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via electronic mail

CONTROLLING HFC CHEMICALS IN CALIFORNIA: IMPROVING ON THE EU F-GAS REGULATION AND OTHER RECOMMENDATIONS

RE: Scoping Plan Update for the California Global Warming Solutions Act of 2006

On behalf of the Environmental Investigation Agency (EIA), we submit these comments on the *Proposed First Update to the Climate Change Scoping Plan: Building on the Framework* (hereinafter "draft Scoping Plan Update") and accompanying environmental assessment.

I. HIGH-GWP F-GAS PHASE-DOWN

The draft Scoping Plan Update proposes working with the U.S. EPA to establish national standards aligned with the European Union (EU) F-Gas Regulation:[1]

> California to work with the U.S. EPA to establish national standards in alignment with the European Union (EU) proposed F-gas phasedown of HFC production and import to just 21 percent (based on CO_2-equivalents) of baseline annual usage (years 2008 – 2011) by the year 2030. Some sector-specific prohibitions are included within the proposed EU phasedown, including a ban on refrigerants with a GWP greater than 2,500 used in new equipment.

The overarching measure in the EU F-Gas Regulation is the establishment of an HFC phase-down running from 2015 through 2030:

Years	Phase-Down Schedule
2015	100%
2016-2017	93%
2018-2020	63%
2021-2023	45%
2024-2026	31%
2027-2029	24%
2030	21%

The HFC phase-down in the EU F-Gas Regulation is the first of its kind, and should serve as a model for other actors. Therefore, in addition to working with U.S. EPA to establish national standards, California should enact at the state level quantitative limits on the amount of HFC chemicals in CO_2e that can be placed on the California market by HFC producers and importers – whether in bulk or pre-charged equipment (referred to hereinafter as simply an "HFC phase-down"). The EU F-Gas Regulation also shows how unilateral action to reduce the HFC use and emissions via an HFC phase-down can be crafted.[2]

In addition, California should seek to increase ambition beyond that in the EU F-Gas Regulation. During legislative consideration of the EU F-Gas Regulation, it became apparent that the HFC phase-down as proposed by the European Commission—and eventually adopted by the European Parliament and Council—was not as ambitious as it could have been. The phase-down schedule in the EU F-Gas Regulation was based on the *AnaFgas* model. The *AnaFgas* model, produced in tandem with the *Preparatory Study for a Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases*, purported to outline a safe, technically feasible, cost-effective, and energy-efficient transition away from HFC chemicals based on when *low-GWP alternative technologies using natural refrigerants* (hereinafter referred to simply as "replacement technologies") could replace new HFC-based products and equipment. Upon closer inspection, however, the HFC phase-down schedule left substantial ambition on the table in several ways:

- The phase-down schedule included intentional "margins of flexibility" in the first two phase-down steps, i.e. 10% in 2016-2017 and 5% in 2018-2020. This meant that the first phase-down step in 2016-2017 should have been at most 83% and the second phase-down step in 2018-2020 should have been at most 58%.

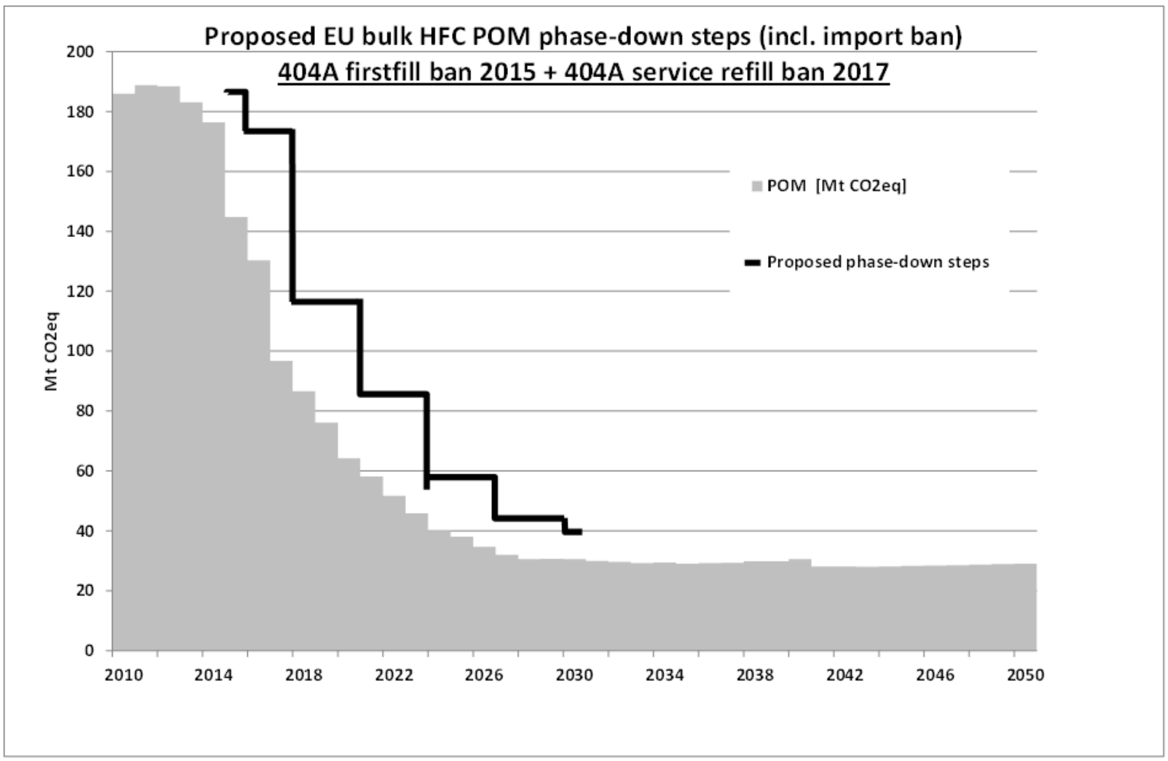
- The EU F-Gas Regulation used reported data for its 2009-2012 baseline. Since the adoption of the first EU F-Gas Regulation in 2006—which was repealed and replaced by the most recent one—studies showed rampant noncompliance with containment and recovery measures. As a result, leakage was unreasonably high in many sectors, inflating HFC demand during service and maintenance of the installed base. Additionally, state-of-the-art electronic leakage detection systems were only starting to be installed in new systems. Therefore, relying on reported data for the baseline without adjusting for noncompliance with containment and recovery measures served to lock in this noncompliance into the baseline.

- The HFC phase-down schedule was based on a snapshot of technologies that existed in 2010. In the intervening years since the publication of the *Preparatory Study*, new replacement technologies came into the market at an increasing rate. Given the fast pace of innovation of replacement technologies, limiting the HFC phase-down to a snapshot of replacement technologies in 2010 when adopting the EU F-Gas Regulation in 2014 did not reflect the proven, commercialized or anticipated innovation in these sectors. Annex I includes a non-exhaustive list of recent reports and studies on the current state of replacement technologies.

- The phase-down schedule did not account for the reduction of HFC demand in existing refrigeration systems resulting from the so-called "Service Ban" in the EU F-Gas Regulation.[3] The Service Ban prohibits refrigeration equipment with charge sizes of 40 tonnes CO_2e or more from servicing with fluorinated greenhouse gases with a GWP 2500 or more (although recycled or reclaimed HFC chemicals may be used for servicing through 2030). The justification for the 40 tonnes CO_2e threshold was due to economic concerns, namely that retrofitting smaller stationary and transport refrigeration systems less than 40 tonnes CO_2e was not as cost-effective and disproportionately impacted smaller companies. In contrast, the costs of retrofitting larger refrigeration systems payback within 1 to

> 3 years due to energy savings.[4] From 2020 onward, the Service Ban prohibits HFC-404A, an HFC blend (GWP 3,922) that is extensively used in EU refrigeration equipment, and similarly in California equipment, and is responsible for the largest proportion of HFC emissions, estimated at 44% of GWP-weighted EU consumption of refrigerants in 2010.[5] The practical implications of these factors, as shown in the graph below, is that each phase-down step following the entry into force of the Service Ban was significantly "over-allocated," including the final step of 21% in 2030.

To illustrate the need for increased ambition in the HFC phase-down in the EU F-Gas Regulation, the lead rapporteur for the European Parliament during the legislative process, MEP Bas Eickhout, commissioned a rerun of the *AnaFgas* model to account for the over-allocation due to the Service Ban alone.[6] The rerun demonstrated that more ambition was achievable than the HFC phase-down schedule proposed by the European Commission, and ultimately adopted by the European Parliament and Council.



Enclosed with this submission is the *Extra Note on HFCs with Very High-GWP in the Current F-Gas Legislation*, dated May 6, 2003, produced for MEP Bas Eickhout by Öko-Recherche.

California should therefore seek an HFC phase-down at the state level, and one that addresses the missed opportunities for ambition in the EU F-Gas Regulation, *in addition to* working with the U.S. EPA to establish national standards. By doing so, California will lead by example.

II. LOW-GWP REQUIREMENTS

The draft Scoping Plan Update proposes establishing low-GWP requirements for several HFC-using sectors, which implies placing-on-the-market prohibitions for new HFC-based products and equipment (hereinafter referred to simply as "bans"):

> Low-GWP substitutes for ozone depleting substances (ODS) and HFCs are becoming increasingly commercially available and cost-effective. As such, it will be vital to require that low-GWP compounds be used for domestic, commercial and industrial refrigeration and air conditioning, insulating foam, motor vehicle air conditioning, transport refrigeration, aerosol propellant, solvents, fire suppressants, sulfur hexafluoride uses, and structural pesticide fumigants if California is to meet its mid-term GHG goals and long-term emission reduction goal of 80 percent below 1990 levels by 2050.

Given the 10-to-30-year lifetimes of most HFC-based refrigeration and air-conditioning equipment, in order to reduce future HFC emissions, an early transition to replacement technologies must occur as soon as new HFC-based products and equipment are no longer needed. This transition can only be ensured through bans.

Several of the policy justifications for introducing bans on new HFC-based products and equipment raised during legislative consideration of the EU F-Gas Regulation are equally applicable in California:

- Without bans, new HFC-based equipment will continue to be placed on the California market in sectors that should have already transitioned to replacement technologies, locking in HFC infrastructure for decades into the future with associated HFC emissions during use and at end-of-life. In contrast, bans tailored to the nature and timing of each subsector ensure those subsectors go HFC-free as soon as possible, preventing the unnecessary build-up of HFC infrastructure.

- Bans send clear market signals to the companies producing replacement technologies to unlock investment and increase their scale of production to capitalize on these opportunities. These clear market signals with concrete timeframes for companies and investors for each subsector allow for proper planning and investment in production facilities. More than 160 companies producing replacement technologies in the United States have been identified, several of which are based in California.[7]

- Bans promote modernization of antiquated safety codes and voluntary industry standards. Some replacement technologies rely upon hydrocarbons and ammonia, which are flammable and/or toxic refrigerants with superior energetic performance. Replacement technologies incorporating these refrigerants have been designed to resolve safety concerns—similar concerns that also once existed for gas-powered stoves and heaters in homes or gas tanks in vehicles—by reducing or dispersing charge sizes and including leakage detection systems, warning alarms and other design improvements. Notwithstanding these improvements, safety codes and voluntary industry standards have not kept pace with innovation thus creating market barriers, most notably in domestic and commercial refrigeration and air conditioning.

- In tandem with an HFC phase-down, bans preserve finite HFC quotas for those sectors that need them, reducing the risk of future price spikes and shortages.

- Allowing HFC-based products and equipment when no longer necessary places undue reliance on containment and recovery measures to limit HFC emissions during use and at end-of-life, measures that are not only expensive but suffer from well-known compliance and enforcement problems.

For these reasons, California should introduce bans on placing new HFC-based products and equipment as soon as replacement technologies can satisfy market demand in California in any given sector. Technical evidence produced before and during legislative consideration of the EU F-Gas Regulation supports a more-ambitious list of bans by California than that found in Annex III of the EU F-Gas Regulation.

The approach taken by the European Commission in the *Preparatory Study* could serve as a model for California. The *Preparatory Study* was a multi-year analytical study led by Öko-Recherche comprising over 730 pages of in-depth analysis of over 26 subsectors and prepared in association with the HFC industry, providers of replacement technologies, institutes, and experts. Öko-Recherche found:

> For each sector, technically feasible and cost-effective alternative technologies to sector-typical conventional F-gas technology were identified and are hereafter referred to as "alternative options." The selection of replacement technology was guided by three criteria including the reduction potential of CO_2-weighted use of F-gas and emissions, cost effectiveness (expressed in abatement cost of €/t CO_2 eq) and energy consumption. For each alternative option, the penetration rate, which is defined as maximum potential of each technical choice to replace new products or equipment relying upon F-gas, was estimated. Penetration rates are given for each alternative option based on technical feasibility to replace existing F-gas technology by a specific alternative technology, at least cost.[8]

Penetration rate is defined as the "maximum market potential of a technical choice (i.e. abatement option) to replace new products or equipment relying upon HFCs in a particular sector."[9] It incorporates safety constraints and costs considerations while factoring in the availability of materials and components, system complexity and know-how.[10] It also ensures, as its basic guiding principle, that abatement options achieve "at least the same level of efficiency as the existing refrigerants."[11] When penetration rates reach 100% for any given subsector, a ban on new HFC-based products and equipment was deemed feasible. These penetration rates served as the basis for the recommendations in the *Impact Assessment: Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases Accompanying the document Proposal for a Regulation on fluorinated greenhouse gases*.[12]

Tables 1 and 2 below compare the penetration rates of replacement technologies in the *Preparatory Study and Impact Assessment* with the so-called "traffic-light analysis" in a report by *SKM Enviros*, which was funded by the HFC industry in Europe, for certain subsectors in refrigeration and air conditioning, respectively.

Table 1: Comparison of Feasibility of Bans and Low-GWP Alternatives in Refrigeration

Sector	*Preparatory Study / Impact Assessment*		*SKM Enviros Report*		
	Subsector	Penetration Rate 100%	Subsector		Very Low GWP GWP <10[13]
Domestic Refrigeration	Refrigerators/Freezers[14]	2015	Refrigerators[15]	MT	🟢
			Freezers[16]	LT	🟢
Commercial Refrigeration	Stand-Alone Systems[17]	2018†	Hermetic Units (medium temp)[18]	MT	🟢
			Hermetic Units (low temp)[19]	LT	🟢
	Condensing Units[20]	2020	Single Condensing Units (MT)[21]	MT	🟢
			Single Condensing Units (LT)[22]	LT	🔴
	Centralized Systems[23]	2019†	Multi-pack Centralised Systems (MT)[24]	MT	🟢
			Multi-pack Centralised Systems (LT)[25]	LT	🟢
Transport Refrigeration	Refrigerated Vans[26]	2020	Vans and Light Trucks[28]	LT & MT	🟢
	Refrigerated Trucks[27]	2026†	Large Trucks and Iso-Containers[29]	LT & MT	🟢
Industrial Refrigeration	Small Industrial Equipment (below 100 kW)[30]	2020*	Small DX LT (low temp)[32]	LT	🟡
			Small DX MT (medium temp)[33]	MT	🟢
			Medium DX LT (low temp)[34]	LT	🟡
			Medium DX MT (medium temp)[35]	MT	🟡
			Large DX LT (low temp)[36]	LT	🟢
	Large Industrial Equipment (above 100 kW)[31]	2020*	Large DX MT (medium temp)[37]	MT	🟢
			Medium-size Industrial Chillers MT[38]	MT	🟢
			Large Industrial Chillers MT[39]	MT	🟢
			Large Flooded LT (low temp)[40]	LT	🟢
			Large Flooded MT (medium temp)[41]	MT	🟢

Notes: 🟢 = Suitable for application, according to *SKM Enviros Report*.[42]
🟡 = Technically feasible but other options usually preferable in terms of capital cost or energy efficiency, according to *SKM Enviros Report*, although no thresholds are provided.[43]
🔴 = Not suitable on safety, efficiency or cost grounds, according to *SKM Enviros Report*, although no criteria or thresholds are provided.[44]
† = Penetration rates exceed 100% according to the *Preparatory Study* (linear penetration of alternatives assumed between 2015, 2020 and 2030).[45]
* = Penetration rates reach 100% in industrial refrigeration for units with a capacity greater than 100 kw by 2020.[46]

Table 2: Comparison of Feasibility of Bans and Low-GWP Alternatives in Air Conditioning

Sector	*Preparatory Study / Impact Assessment*		*SKM Enviros Report*	
	Subsector	Penetration Rate 100%	Subsector	Very Low GWP GWP <10[47]
Stationary Air Conditioning	Moveable Systems[48]	2020	Small portable units, cooling only (air-to-air)[49]	● (green)
	Split Systems[50]	2020	Small split systems, cooling only (air-to-air)[53]	● (yellow) ‡
			Small split systems, heating & cooling (air-to-air)[54]	● (yellow) ‡
			Medium split systems, cooling only (air-to-air)[55]	● (red) *
			Medium split systems heating & cooling (air-to-air)[56]	● (red) *
	Rooftop Systems[51]	2020	Large split systems, cooling only (air-to-air)[57]	● (red) *
			Large split systems heating & cooling (air-to-air)[58]	● (red) *
			Packaged systems, cooling only (air-to-air)[59]	● (red) *
			Packaged systems, heating & cooling (air-to-air)[60]	● (red) *
	Multi-Split/VRF System[52]	2021†	VRF systems, cooling only (air-to-air)[61]	● (red) *
			VRF systems, heating & cooling (air-to-air)[62]	● (red) *
	Chillers (Displacement)[63]	2020	Small - cooling only (scroll/screw, air-cooled)[64]	● (yellow) ‡
			Medium - cooling only (scroll/screw, air-cooled)[65]	● (green)
			Large - cooling only (screw, air-cooled)[66]	● (green)
			Small - cooling only (scroll/screw, water-cooled)[67]	● (yellow) ‡
			Medium - cooling only (scroll/screw, water-cooled)[68]	● (green)
			Small - reversible heating/cooling, air-source, hydronic[69]	● (yellow) ‡
			Medium - reversible heating/cooling, air-source, hydronic[70]	● (green)
	Centrifugal Chillers[71]	2027†	Large - cooling only (centrifugal, water-cooled)[72]	● (green)
	Heat Pumps[73]	2020	Domestic - heat only, air-source, hydronic[74]	● (yellow) ‡
			Small - heat only, air-source, hydronic[75]	● (green)
Mobile AC	Rail Vehicle AC	---	Buses, trains[76]	● (green)

Notes:
● (green) = Suitable for application, according to the *SKM Enviros Report*.[77]
● (yellow) = Technically feasible but other options usually preferable in terms of capital cost or energy efficiency, according to the *SKM Enviros Report*, although no thresholds are provided.[78]
● (red) = Not suitable on safety, efficiency or cost grounds, according to the *SKM Enviros Report*, although no criteria or thresholds are provided.[79]
† = Penetration rates exceed 100% according to the *Preparatory Study* (linear penetration of alternatives assumed between 2015, 2020 and 2030).[80]
‡ = Traffic light determination excludes hydrocarbon-based alternatives from consideration (other studies have found them technically feasible).[81]
* = This conclusion conflicts with the findings in other studies and current practices, in particular by discounting the suitability of hydrocarbons and CO_2.[82]

In addition to the subsectors above, the *Preparatory Study* also analyzed other HFC-using subsectors. Table 3 contains the penetration rates for those subsectors.

Table 3: Feasibility of Bans in Certain Mobile Applications, Fire Protection, Aerosols and Foams (*Preparatory Study / Impact Assessment*)

Sector	Subsector	Maximum Penetration Rate of Replacement Technologies		
		2015	2020	2030
Transport Refrigeration	Fishing Vessels[83]	70%	90%	95%
Mobile Air Conditioning	Cargo Ship AC[84]	71%	100%	180%
	Passenger Ship AC[85]	1%	20%	90%
Fire Protection	Fire Prot. HFC-23[86]	100%	100%	100%
	Fire Prot. HFC-227ea[87]	70%	80%	90%
Aerosol	Technical Aerosols (excluding MDI)[88]	25%	95%	95%
Foams	XPS with HFC-134a[89]	120%	190%	190%
	XPS with HFC-152a[90]	130%	200%	200%
	PU Spray Foam[91]	150%	200%	200%
	Other PU[92]	125%	195%	195%

As can be seen, even using only the replacement technologies available in 2010, most subsectors can go HFC-free on or before 2020. To the extent California seeks to respond to the climate imperative, it should re-evaluate the abatement potential for all sectors using HFC chemicals taking into account the rapid advances in HFC-free technologies that have occurred since 2010 and which are publically under development, and pursue the introduction of bans at the earliest possible date.

Given the similarities between climate conditions in California and the EU, California should be in a position to advance bans on new HFC-based products and equipment in many sectors on or before 2020. Indeed, an analysis of the California marketplace would likely produce similar—if not earlier—dates as the ones identified during preparation and consideration of the EU F-Gas Regulation. Significant innovation has occurred in the intervening years since 2010. Profiles of certain select sectors in the EU are included in Annexes II to VI as a basis of comparison for California, and additional observations are provided below that could help inform California when considering the introduction of bans on new HFC-based products and equipment.

For foams, their lifetimes can last up to 50 years. The *Impact Assessment* indicated that "a lack of public intervention today would result in higher emissions up to several decades into the future,"[93] especially as increasing insulation operations are undertaken to save energy in new and existing buildings. This conclusion holds true for California as well. The *Impact Assessment* and *Preparatory Study* show that replacement technologies are cost-effective and achieve clear reductions in HFC emissions, with penetration rates reaching 100% in 2015.[94] In addition, it is costly and difficult to recover HFC chemicals from foam products. Indeed, it is not always a question of simply recovering HFC emissions through methane capture, as California identified, since the removal of foams produces HFC emissions before disposal. A March 2012 report commissioned by the European Commission demonstrated that no end-of-life recovery measures were possible within €50 per t/CO_2-eq. whereas a phase-out of HFC use in XPS and PU spray foams generates substantial emission reductions at reasonable cost-effectiveness.[95] Replacement technologies exist for creating every kind of foam; these replacement technologies produce foams that meet the highest energy efficiency standards in the world. There is no reason not to immediately impose a ban on the use of HFC chemicals in all new foam-blowing equipment.

For technical aerosols, the *Impact Assessment* and *Preparatory Study* show that replacement technologies are cost-effective and achieve clear reductions in HFC emissions, with penetration rates reaching close to 100% in 2020.[96]

For commercial refrigeration, a broad categorization of refrigeration in commercial use could be considered, i.e. treating hermetically sealed stand-alone units, condensing units, and multi-pack centralized systems together. Although earlier drafts of the EU F-Gas Regulation included a ban on new HFC-based equipment in all stationary refrigeration in *commercial use* by 2020, the ban contained in the final EU F-Gas Regulation was limited to bans for hermetically sealed stand-alone units (in 2022) and multi-pack centralized systems (in 2022 with an exception for cascade systems). This was a negotiated compromise, and the omission of condensing units was largely due to unsubstantiated concerns from certain EU Member States about the use of flammable refrigerants by untrained personnel at smaller companies, such as the "local brewer" or "butcher on the corner." California should review the available alternatives for this sector and take the stronger action originally envisioned by the EU. For example, commercial refrigeration using CO_2, hydrocarbons, ammonia—in addition to hydrocarbon cascade systems and even water in solar refrigeration systems—have been proven and commercialized. More than 3000 supermarkets are employing CO_2 refrigeration systems, including traditional and transcritical systems around the world, and the rate of transitions to these systems is rapidly increasing. HFC-free commercial cascade refrigeration systems are also gaining popularity. In cascade systems, ammonia or R-290 (propane) is used as the primary refrigerant to chill the secondary refrigerant, CO_2, which is pumped throughout occupied spaces increasing safety for consumers. Finally, hermetically sealed propane units with small charge sizes are being used in combination to fulfill commercial-refrigeration needs.

For industrial refrigeration, state of the art is ammonia or ammonia cascade systems. This is the refrigerant of choice in all developed countries for large industrial refrigeration units above 100 kW due to significant energy savings. In California, this also holds true as there are more than 450 industrial facilities using ammonia in the state.[97] For smaller industrial refrigeration units, concerns regarding the availability of replacement technologies at the smaller end of the spectrum led those to be carved out for individual treatment in earlier drafts of the EU F-Gas Regulation. In the end, however, as a negotiated compromise, no bans on new HFC-based equipment in industrial refrigeration were included in the EU F-Gas Regulation. Based on the large number of facilities that are already using ammonia and the increasing availability of energy-efficient ammonia cascade systems, which keep the ammonia out of occupied spaces, California should consider banning HFC chemicals in this sector.

For stationary air conditioning, in general, the use of hydrocarbon refrigerants has been rapidly growing over the past decade. Unfortunately, voluntary industry standards and antiquated safety codes have not always kept pace, impacting the placement of replacement technologies when using flammable refrigerants. Inroads have been made, in particular through design improvements and safe handling and management, but the market is only now beginning to accommodate the large-scale deployment of hydrocarbon-based replacement technologies. For example, voluntary European standard EN 60335-2-40:2013 limits hydrocarbon charge size to 1 kg,[98] while draft European standard EN 378 increases allowable hydrocarbon charge size to 1.5 kg, which corresponds to approximately 3 kg of HFC chemicals. This is the basis for the distinction in the EU F-Gas Regulation between "single split air-conditioning systems containing less than 3kg of fluorinated greenhouse gases" with those air-conditioning systems containing 3kg or more of fluorinated greenhouse gases.[99] Indeed, stationary air-conditioning systems can be largely divided into three categories. *First*, there are stationary air-conditioning systems containing less than 3kg of fluorinated greenhouse gases. This would include moveable systems, smaller split systems and domestic heat pumps, which are the fastest growing sources of HFC emissions in the EU, and accounted for approximately 21% of HFC emissions in RAC in 2010. Due to their smaller charges sizes, these should be subject to an early ban. *Second*, there are stationary air-conditioning systems containing 3kg or more of fluorinated greenhouse gases. This would include larger split systems, packaged systems, VRF systems and non-domestic heat pumps. Due to the larger charges sizes, these could be subject to a later ban to allow additional time for further innovation and modernization of voluntary industry standards and safety codes. This category accounted for approximately 3.4% of HFC emissions in RAC in 2010 in the EU. *Third*, there are chillers. Chillers tend to be located in separate rooms or well-ventilated areas, and thus when using flammable refrigerants are not restricted by voluntary industry standards and safety codes in the same way as larger split systems, packaged systems, VRF systems and non-domestic heat pumps. Chillers accounted for approximately 8% of HFC emissions in RAC in 2010 in the EU. This category should also be subject to an early ban. To the extent legitimate safety concerns exist for discrete applications, such as military use, discrete derogations could be considered on a case-by-case basis.

III. HIGH GWP FEE

The draft Scoping Plan Update proposes establishing an upstream mitigation fee on sales of high-GWP gases:

> An upstream mitigation fee on sales of high-GWP gases would incentivize a faster transition to low-GWP substitutes, and could further incentivize improved refrigerant recovery practices. The fee would also be applied to sales or import of equipment pre-charged with high-GWP gases. The mitigation fee would complement rather than replace downstream high-GWP regulations currently in effect or being developed.

The EU entertained a similar measure for inclusion in the EU F-Gas Regulation—as opposed to a system based on grandfathering—but opted instead for grandfathering in the early years at which point it would consider a fee or auction at a future date following additional analysis. To this end, the EU F-Gas Regulation provides that:[100]

> No later than 1 July 2017, the [European] Commission shall publish a report assessing the quota allocation method, including impact of allocating quota for free, and the costs of implementing this Regulation in Member States and of a possible international agreement on hydrofluorocarbons, if applicable. In light of that report the [European] Commission shall submit, if appropriate, a legislative proposal to the European Parliament and to the Council with a view to:
>
> a) amending the quota allocation method;
>
> b) establishing an appropriate method of distributing any possible revenues.

The policy justifications for a mitigation fee are several. In addition to promoting containment and recovery, a mitigation fee can provide resources to ensure proper implementation and enforcement. It also discourages HFC producers or importers from locking in high-GWP infrastructure, and levels the playing field for replacement technologies that, unlike those relying on HFC chemicals, are not manufactured at a similar scale of production to HFC-based products and equipment and hence do not enjoy equivalent economies of scale. Indeed, during legislative consideration of the EU F-Gas Regulation, it was repeatedly shown that there is nothing inherently more expensive about the hardware costs of replacement technologies once produced at a similar scale (and, indeed, annual costs are actually lower due to energy efficiency gains and cost-avoidance for expensive HFC chemicals during servicing). The *Impact Assessment* for the EU F-Gas Regulation further showed that placing a price on HFC use benefitted the economy: the impact on GDP is less when HFC chemicals are placed on the market at cost versus at no cost.[101] The *Impact Assessment* also showed impacts on employment can be positive when that revenue is reinvested into the economy, contrasting to the negative impacts on employment when HFC chemicals are secured at no cost.[102] In addition, a mitigation fee can compensate agencies and end-users for the cost of controlling HFC use once placed on the market. In the context of the EU F-Gas Regulation, the annual recurring costs on EU national authorities, certified personnel, companies, and operators is expected to be €1 billion in 2015, increasing to €1.5 billion in 2030.[103] By contrast, the annual recurring costs on HFC producers and importers—those actually producing HFC chemicals and putting them on the market in bulk or in pre-charged equipment—are expected to be only €400,000 in 2015 through 2030, mostly due to fulfilling reporting obligations.[104] Therefore, for the reasons identified in the draft Scoping Plan Update and raised during legislative consideration of the EU F-Gas Regulation, California should enact an upstream mitigation fee on the sales of HFC chemicals based on their CO_2e to promote the fastest transition away from the higher-GWP HFC chemicals.[105]

IV. BY-PRODUCT DESTRUCTION DURING HFC AND FEEDSTOCK PRODUCTION

California should impose requirements for by-product destruction during HFC and feedstock production. The EU F-Gas Regulation requires that HFC producers and importers provide evidence of destruction of HFC-23 by-product emissions when placing their HFC chemicals on the European market:[106]

Article 11
Emissions of fluorinated greenhouse gases in relation to production

1. Producers of fluorinated compounds shall take all the precautions necessary to limit emissions of fluorinated greenhouse gases to the greatest extent possible during:

   (a) production;

   (b) transport; and

   (c) storage.

   This Article also applies where fluorinated greenhouse gases are produced as by-products.

2. Without prejudice to Article 11(1), the placing on the market of fluorinated greenhouse gases and gases listed in Annex II shall be prohibited unless, where

> relevant, producers or importers provide evidence, at the time of such placing, that trifluoromethane, produced as a by-product during the manufacturing process, including during the manufacturing of feedstocks for their production, has been destroyed or recovered for subsequent use, in line with best available techniques.

This provision, while a welcome contribution to reducing upstream HFC-23 emissions associated with HFC and feedstock production, was limited to HFC-23. It is similar to a provision in both the North American and Micronesian proposals to amend the Montreal Protocol on Substances to Deplete the Ozone Layer to control HFC production and consumption. The justification for this provision, however, is not limited to HFC-23 by-product. California should therefore consider using its market access to ensure that all HFC and ozone-depleting substance (ODS) by-product emissions are destroyed prior to placement of HFC chemicals on the California market.

An HFC phase-down and bans on high-GWP HFC chemicals or blends will result in the proliferation of certain lower-GWP HFC chemicals, such as HFC-32 (GWP 675), HFC-134a (GWP 1430) and HFOs (GWP <10), and HFC blends, such as HFC-407A (2107) and HFC-407F (GWP 1824). It could also result in the proliferation of common feedstocks for HFC production, such as HCFC-22 (GWP 1810). An indication of the magnitude of the problem to climate and the ozone layer is evidenced in looking at just two of these chemicals and their known by-product emissions:

HCFC-22	▪ HCFC-22 production results in ***HFC-23 (GWP 14,800)*** by-product emissions ▪ HCFC-22 has been reported as a potential feedstock for HFC-32 and certain HFO chemicals, among others, meaning HCFC-22 production and associated HFC-23 emissions could increase even as direct emission decrease. ▪ Global HFC-23 emissions were estimated at ***127 MT/year*** in 2010.[107]
HFC-134a	▪ For every 1000 kg of HFC-134a production, HFC by-product emissions are:[108] – ***7.9 kg of HFC-143a (GWP 4470)*** – ***0.5 kg of HFC-125 (GWP 3500)*** ▪ Global production of HFC-134a in 2011 was 312,000 metric tonnes, meaning HFC by-product emissions constituted ***~11 MT CO_2e***.[109] ▪ HFC-134a production also results in the production of ODS chemicals – for every 1000 kg of HFC-134a production, 4.9 kg of ***HCFC-133a (ODP 0.02-0.06)*** is produced as by-product.[110]

An analysis of total by-product emissions from all CFC-HCFC-HFC chemicals and their feedstocks would yield staggering figures. In order to prevent undermining the environmental benefit of moving to lower-GWP HFC chemicals and blends—when replacement technologies are unavailable or prior to bans entering into effect—California should extend a provision on by-product destruction to *all by-products resulting from CFC-HCFC-HFC production whether for emissive or feedstock uses*.

V. LEAKAGE

Addressing the significant leakage of HFC chemicals from the installed base of refrigeration and air-conditioning systems, in addition to new systems, is necessary to control HFC emissions. In the U.S., it is estimated that HFC emissions from leaks in supermarket refrigeration equipment and associated loss of energy efficiency can account for almost 50% of a supermarket's total GHG emissions.[111] This is because U.S. supermarket refrigeration systems have an average annual leakage rate of 25% of the refrigerant charge. Each supermarket is therefore emitting on average 1,556 metric tons of CO_2e of HFC emissions a year just from leaks in their refrigeration units.[112] To combat this problem, California should institute best practices, and establish maximum leakage rates for each sector – see Annex VII for examples in Europe. Specifically, for existing supermarket markets and other commercial refrigeration systems, California should explore maximum leakage rates of less than 10%, which can be easily met. For example, Walmart's UK chain, ASDA, has reduced leakage rates from 20% to 7.1% since 2005 by employing comprehensive maintenance of its refrigeration systems.[113] For new equipment, electronic leakage detection systems should be required on all HFC-based equipment above a certain threshold to bring leakage rates to as close to zero as possible.

In addition to reducing the allowable leakage rates, California must provide resources to enforce leakage rates. Noncompliance with containment measures is rampant, and leads to unreasonably high HFC demand and emissions. Indeed, the first enforcement action in the U.S. for violating leakage rates for HCFC-22 only occurred last year. The U.S. EPA settled Clean-Air-Act violations with Safeway Corporation for failing to repair HCFC-22 leaks.[114] Safeway now needs to reduce its leakage rates from an average above 25% to 18% or below. Noncompliance was also common under the old EU F-Gas Regulation. Without enforcement, leakage rates will continue to remain unchecked leading to unnecessary and damaging GHG emissions.

VI. ODS DESTRUCTION

The Scoping Plan recommends incentivizing end-of-life recovery and destruction:

> The Montreal Protocol has reduced ODS emissions significantly (by almost 60 percent) by reducing the production and consumption of ODS. However, it appears that end-of-life emissions from legacy equipment are still significant. Due to higher demand and therefore higher value of recovered ODS, there is currently less incentive for ODS destruction. More than 80 percent reduction in ODS emissions (approximately 20 MMTCO2e) can be obtained by 2030 by incentivizing recovery and destruction of ODS at the end-of-life. This can be done by a combination of strategies, including adjustments to current ODS destruction protocols, implementing a mitigation fee, and/or using cap-and-trade revenue to help pay for higher costs.

End-of-life destruction is extremely important as emissions of halons, CFC and HCFC chemicals, and other ODS in banks are contributing billions of tonnes of CO_2e to climate change. The Montreal Protocol's Technical and Economic Assessment Panel (TEAP) estimated that emissions contained in ODS Banks in 2002 were approximately 21 Gt CO_2e and were reduced to 16-17 Gt CO_2e in 2010.[115] As active recovery has not been undertaken, the 4-5 Gt CO_2e difference is due to the release of ODS into the atmosphere. According to the Intergovernmental Panel on Climate Change (IPCC) and TEAP, ODS Banks in 2010 consisted of 12 Gt CO_2e of CFC emissions and 4-5 Gt CO_2e of HCFC emissions.[116] Actions to recover and destroy CFC and HCFC chemicals in refrigeration and air-conditioning banks represent one of the most cost-effective climate-mitigation opportunities. It was reported that simply destroying the most cost-effective banks in refrigeration and air conditioning at end-of-life could have accelerated the return of the ozone layer by up to two years.[117] These ozone benefits should be accounted for when considering the cost of managing ODS-bank destruction, as they will significantly reduce health-care costs associated with skin cancer, eye cataracts, other ozone-related ailments as well as adverse impacts to the environment.[118] California should therefore begin incentivizing recovery and destruction of ODS at the end-of-life, specifically through implementing a mitigation fee.

VII. CONCLUSION

EIA supports CARB's consideration of measures to reduce HFC emissions. While the EU F-Gas Regulation provides a good model for action, it was a political compromise not always based on what is cost-effective or technically feasible. California can and should adopt a more ambitious HFC phase-down and list of bans than were adopted in the EU. Additionally these measures should be combined with a mitigation fee; requirements for by-product destruction during CFC-HCFC-HFC and feedstock production; controls to address leakage from the installed base and in new systems; and controls on ODS emissions from legacy equipment and banks. We look forward to working with CARB to implement an ambitious HFC and ODS control plan that will enable California to meet its 2050 GHG reduction target.

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Annex I

Recent Reports and Studies on the State of Replacement Technologies

Technology and Economic Assessment Panel (TEAP), *Decision XXIV/7 Task Force Report: Additional Information to Alternatives on ODS* (2013).

German Federal Environment Agency (UBA), *Avoiding Fluorinated Greenhouse Gases: Prospects for Phasing Out* (2011).

SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (2012).

Shecco, *Natural Refrigerants Market Growth for Europe* (2014).

Bureau Veritas, *Étude d'Impact des Scénarios de Réduction de la Production et de la Consommation des Gaz à Effet de Serre Fluorés de Type Hydrofluorocarbures en France* (2012).

Environmental Investigation Agency, *Chilling Facts V: Retailers on the Cusp of a Global Cooling Revolution* (2013).

Environmental Investigation Agency, *Putting the Freeze on HFCs: A Digest of the Global Transition to Environmentally friendly Refrigerants* (2014).

European Commission, *Impact Assessment: Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases* (2012).

Annex II

Condensing Units and Centralized Systems

- Condensing units comprised 4% of HFC emissions in RAC in 2010 in the EU.
- Centralized systems comprised 33% of HFC emissions in RAC in 2010 in the EU.
- Commercial refrigeration is the leakiest sector and largest source of HFC emissions in the EU.
- Replacement technologies:
  - *Condensing units*: hydrocarbon direct systems; hydrocarbon + secondary liquid, transcritical CO_2[119]
  - *Centralized systems*: transcritical CO_2; hydrocarbon or NH_3-CO_2 cascade; hydrocarbon + secondary liquid[120]
- Replacement technologies in commercial refrigeration are supported by an unparalleled body of technical evidence,[121] and an abundance of real-world experiences.[122]
- Replacement technologies using natural refrigerants are proven to be more energy-efficient than HFC chemicals, including in warmer climates.
- All HFC-based condensing units and centralized systems must be recovered under the EU F-Gas Regulation (installed base: 1.6 million units in 2010, increasing to 3.3 million units in 2030)[123] – significant burden with high noncompliance risk.
- Most condensing units and all centralized systems containing HFC chemicals are required to undertake mandatory leakage checks under the EU F-Gas Regulation (above the 5 tonne CO_2-eq threshold).
- European Commission identified bans on new condensing units and centralized systems containing HFC chemicals as feasible in 2020.[124]
- The German Federal Environment Agency proposed a ban in 2020 on new centralized systems containing HFC chemicals during public consultation on the EU F-Gas Regulation.[125]

European Union	
Condensing Units (Medium and Low Temperature)	**Centralized Systems (Medium and Low Temperature)**
Annual New Systems 2010: 300,000 units 2030: 260,000 units	**Annual New Systems** 2010: 37,000 units 2030: 35,000 units
Installed Base 2010: 1.3 million units 2030: 2.8 million units	**Installed Base** 2010: 384,000 units 2030: 513,000 units
Net Imports 0%	**Net Imports** 0%
Annual Leakage 14%	**Annual Leakage** 21%
End-of-Life Leakage 66%	**End-of-Life Leakage** 20%

Annex III
Industrial Refrigeration

- Industrial refrigeration comprised 12.1% of HFC emissions in RAC in 2010 in the EU.
- Ammonia in larger industrial systems is state of the art and preferred technology.
- Replacement technologies:[126]
  - *Smaller systems*: hydrocarbons
  - *Larger systems*: ammonia; ammonia-CO_2 cascade
- Proven energy efficiency (at least 15%) in larger industrial systems.
- The European Commission identified a ban on new industrial refrigeration systems containing HFC chemicals greater than 100 kW as feasible in 2020.[127]
- The German Federal Environment Agency (UBA) proposed ban in 2020 on new industrial refrigeration containing HFC chemicals greater than 100 kW during public consultation on the EU F-Gas Regulation.

European Union		
Small Industrial Refrigeration (Medium and Low Temperature)	**Medium Industrial Refrigeration (Medium and Low Temperature)**	**Large Industrial Refrigeration (Medium and Low Temperature)**
Charge Size HFC-410A: ~ 30 to 45 kg	**Charge Size** HFC-410A: ~ 100 to 150 kg	**Charge Size** HFC-410A: ~ 450 to 3000 kg
Cooling 20 to 30 kW	**Cooling** 80 to 200 kW	**Cooling** 300 to 1000 kW
Annual New systems 2010: 22,1000 units 2030: 17,200 units	**Annual New systems** 2010: 5,300 units 2030: 6,500 units	**Annual New systems** 2010: 2780 units 2030: 1790 units
Installed Base 2010: 228,000 units 2030: 297,000 units	**Installed Base** 2010: 124,600 units 2030: 129,500 units	**Installed Base** 2010: 44,900 units 2030: 49,300 units
Net Imports 0%	**Net Imports** 0%	**Net Imports** 0%
Annual Leakage 14%	**Annual Leakage** 9 to 14%	**Annual Leakage** 5 to 14%
End-of-Life Leakage 20%	**End-of-Life Leakage** 20%	**End-of-Life Leakage** 20%

Annex III

Split Systems

- Split systems comprised 20% of HFC emissions in RAC in 2010 in the EU.[128]
- Split systems are the fastest growing source of emissions in the EU.
- Hydrocarbons are energetically superior to all HFC chemicals – hydrocarbons require approximately 0.15 kg per kW of cooling capacity versus 0.25 kg per kW for HFC chemicals.[129]
- Replacement technologies:[130]
  - *Smaller systems*: hydrocarbon direct systems predominate due to small charge size
  - *Larger systems*: hydrocarbons + secondary liquid (water) or evaporating fluid (CO_2) in indirect systems to limit hydrocarbon charge size; transcritical CO_2
- Voluntary European standard EN 60335-2-40:2013 limits hydrocarbon charge size to 1 kg,[131] while draft European standard EN 378 will increase allowable hydrocarbon charge size to 1.5 kg, corresponding to approximately 3 kg of HFC chemicals.
- Most HFC-based split systems avoid mandatory leakage checks under the EU F-Gas Regulation (below the 5 tonne CO_2-eq threshold or, if hermetically sealed, the 10 tonne CO_2-eq threshold).
- All HFC-based split systems must be recovered under EU F-Gas Regulation (installed base: 67.7 million units in 2010, increasing to 120.9 million units in 2030)[132] – significant burden with high noncompliance risk.
- Most split systems are pre-charged, placing a disproportionate strain on any traceability scheme.
- The European Commission identified ban on split systems less than 3kg (over 97% of all new splits) as feasible in 2020.[133]

European Union		
Small Split Systems	**Medium Split Systems**	**Large Split Systems**
Charge Size HFC-410A: ~ 0.8 to 1.2 kg Hydrocarbons: ~ 0.525 kg	**Charge Size** HFC-410A: ~ 2 to 2.5 kg Hydrocarbons: ~ 1.065 kg	**Charge Size** HFC-410A: ~ 5.6 kg Hydrocarbons: ~ 2.1 kg
Annual New Systems 2010: 5.65 million units 2030: 7.3 million units	**Annual New Systems** 2010: 1.87 million units 2030: 2.5 million units	**Annual New Systems** 2010: 228,000 units 2030: 232,000 units
Installed Base 2010: 48.4 million units 2030: 88.4 million units	**Installed Base** 2010: 16.2 million units 2030: 29.1 million units	**Installed Base** 2010: 3.1 million units 2030: 3.4 million units
Net Imports 90%	**Net Imports** 70%	**Net Imports** 70%
Annual Leakage 6%	**Annual Leakage** 6%	**Annual Leakage** 6%
End-of-Life Leakage 90%	**End-of-Life Leakage** 90%	**End-of-Life Leakage** 90%

Annex IV

Packaged Systems and VRF Systems

- Packaged and VRF systems comprised 2.4% of HFC emissions in RAC in 2010 in the EU.[134]
- Safety concerns for packaged and VRF systems containing flammable refrigerants arise primarily from charge size and when placed in confined spaces.
- Replacement technologies:[135] hydrocarbons + secondary liquid (water) or evaporating fluid (CO_2) in indirect systems to limit hydrocarbon charge size; transcritical CO_2
- Packaged and VRF systems containing HFC chemicals are required to undertake mandatory leakage checks under the EU F-Gas Regulation (above the 5 tonne CO_2-eq threshold)[136]
- Packaged and VRF systems containing HFC chemicals must be recovered under the EU F-Gas Regulation (installed base: 540,000 units in 2010, increasing to 1.8 million units in 2030)[137] – significant burden with high noncompliance risk
- The European Commission identified a ban on new packaged and VRF systems containing HFC chemicals as feasible in 2020.[138]
- Distinction between *confined* and *non-confined* systems can be drawn, as done in EU ODS Regulation and per European standards, for stationary air conditioning containing more than 3kg of fluorinated greenhouse gases or more than 12 kW of cooling capacity, i.e. allowable charge sizes for those placed outdoors/well-ventilated areas can be larger while allowable charge sizes for those placed indoors/poor-ventilated areas can be smaller due to safety concerns.

European Union	
Packaged Systems	**VRF Systems**
Charge Size HFC-410A: ~ 20 kg Hydrocarbons: ~ 1.5 kg	**Charge Size** HFC-410A: ~ 25 kg Hydrocarbons: ~ 2 to 4 kg
Annual New Systems 2010: 12,900 units 2030: 13,000 units	**Annual New Systems** 2010: 51,600 units 2030: 130,000 units
Installed Base 2010: 176,000 units 2030: 200,000 units	**Installed Base** 2010: 364,000 units 2030: 1.6 million units
Net Imports 20%	**Net Imports** 50%
Annual Leakage 5%	**Annual Leakage** 6%
End-of-Life Leakage 55%	**End-of-Life Leakage** 90%

Annex V

Heat Pumps (Heating Only)

- Heating-only heat pumps compromised 2% of HFC emissions in RAC in 2010 in the EU.[139]
- This is a rapid growth sector – energy efficiency gains from heat pumps will be compromised if they use HFC chemicals.
- HFC-based heating-only heat pumps are often required to undertake mandatory leakage checks under the EU F-Gas Regulation (above the 5 tonne CO_2-eq threshold).
- Replacement technologies: [140] hydrocarbons; CO_2
- All HFC-based heat pumps must be recovered at end-of-life under the EU F-Gas Regulation (installed base: 2.2 million units in 2010, increasing to 8.6 million units in 2030)[141] – significant burden with high noncompliance risk.
- The European Commission identified a ban on heating-only heat pumps containing HFC chemicals as feasible in 2020.[142]

European Union	
Domestic Heat Pumps	**Small Heat Pumps**
Charge Size	**Charge Size**
HFC-410A: 4.4 kg	HFC-410A: 29 kg
Hydrocarbons: ~2.2 kg	Hydrocarbons: variable
Annual New Systems	**Annual New Systems**
2010: 240,000 units	2010: 6,000 units
2030: 670,000 units	2030: 17,000 units
Installed Base	**Installed Base**
2010: 2.2 million units	2010: 55,000 units
2030: 8.6 million units	2030: 215,000 units
Net Imports	**Net Imports**
0%	0%
Annual Leakage	**Annual Leakage**
5%	5%
End-of-Life Leakage	**End-of-Life Leakage**
25%	25%

Annex VI
Chillers

- Chillers comprised 8% of HFC emissions in RAC in 2010 in the EU.[143]
- HFC-based chillers are required to undertake mandatory leakage checks under the EU F-Gas Regulation (above the 5 tonne CO_2-eq threshold).
- Voluntary European standards do not limit hydrocarbon charge size in chillers, although when used in machinery rooms (small proportion of market) some additional safety measures apply.[144]
- Replacement technologies: [145] hydrocarbons; ammonia; CO_2
- All HFC-based chillers must be recovered at end-of-life under the EU F-Gas Regulation (installed base: 835,000 units in 2010, increasing to 1.3 million units in 2030)[146] – significant burden with high noncompliance risk.
- The European Commission identified a ban on new displacement chillers containing HFC chemicals as feasible in 2020.[147]

European Union		
Small Chillers	**Medium Chillers**	**Large Chillers**
Charge Size HFC-410A: 29 kg Hydrocarbons: variable	**Charge Size** HFC-410A: 150 kg Hydrocarbons: variable	**Charge Size** HFC-410A: 360-750 kg Hydrocarbons: variable
Annual New Systems 2010: 60,400 units 2030: 72,700 units	**Annual New Systems** 2010: 13,300 units 2030: 16,200 units	**Annual New Systems** 2010: 1,650 units 2030: 1,130 units
Installed Base 2010: 670,000 units 2030: 1.1 million units	**Installed Base** 2010: 144,000 units 2030: 256,000 units	**Installed Base** 2010: 21,000 units 2030: 22,000 units
Net Imports 0%	**Net Imports** 0%	**Net Imports** 0%
Annual Leakage 5%	**Annual Leakage** 5%	**Annual Leakage** 5%
End-of-Life Leakage 25%	**End-of-Life Leakage** 25%	**End-of-Life Leakage** 20%

Annex VII
Containment and Recovery in EU Member States

Containment is required to reduce leakage once HFC-based products and equipment is placed on the market. Recovery is required once HFC-based equipment is placed on the market, meaning HFCs will need to be reclaimed, recycled or destroyed at end-of-life. Given the lifetimes of HFC-based equipment, the full implications of recovery have yet to be felt. But experiences with ozone-depleting substances confirm it can be burdensome and expensive. Containment and recovery suffer from well-known compliance and enforcement problems, and tend to shift significant from HFC producers and importers to end-users.

In addition to measures on mandatory leakage checks and repair in the EU F-Gas Regulation, national legislation in EU Member States provides lessons for how containment and recovery measures can help reduce HFC emissions in California during use and at end-of-life.

> **Include maximum leakage rates for each sector**. Maximum leakage rates, an important backstop to unabated leakage, already exist in certain Member States, such as Germany, Belgium and Luxembourg.[148] From both a compliance and enforcement perspective, maximum leakage rates provide clear benchmarks that set out impermissible limits and allow violations to be pursued. Findings in the *Preparatory Study* support this conclusion on maximum leakage rates: "[f]rom a legal point of view, the establishment of maximum leakage rates would lead to clear identification of leaks and hence provide an additional tool for control and enforcement of containment measures resulting in F-gas emission reductions."[149] The *Preparatory Study* also notes that maximum leakage rates are already set out in several sectors by international and European standards.[150] It does caution, however, that "the choice of maximum leakage rates would need to be supported by experiences on best practices and determination of such rates." Maximum leakage rates depend on the subsector in question hence subsector specific maximum leakage rates should be adopted to account for the particularities of each subsector and ensure best practices.
>
> **Require producer responsibility schemes to promote recovery**. Several EU Member States have adopted producer responsibility schemes, including take-back schemes in Sweden and Germany[151] and a deposit-refund scheme in Denmark.[152] These serve to internalize the costs of HFC recovery into the prices of new HFC-based equipment, and promote compliance. California should consider similar adopting measures.

[1] Regulation (EU) XXX/XXXX of the European Parliament and of the Council on Fluorinated Greenhouse Gases and Repealing Regulation (EC) No 842/2006 (hereinafter "EU F-Gas Regulation")(adopted by the European Parliament on March 12, 2014 and the Council of the European Union on April 14, 2014, and awaits publication in the Official Journal of the European Union).

[2] The European Union grappled with how to ensure the integrity of the phase-down in the absence of multilateral action. The European Commission first proposed a ban on pre-charged HFC-based products and equipment from being placed on the market (approximately 11% of HFC demand), thus requiring their charging in the EU with HFC chemicals traceable to quotas under the HFC phase-down. Due to intense lobbying from impacted companies, the European Parliament and the Council opted for a traceability system that allows pre-charged HFC-based products and equipment to be placed on the European market when companies show that their HFC chemicals are traceable to a specific HFC quota allocated thereunder.

[3] EU F-Gas Regulation, Article 13(3).

[4] SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Final Report, Version 11, September 2012) [hereinafter "*SKM Enviros Report*"], p. 61.

[5] *SKM Enviros Report*, p. 20.

[6] The *AnaFgas* model was rerun with the date for the Service Ban as proposed by the European Parliament—i.e. 2017—though this date was pushed back to 2020 in the EU F-Gas Regulation.

[7] Shecco, *Guide 2013: Natural Refrigerants Market Growth for North America* (March 2013), pp. 133-151 *available at* http://publications.shecco.com/publications/view/6.

[8] Öko-Recherche *et al.*, *Preparatory Study for a Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases, Final Report* (September 2011)(hereinafter "Preparatory Study"), Executive Summary, p. XI.

[9] *Preparatory Study*, p. 195.

[10] *Preparatory Study*, pp. 195-198.

[11] *Preparatory Study*, pp. 196-197.

[12] European Commission, *Impact Assessment: Review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases* (Commission Staff Working Paper), SWD(2012)0364 (hereinafter "Impact Assessment"), p. 37.

[13] SKM Enviros Report, p. 35; *see also* SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Draft Version 3, July 2012), pp. 31-32 (earlier version includes complete traffic light analysis, not included in final version, with more favorable conclusions for alternative technologies due to the inclusion of hydrocarbon-based alternatives available in 2012).

[14] *Impact Assessment*, p. 115; *Preparatory Study*, Annex V, p. 244.

[15] *SKM Enviros Report*, p. 77.

[16] *SKM Enviros Report*, p. 78.

[17] *Impact Assessment*, p. 115; *Preparatory Study*, Annex V, p. 245.

[18] *SKM Enviros Report*, p. 79.

[19] *SKM Enviros Report*, p. 80.

[20] *Impact Assessment*, p. 115; *Preparatory Study*, Annex V, p. 246.

[21] *SKM Enviros Report*, p. 81.

[22] *SKM Enviros Report*, p. 82.

[23] *Impact Assessment*, p. 115; *Preparatory Study*, Annex V, p. 247.

[24] *SKM Enviros Report*, p. 83.

[25] *SKM Enviros Report*, p. 84.

[26] *Impact Assessment*, p. 118; *Preparatory Study*, Annex V, p. 250.

[27] *Impact Assessment*, p. 120; *Preparatory Study*, Annex V, p. 251.

[28] *SKM Enviros Report*, p. 85.

[29] *SKM Enviros Report*, p. 86.

[30] *Impact Assessment*, p. 116; *Preparatory Study*, Annex V, p. 248.

[31] *Impact Assessment*, p. 116; *Preparatory Study*, Annex V, p. 249.

[32] *SKM Enviros Report*, p. 87.

[33] *SKM Enviros Report*, p. 88.

[34] *SKM Enviros Report*, p. 89.

[35] *SKM Enviros Report*, p. 90.

[36] *SKM Enviros Report*, p. 91.

[37] *SKM Enviros Report*, p. 92.

[38] *SKM Enviros Report*, p. 93.

[39] *SKM Enviros Report*, p. 94.

[40] *SKM Enviros Report*, p. 95.

[41] *SKM Enviros Report*, p. 96.

[42] *SKM Enviros Report*, p. 35.

[43] *SKM Enviros Report*, p. 35.

[44] *SKM Enviros Report*, p. 35.

[45] *Preparatory Study*, Annex V, pp. 244-272.

[46] *Impact Assessment*, p. 173 *citing* Umweltbundesamt, *Avoiding Fluorinated Greenhouse Gases: Prospects for Phasing Out* (June 2011, English Version), *available at* http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3977.pdf.

[47] *SKM Enviros Report*, p. 35; *see also* SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Draft Version 3, July 2012), pp. 31-32 (includes complete traffic light analysis not included in final version with more favorable conclusions for alternative technologies due to the inclusion of hydrocarbon-based alternatives available in 2012).

[48] *Impact Assessment*, p. 116; *Preparatory Study*, Annex V, p. 253.

[49] *SKM Enviros Report*, p. 97.

[50] *Impact Assessment*, p. 117; *Preparatory Study*, Annex V, p. 254 and Annex VI, p. 307 (includes reversible heat pumps).

[51] *Impact Assessment*, p. 117; *Preparatory Study*, Annex V, p. 256 and Annex VI, p. 308 (includes reversible heat pumps).

[52] *Impact Assessment*, p. 117; *Preparatory Study*, Annex V, p. 255 and Annex IV, pp. 307-308 (includes reversible heat pumps).

[53] *SKM Enviros Report*, p. 98.

[54] *SKM Enviros Report*, p. 99.

[55] *SKM Enviros Report*, p. 100.

[56] *SKM Enviros Report*, p. 101.

[57] *SKM Enviros Report*, p. 102.

[58] *SKM Enviros Report*, p. 103.

[59] *SKM Enviros Report*, p. 104.

[60] *SKM Enviros Report*, p. 105.

[61] *SKM Enviros Report*, p. 106.

[62] *SKM Enviros Report*, p. 107.

[63] *Impact Assessment*, p. 117; *Preparatory Study*, Annex V, p. 257 (includes reversible cycle mode).

[64] *SKM Enviros Report*, p. 108.

[65] *SKM Enviros Report*, p. 109.

[66] *SKM Enviros Report*, p. 110.

[67] *SKM Enviros Report*, p. 111.

[68] *SKM Enviros Report*, p. 112.

[69] *SKM Enviros Report*, p. 113.

[70] *SKM Enviros Report*, p. 114.

[71] *Impact Assessment*, p. 117; *Preparatory Study*, Annex V, p. 258.

[72] *SKM Enviros Report*, p. 115.

[73] *Impact Assessment*, p. 118; *Preparatory Study*, Annex V, p. 259 and Annex VI, p. 309 (heat pumps defined as heating only; reversible air conditioners containing heat pumps are covered by the relevant air-conditioning subsector).

[74] *SKM Enviros Report*, p. 116.

[75] *SKM Enviros Report*, p. 117.

[76] *SKM Enviros Report*, p. 119.

[77] *SKM Enviros Report*, p. 35.

[78] *SKM Enviros Report*, p. 35; *see also* SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Draft Version 3, July 2012), pp. 31-32 (earlier version includes complete traffic light analysis, not included in final version, with more favorable conclusions for alternative technologies due to the inclusion of hydrocarbon-based alternatives available in 2012); *see generally Preparatory Study*; *Impact Assessment*.

[79] *SKM Enviros Report*, p. 35; *see also* SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Draft Version 3, July 2012), pp. 31-32 (earlier version includes complete traffic light analysis, not included in final version, with more favorable conclusions for alternative technologies due to the inclusion of

hydrocarbon-based alternatives available in 2012); *see generally*; Armines, *Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product Group Analysis/2, Lot 6: Air-Conditioning and Ventilation Systems: Air Conditioning Systems* (Final Report, 25 July 2012; Corrected Final Report, 5 September 2012); Shecco, *Guide 2012: Natural Refrigerants Market Growth for Europe* (2012).

80 *Preparatory Study*, Annex V, pp. 244-272.

81 *Compare SKM Enviros Report*, pp. 98, 99, 108, 111, 114, 116 (hydrocarbon-based alternatives not included market sub-sector profiles) *with* SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Draft Version 3, July 2012), pp. 94, 95, 104, 107, 110, 112 (hydrocarbon-based alternatives included in market sub-sector profiles); *see also* Öko-Recherche *et al.*, *Preparatory Study for a Review of Regulation (EC) No 842/2006 on Certain Fluorinated Greenhouse Gases, Final Report* (September 2011)(hereinafter "*Preparatory Study*"); Umweltbundesamt, *Avoiding Fluorinated Greenhouse Gases: Prospects for Phasing Out* (June 2011, English Version) (hereinafter "*UBA Report*").

82 *Compare SKM Enviros Report with Preparatory Study*; *UBA Report*; SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Draft Version 3, July 2012), pp. 31-32 (earlier version includes complete traffic light analysis, not included in final version, with more favorable conclusions for alternative technologies due to the inclusion of hydrocarbon-based alternatives available in 2012); *see generally*; Armines, *Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product Group Analysis/2, Lot 6: Air-Conditioning and Ventilation Systems: Air Conditioning Systems* (Final Report, 25 July 2012; Corrected Final Report, 5 September 2012); Shecco, *Guide 2012: Natural Refrigerants Market Growth for Europe* (2012).

83 *Preparatory Study*, Annex V, p. 252.

84 *Preparatory Study*, Annex V, p. 260.

85 *Preparatory Study*, Annex V, p. 261.

86 *Preparatory Study*, Annex V, p. 264.

87 *Preparatory Study*, Annex V, p. 263.

88 *Preparatory Study*, Annex V, p. 265.

89 *Preparatory Study*, Annex V, p. 266.

90 *Preparatory Study*, Annex V, p. 267.

91 *Preparatory Study*, Annex V, p. 268.

92 *Preparatory Study*, Annex V, p. 269.

93 *Impact Assessment*, p. 9.

94 *Impact Assessment*, pp. 113-114 (ban of HFC-152a in XPS foam blowing reduces 460 $ktCO_2eq$ at -1.6 €/tCO_2eq; ban of HFC 134-a in XPS foam blowing reduces 1,553 $ktCO_2eq$ at 1.0 €/tCO_2eq; ban of HFCs in PU spray foam blowing reduces 1,369 $ktCO_2eq$ at 61.6 €/tCO_2eq; ban of HFC in other PU spray foam blowing reduces 587 $ktCO_2eq$ at 3.5 €/tCO_2eq although a minor exemption may be needed for discrete applications since penetration rate in 2015 is only 95%); *Preparatory Study*, pp. 260-261, 290 and Annex V, pp. 266-269.

95 SKM Enviros, *Further Assessment of Policy Options for the Management and destruction of Banks of ODS and F-gases in the EU* (Final Report, Revised Version 2, March 2012) *available at* http://ec.europa.eu/clima/policies/ozone/research/docs/ods_f-gas_destruction_report_2012_en.pdf.

96 *Impact Assessment*, p. 112 (ban of HFCs in technical aerosols reduces 3,637 $ktCO_2eq$ at 10 €/tCO_2eq); *Preparatory Study*, pp. 260-261 and Annex V, p. 265.

97 The Right to Know Network, *available at* http://www.rtknet.org/db/rmp/rmp.php?state=CA&execsum=refrigeration&chemical_id=56&sortp=F&datype=T&reptype=f&database=rmp&detail=1&submit=GO.

98 *Preparatory Study*, pp. 61-62 and Annex VI, p. 313.

99 EU F-Gas Regulation, Annex III, point 15.

100 EU F-Gas Regulation, Article 21(5).

101 *Impact Assessment*, p. 235.

102 *Impact Assessment*, p. 236.

103 *See Preparatory Study*, p. 155; s*ee also Impact Assessment*, p. 212 and 220 (annual recurring costs of the HFC phase-down and bans on certified personnel and companies, operators, HFC producers and importers is approximately €430,000; annual recurring costs of the phase-down and bans on EU Member States is approximately €1.2 million).

104 *See Preparatory Study*, p. 155.

105 One interesting approach worth considering, drawn from a similar proposal made during legislative consideration of the EU F-Gas Regulation, is the possibility of promoting a scale-up approach for the mitigation fee to ensure a steady revenue stream. In the context of the HFC phase-down schedule in the EU F-Gas Regulation, by way of example, assuming a baseline of 180 Mt CO_2-eq tonnes in 2015, proposals were made to place a fee of €10 per CO_2-eq tonne, which would yield

€1.8 billion annually. This was would be scaled up to €1.08 per CO_2-eq tonne during the first phase-down step (93%) to ensure €1.8 billion is still generated and so on for each phase-down step.

106 EU F-Gas Regulation, Article 11.

107 Miller et al. (2010).

108 Banks and Sharrat, Environmental Impacts of the Manufacture of HFC-134a (7 November 1996).

109 Freedonia 2012, p. 55 (this figure does not include by-product emissions from the production of its feedstock, HCFC-133a, nor "intermittent emissions" of HFC-134a, e.g. fugitive emissions that occur from leaking valves and seals, which are estimated to be as high as 35% of the by-product emissions); *see also* Banks and Sharrat, Environmental Impacts of the Manufacture of HFC-134a (7 November 1996).

110 Banks and Sharrat, Environmental Impacts of the Manufacture of HFC-134a (7 November 1996).

111 EPA, *An Overview of Supermarket Refrigeration Technologies* Presented by Bruce Hierlmeier, Zero Zone; Travis Lumpkin, Hussmann; Scott Martin, Hill PHOENIX; Dustan Atkinson, Kysor/Warren; Masood Ali, Kysor/Warren; at the April GreenChill Webinar (June 23, 2011) *available at*: http://www.epa.gov/greenchill/events.html.

112 *See* http://www2.epa.gov/sites/production/files/documents/gc_averagestoreprofile_final_june_2011_revised_1.pdf.

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114 EPA, *EPA reaches settlement with Safeway to reduce emissions of ozone-depleting refrigerants nationwide* (2013) *available at* http://yosemite.epa.gov/opa/admpress.nsf/0/F1AE0B5361D2AB7E85257BDC0067F850.

115 *See* IPCC/TEAP 2005 Special Report, at 9 (giving estimates of CFC and HCFC banks from 2002-2015); *see also* TEAP Decision XX/8 Report, at 10; TEAP Decision XX/7 Interim Report, at 21-25.

116 *See* IPCC/TEAP 2005 Special Report, at 9 (providing an estimate of CFC and HCFC banks from 2002-2015).

117 *See* UNEP, Technology and Economic Assessment Panel, Supplement to the IPCC/TEAP Report at x (2005), *available at* http://ozone.unep.org/teap/Reports/TEAP_Reports/teap-supplement-ippc-teap-report-nov2005.pdf.

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119 *Preparatory Study*, Annex VI, pp. 285-286.

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130 *Preparatory Study*, Annex VI, pp. 313-315.

131 *Preparatory Study*, pp. 61-62 and Annex VI, p. 313.

132 SKM Enviros, *Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector* (Final Report, Version 11, September 2012), pp. 98-103.

133 *See Impact Assessment*, p. 117; *see also Preparatory Study*, Annex V, p. 254 and Annex VI, p. 307 (includes reversible heat pumps).

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135 *Preparatory Study*, Annex VI, pp. 314-315.

136 CION Proposal, Article 3(1) (more equipment may be exempt depending on definition of "hermetically sealed equipment")

137 *SKM Enviros Report*, pp. 104-107.

[138] *See Impact Assessment*, p. 117; *see also Preparatory Study*, Annex V, p. 254 and Annex VI, p. 307 (includes reversible heat pumps).

[139] Gluckman, Ray (SKM Enviros), Traffic Light Analysis for RAC Market (provided to policymakers during Parliament deliberations).

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[141] *SKM Enviros Report*, pp. 114-115.

[142] *See Impact Assessment*, p. 117; *see also Preparatory Study*, Annex V, p. 254 and Annex VI, p. 307 (includes reversible heat pumps).

[143] Gluckman, Ray (SKM Enviros), Traffic Light Analysis for RAC Market (provided to policymakers during European Parliament deliberations).

[144] *Preparatory Study*, Annex VI, pp. 315-316.

[145] *Preparatory Study*, Annex VI, pp. 315-316.

[146] *SKM Enviros Report*, pp. 108-117.

[147] *See Impact Assessment*, p. 117; *see also Preparatory Study*, Annex V, p. 254 and Annex VI, p. 307 (includes reversible heat pumps).

[148] *Preparatory Study*, p. 256.

[149] *Preparatory Study*, p. 256.

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