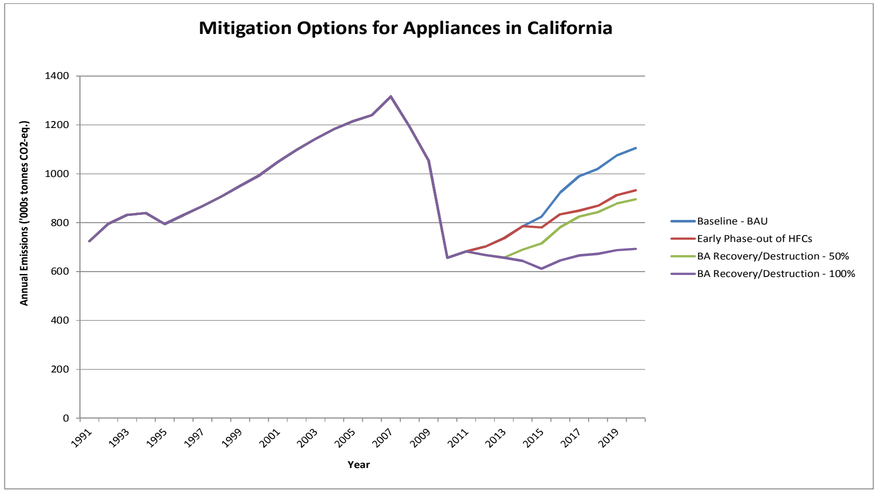
Factor	End-of-Life Management
Assumptions	•EOL measures require short lead times •Measures can be initiated in 2012 and implemented by 2014
Products/Equipment targeted	•All appliances •Vending machines/commercial refrigeration •PU Steel Panels •Other buildings foam insulation
Appliances Scenarios 100% → 50% → Buildings Scenarios – technical 100% → 50% → Buildings Scenarios realistic 50% → 25% →	 •Technical potential •Realistic potential •PU Steel Faced Panels •Combined with other buildings foam insulation •PU Steel Faced Panels •Other buildings foam insulation

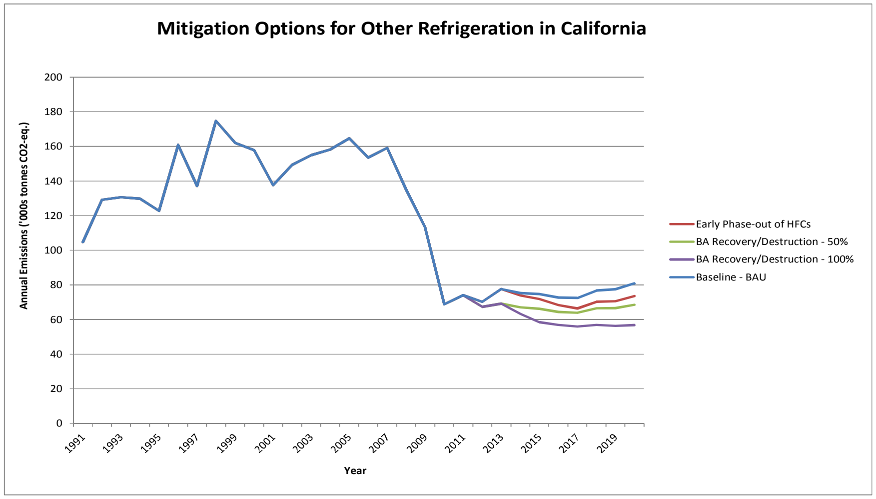
Mitigation Options - Background (2)

Factor	HFC Early Phase-out
Assumptions	•Decision to implement requires consultation •Measures could commence in 2014 and would not be fully achieved before 2017
Products/Equipment targeted	•All appliances •Vending machines/commercial refrigeration •PU Steel Panels •Other buildings foam insulation

Mitigation Options – Appliances and Other Refrigeration (3)

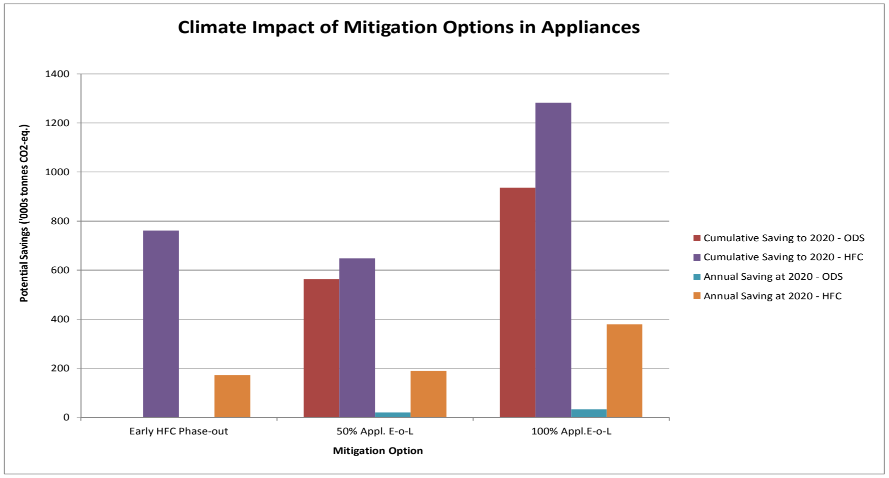
- Both classes of mitigation options can be applied to this sector
- HFC phase-out measures will only impact equipment that will be decommissioned well after 2020, so the measures can be considered as complementary to one another
- The analysis evaluates each measure in isolation and does not evaluate combinations
- Figures show the reductions achieved against baseline emissions for the appliances and other refrigeration sectors

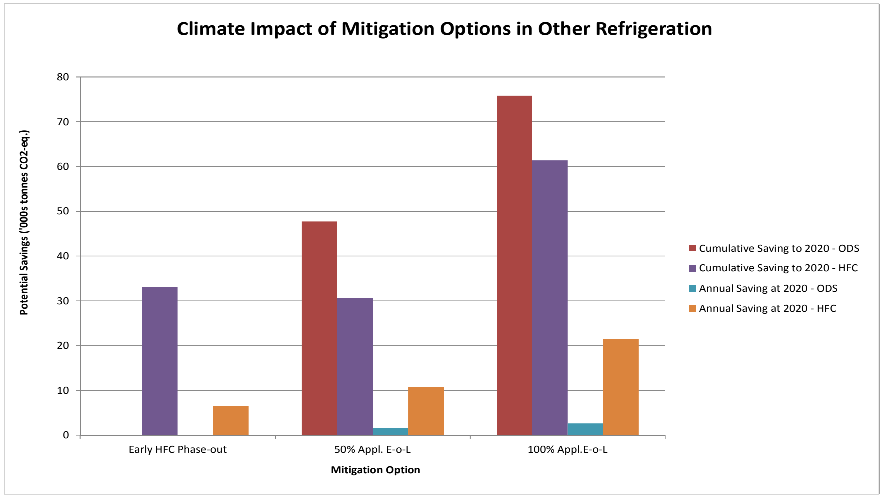




Mitigation Options – Appliance and Other Refrigeration (4)

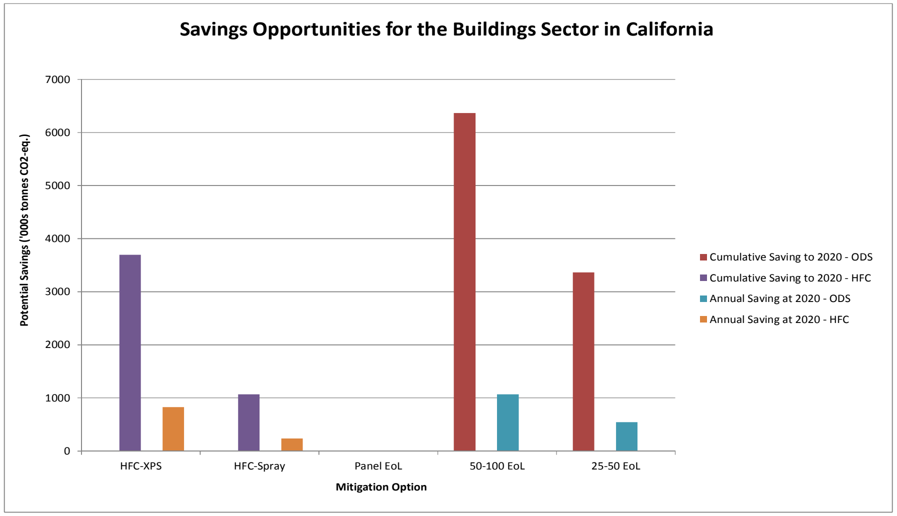
- The impact of early HFC phase-out in 'Other Refrigeration' is slightly lower proportionately than for the Appliance sector
- Each measure in the appliance sector delivers a cumulative saving in excess of 1 million tCO_2-eq. by 2020 while no measure in the Other Refrigeration sector delivers more than 0.14 million tCO_2-eq. in the same period
- A policy for appliances is likely to spill over into the 'Other Refrigeration' sector, so it is assumed that these emissions savings are additive for the same policy instrument

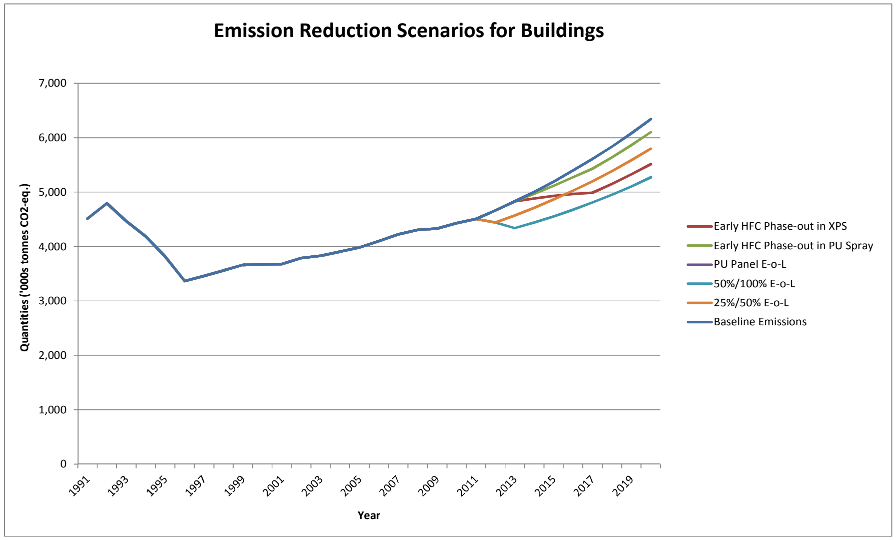




Mitigation Options - Buildings (5)

- There are no significant savings from end-of-life action on PU Panels alone
- The potential cumulative emissions savings range from 4.66 million tCO_2-eq. to 8.73 million tCO_2-eq. for all GHGs, and 0.68 to 1.34 million tCO_2-eq for HFCs alone
- The impact of early HFC phase-out measures in the XPS sector could reach 3.7 million tCO_2-eq. in reductions by 2020, with the PU Spray sector potentially contributing a further reduction of 1 million tCO_2-eq.



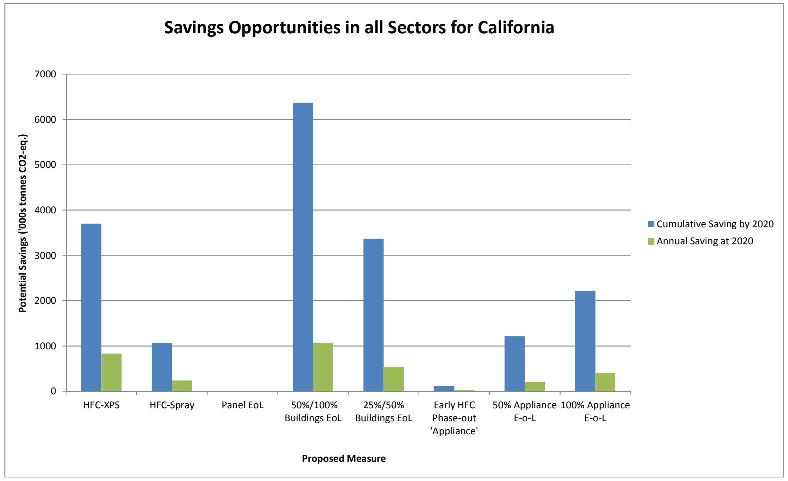


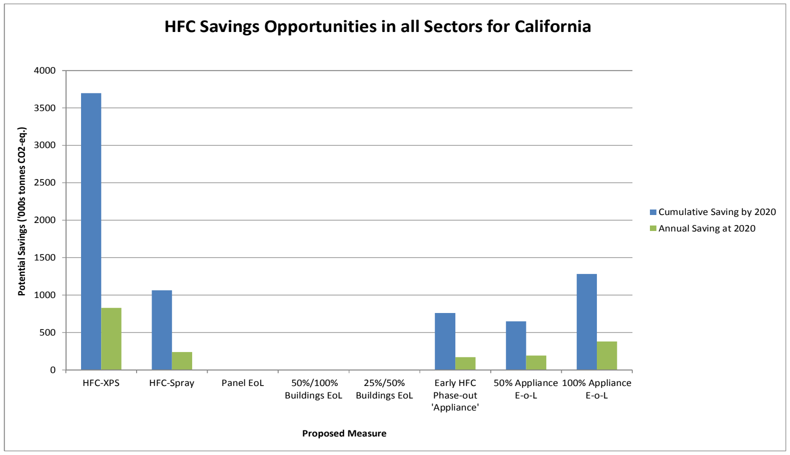
Mitigation Options - Summary (6)

- Cumulative emissions savings of between 10.22 and 14.29 million tCO_2-eq. could be achieved by a suite of measures in the period to 2020

- Annual savings at that stage range from 2.01-2.76 million tCO_2-eq.

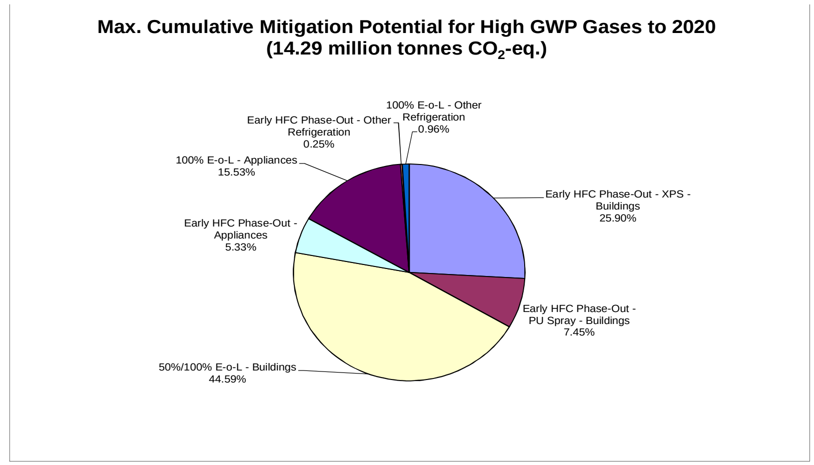
- No HFC savings are realized by 2020 from panel and building EOL

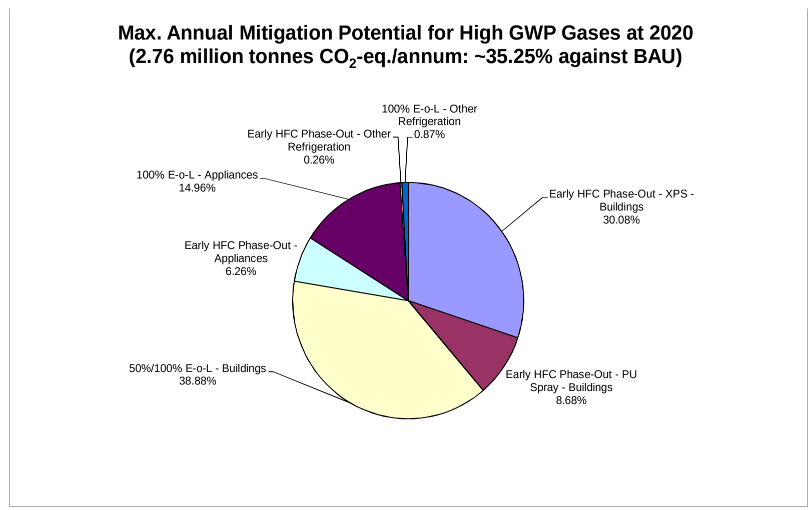




Mitigation Options - Summary (7)

- These figures show the distributions of cumulative and annual savings for both HFC and ODS based on the maximum achievable technical potential





Implementing End-of-Life Measures (1)

- Caleb identified the following foam sectors for their potential to deliver End-of-Life emission savings:

  a. Appliances
  b. Commercial Refrigeration
  c. Steel-faced Panels
  d. Block Pipe Section and Slab

- The cost of recovery and destruction of HCFCs in appliance foam can range from $115-$150 per tCO_2-eq. saved

- This compares to a figure of $10 per t$CO_2$-eq. saved for CFCs when recovered from both the refrigerant and foam at the same time

- For steel-faced panels there is some potential to use existing refrigerator de-manufacturing equipment or even direct incineration

Implication of Findings – Context

- AB-32 requires real savings of 173 million tCO_2-eq. by 2020, and California's Climate Action Plan sets out how these could b achieved. High Global Warming Potential Gases are part of that Plan, particularly where HFCs have been replacements for ODS

- The central proposition behind this project is that it could make environmental sense from a climate policy perspective to mitigate emissions by:-

a. reducing current reliance on high-global warming potential (GWP) blowing agents
b. separating and diverting ozone-depleting substance (ODS) and hydro fluorocarbon (HFC) containing foams out of the waste stream to be processed in ways that avoid ozone depletion and greenhouse gas emissions

and that it is practicable to do so

Implementing End-of-Life Measures (2)

End-of-Life Cost Analysis

- The management of appliance foam is more cost effective in climate terms on a per kilogram basis than building foams
- Blowing agent from insulation in steel-faced panels would be approximately twice as expensive to manage as blowing agent from appliances
- This is not the case on a per $MTCO_2E$ reduction basis

Foam Recovery Activity	Domestic Appliance (for baseline cost comparison)	Steel-Faced Panels JTCCM (Japan) [a]	Steel-Faced Panels - Kingspan Panels (U.K. Trial Projects) [b]	Steel-Faced Panels Austria Study [c]
Dismantling	--------------- [d]	$70 - $83	$83 - $115	N/A - Discounted
Sorting	--------------- [d]	$4 - $5	$5 - $8	N/A - Discounted
Transport	$32 - $45	$26 - $32	$6 - $13	$32 - $38 both transport and Destruction
Destruction	$51 - $64	$26 - $32	$32 - $45	
Total Cost ($/kg foam blowing agent)	$83 - $109	$126 - $152	$126 - $181	$32 - $38 (discounted)
Total cost converted to $/MTCO$_2$E [e]	$115 - $150	$41 - $50	$41 - $59	$12 - $14 (discounted)

Cost is shown in $/kilogram of insulating foam unless otherwise stated

Implementing an early Phase-out of HFC's (1)

- The three main areas of HFC use identified in this study are those associated with the manufacture of PU foams in appliances, PU Spray Foam and extruded polystyrene (XPS)

- The US appliance industry has reached a level of 25% hydrocarbon use (AHAM, 2010), but it has retained HFCs and, in particular, HFC-245fa on the basis of ever-tightening energy regulations and also on the basis of the particularity of US domestic refrigerator design

- There is some evidence that manufacturers are awaiting the commercial introduction of unsaturated HFCs (also referred to as hydro fluoro-olefins or HFOs) which are showing particular promised in respect of thermal performance

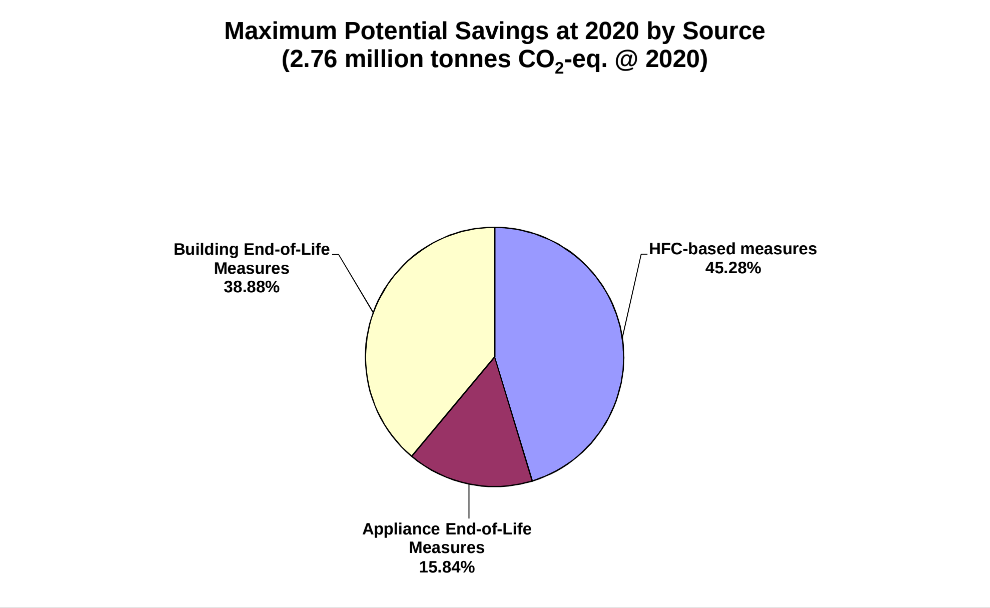
- In the PU Spray Foam industry hydrocarbons have been ruled out on safety grounds. Efforts are being deployed to evaluate alternatives such as super-critical CO_2 and methyl formate. There is no obvious alternative at this stage

Implementing an early Phase-out of HFC's (2)

- In all three sectors there are still gaps in the available alternatives. Much hope is therefore placed on a new generation of unsaturated HFCs
- The United States is well placed to take early advantage of these potential blowing agents, so there is a legitimate prospect that early HFC phase-out can become a reality
- This will be even more the case if transitions from high GWP HFCs to these new low GWP unsaturated HFCs can be incentivized through monetization of the carbon emission saving
- Bearing in mind the uncertainties remaining, the modeled phase-out has been scheduled from 2014 with completion in 2017

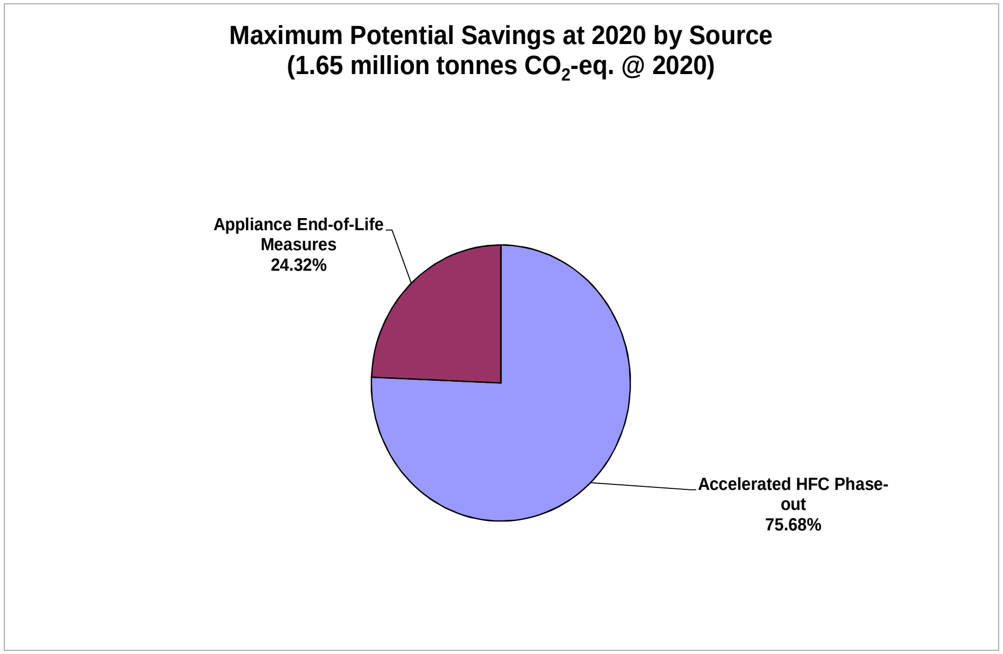
Potential Savings at 2020 by Source

- Savings of up to 2.76 million tCO_2-eq. per annum can be achieved by 2020 (1.65 million tCO_2-eq from HFC, and 1.11 million tCO_2-eq from ODS)
- Against the AB 32 total target of 173 million tCO_2-eq. per annum reduction goal, the HFC savings represents a small (0.95%), but still a significant, potential saving
- End-of-life savings are slightly in the majority overall but that these are split between two very different sectors, buildings and appliances



Potential Savings at 2020 by Source from HFC- based measures

- End-of-Life savings are less significant when shown by the HFC-portion only
- The benefits from measures in the buildings sector often occur well into the future and can be spread over many years
- Since this study is limited to evaluations up to 2020, many of the end-of-life measures are only just taking effect in the latter part of the next decade



Potential Savings at 2020

- End-of-life measures in buildings could account for over 35% of the annual savings by 2020, and this is expected to grow further in the following decade
- The opportunities for appliance de-manufacture at end-of-life at their maximum potential would only deliver around 16% of the savings
- Carbon finance could be further leveraged for appliances recovery & recycling. But this is less likely the case for building end-of-life – at least in the short-term
- Early phase-out of HFCs in foam-based products is both realizable and economically attractive as a mitigation option, with XPS being the most lucrative sector from a mitigation perspective. The challenge for California is now that all XPS used in the State is manufactured outside of its borders
- Any steps taken to curb the use of HFC-containing XPS foam would need to be applied at the product level rather than the process level. A progressive product ban would be one option, although the use of a progressive taxation might be another

Summary & Conclusions (1)

Summary of the ODS/HFC Bank

- The ODS/HFC Bank peaked in 1996 at nearly 364 million tCO_2-eq.and is estimated to reduce to 227 million tCO_2-eq.by 2020
- The buildings end-use accounted for 85% and the appliances end-use accounted for 9% of the 2005 Bank
- The HFC bank continues to increase, with an estimated 31.6 million tCO_2eq in 2010; growing to 98.8 million tCO_2eq by 2020
- The majority of HFC banks growth after 2010 will be in the buildings the sector

Banks per Application/End-Use Category (million tCO_2-eq) - All						
Year	Buildings	Appliances	Other Refrigeration	TRUs	Marine & Other	**Totals**
1996	286.31	41.28	6.08	15.01	15.01	**363.69**
2005	267.72	28.89	2.82	7.81	7.81	**315.05**
2010	244.97	25.15	1.59	3.65	3.65	**279.01**
2020	182.73	37.92	2.01	2.49	2.49	**227.64**

Banks per Application/End-Use Category (million tCO_2-eq) - HFCs only						
Year	Buildings	Appliances	Other Refrigeration	TRUs	Marine & Other	**Totals**
1996	0.00	0.04	0.00	0.00	0.00	**0.04**
2005	2.93	5.79	0.25	0.69	0.69	**10.35**
2010	9.99	17.27	0.89	1.72	1.72	**31.59**
2020	53.98	37.88	2.00	2.47	2.47	**98.80**

Summary & Conclusions (2)

Summary of the ODS/HFC Emissions

- GHG emissions from the 2005 Bank were 6 million tCO_2-eq. – with 66% arising from the buildings end-use and 20% from the appliances end-use
- By 2020, annual emissions are estimated to be approaching 8 million tCO_2-eq.
- HFC emissions increase from 0.8 million tCO_2eq in 2010 to 2.43 million tCO_2eq in 2020 and will continue to increase
- The majority of HFC emissions in the period from 2010 to 2020 emanate from the building sector, despite the fact that some relevant appliances will reach end-of-life before 2020

Emissions per Application/End-Use Category (million tCO_2-eq) - All						
Year	Buildings	Appliances	Other Refrigeration	TRUs	Marine & Other	**Totals**
1996	3.37	0.83	0.16	0.30	0.30	**4.96**
2005	3.98	1.21	0.16	0.33	0.33	**6.01**
2010	4.43	0.66	0.07	0.27	0.27	**5.70**
2020	6.34	1.10	0.08	0.15	0.15	**7.82**

Emissions per Application/End-Use Category (million tCO_2-eq) - HFCs only						
Year	Buildings	Appliances	Other Refrigeration	TRUs	Marine & Other	**Totals**
1996	0.00	0.00	0.00	0.00	0.00	**0.00**
2005	0.11	0.13	0.01	0.02	0.02	**0.29**
2010	0.60	0.17	0.01	0.01	0.01	**0.80**
2020	1.41	0.84	0.04	0.07	0.07	**2.43**

Summary & Conclusions (3)

Uncertainties & Sensitivity Analysis	
Lack of Baseline Emissions Data from Landfills	**Potential delay in HFC Phase-out Schedule**
•Estimates of CFC and HCFC emissions are highly sensitive to actual attenuation in California's landfills •Typically 50-60% of the blowing agent remains at the point of disposal •When considering annual emissions, the impact from attenuation may be small, but the impact on cumulative emissions may be significant	•Phase-out may be affected by the timely availability of non-HFC blowing agents •Potential emission reductions from a Phase-out represent some 45% of the total potential reductions •It is possible that no Phase-out happens until after 2020 – resulting in only about 50% of the projected emission reductions being achieved

Summary & Conclusions (4)

- There is technical potential to reduce 1.45-1.65 million tCO_2-eq of the HFC baseline annual emissions from the foam sector in 2020. If we include ODS emissions as well, the reduction potential increases to emission savings of 25-35% of the baseline annual emissions of high GWP gas emissions from the foam sector in 2020, equating to up to 2.76 million tCO_2-eq.
- The absolute potential will be influenced by the average life-cycles of the products and equipment involved, many of which will be contained in buildings and therefore influenced by the variation in age profiles and lifecycles of the buildings themselves
- The major short-term and medium-term opportunities exist in the accelerated phase-out of HFCs in the foam sector and the potential for end-of-life management of appliances
- Although the management of building foams at end-of-life provides a significant opportunity (>35%) for mitigation even at 2020, the cost may be prohibitive when compared with other options available to the Climate Action Plan
- Some uncertainties remain over actual high-GWP greenhouse gas emissions from California landfill locations

Recommendations

Recommendations for further Research

I. To commission further research into the actual variation of building life-cycles by use and construction type

II. To stimulate research into the development of innovative end-of-life treatment options for foams emanating from buildings taking due account of any additional information emerging on actual baseline emissions

III. To maintain a watching brief on the approach of other regions and jurisdictions to the management of building foams at end-of-life and to monitor the cost structure of any activities being taken in California for comparison

Recommendations for Regulatory changes

I. To seek early dialogue with those foam sectors continuing to rely on HFC use for their products in order to agree a schedule for the phase-out of products containing high-GWP HFCs

II. To further evaluate the potential for leveraging voluntary carbon finance for ODS Bank management with particular focus on the underpinning of the climate value of these savings and promotion of the sound practices specified by the current Climate Action Reserve (CAR) protocol

End of Presentation

Q & A