Is STEK as good as reported?

Uncertainties in the concept underlying the proposed European Regulation on fluorinated gases

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Executive Summary

Fluorinated greenhouse gases (F-gases) are synthetic compounds that form part of a basket of six greenhouse gases, which the EU has committed to reducing by 8% below 1990 levels in the 2008-2012 commitment period of the Kyoto Protocol. The most common F-gas, HFC-134a, causes 1300 times more warming than a similar mass of CO_2. Used in everything from aerosol cans to refrigeration, these compounds are increasingly prevalent - particularly as they continue to replace CFCs and HCFCs, which are being phased out under the Montreal Protocol.

In an attempt to limit emissions of F-gases in the EU, the European Commission proposed a Regulation that is soon to enter a second reading in the European Parliament. The Regulation focuses on containment and improved handling of refrigerants, with limited marketing and use restrictions in other minor applications. The approach to refrigerants emerged from recommendations of the European Climate Change Programme, and is modelled on a system in place in the Netherlands, known as 'STEK.' This is said to have reduced Dutch emissions of F-gases by more than half in five years, to below 5% of charge per year in stationary cooling. An analysis of an extension of STEK to the rest of Europe, by Enviros consultants on behalf of the European Commission, showed that other Member States might similarly halve business as usual emissions to 5.5% annually by 2010, if they employ a similar approach.

However, potential emissions reductions brought about by the STEK system are hard to identify with great clarity. More detailed study of STEK-sponsored research shows that leak rates could be double the 4.8% figure that inspired the Regulation – depending on how the data are interpreted. Comparing end-user leakage data with sales figures from HFC distributors shows potential leak rates of anywhere from 6.9% to 12.7% annually. The higher leakage figures should not come as a surprise for two main reasons: as was reported by STEK itself, there was likely to be a bias towards non-reporting of high emissions by companies worried about measures that they may face in future to reduce emissions; secondly, when looking at countries with very similar leakage reduction efforts, like Sweden, reported emissions rates are significantly higher.

It is the lack of clarity about how well this model of achievement has performed in real life that brings the Regulation's approach into question. An initial assessment of STEK-like measures across Europe showed a cost of carbon reduction of €18.32/tonne CO_2; if reductions are half as effective as estimated, the costs could rise to over €50/tonne, which is well above €20 level the Commission has generally spoken of as being 'cost-effective' mitigation. The European Parliament has considered and rejected more stringent measures to promote replacement of F-gases with less damaging compounds during its first reading of the Regulation in 2004; however, it is likely that the Parliament took the achievable reductions from containment as a given. This research shows that such reductions are anything but certain, and that alternative approaches may need to be considered more seriously.

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Introduction

Fluorinated greenhouse gases (F-gases) are synthetic compounds used as refrigerants, solvents, aerosol propellants, and other things. There are three sets of F-gases controlled under the Kyoto Protocol: perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). They form part of a basket of six gases, which the EU has committed to reducing by 8% below 1990 levels in the 2008-2012 commitment period.

By far the main set of substances at issue are HFCs – and in particular, one compound known as HFC-134a. This is used in refrigeration, including automobile air conditioning. HFCs were introduced as a replacement for chlorofluorocarbons (CFCs) and to some extent for hydrochlorofluorocarbons (HCFCs), which are being phased out under the Montreal Protocol because they damage the ozone layer. They are also powerful greenhouse gases (GHGs). So while HFCs do no damage to the ozone layer (lacking chlorine or bromine atoms), they are still strong greenhouse gases. The standard measure of comparison, global warming potential (GWP), shows that a similar amount of HFC-134a causes 1300 times more warming than CO_2 (see Annex 1 for GWPs).

There are two main alternatives to deal with f-gas emissions. The first is to make sure equipment is leak-tight, that installation and servicing personnel are well trained, and that refrigerants are carefully handled and transferred at all stages through the refrigerant's life – this is known as 'containment'. The second option is to use different substances with far less serious global warming potentials. In the phase-out from CFCs, many applications have done just that: for example the wide use of hydrocarbons in aerosol cans, foam blowing and domestic refrigeration. For the great majority of other applications there are replacements, and many equipment manufacturers make a range of products using both HFCs and their alternatives. Often there are issues of cost, familiarity, or safety standards that inhibit more substantial uptake.

The proposed Regulation

A Regulation on reducing emissions of F-gases is slated for a second reading in the European Parliament in the summer of 2005. That the Regulation chose to focus on containment of emissions for the vast bulk of applications, rather than on efforts to promote, or require, the use of non-fluorocarbon alternatives, has been a source of considerable controversy. Many countries favour more aggressive policies[1]: Denmark and Austria are phasing out HFCs in a range of applications, the UK and Ireland have legal presumptions against the use of HFCs unless proven necessary, and Germany has investigated bans on HFCs in several cooling applications. Many observers feel that elements from these approaches and others (such as taxes in Norway, or charge size restrictions in Sweden) could be translated Europe-wide. Instead, policies would be forced to comply with the new Regulation, and the focus would rest on containment. This would in fact overturn national law in Denmark and Austria.

Development of the Regulation

Limits on use of fluorinated gases already have a long history, because CFCs and HCFCs are being phased out under the Montreal Protocol. Europe's Regulation 2037/2000[2] is the most recent EU

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[1] It should be noted that all stakeholders and Member States have shown agreement that technician training, improved handling, and recovery were important for the sector for a range of reasons, including the need to handle the existing bank of CFCs, HCFCs, and HFCs and to guarantee safe use of hydrocarbons, ammonia and CO_2 refrigerants – but there is disagreement about to what degree containment should be the *primary* means of ensuring greenhouse gas emissions mitigation for new equipment.

[2] Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer; Official Journal L 244 , 29/09/2000 P. 0001 - 0024

legislation on the elimination of these substances, and is noteworthy for its accelerated HCFC phaseout. HFCs are largely replacements for CFCs and HCFCs, and so the vigorous discussion between government, industry and environmental stakeholders has moved from the ozone context to the climate context. Because so many different applications are touched by the issue, and because industry is having to digest the phase out of ozone-depleting substances, there is considerable among certain sections of industry to defend HFCs. There are rancorous technical arguments between them and those who favour alternatives to HFCs, in what might to outside observers seem a relatively obscure part of the climate issue.

The European Climate Change Programme was a European Commission initiative that structured the development of climate change policy to help comply with the Kyoto Protocol. Among the many stakeholder consultation groups was a fluorinated gases sub-group of the Industry working group[3]. This subgroup primarily included representatives of the many industries producing or using fluorinated gases. They recommended a framework directive on containment with limited marketing and use restrictions, coupled with voluntary agreements and some form of support to alternative (non f-gas) substances. This idea was originally transformed by the Commission to a plan to amend the ozone Regulation 2037/2000, ostensibly as part of an initiative to reduce the proliferation of legislation. Industry balked at linking HFCs to any kind of phaseout, which is the goal of the ozone Regulation, and some member states similarly found Regulation 2037 a less than ideal model due to its rather difficult implementation requirements. As a result, a freestanding Regulation emerged as the Commission proposal in August of 2003[4]. Parallel but separate from the ECCP working group was a process focussed on the phaseout of HFC-134a in mobile air conditioning (MAC) systems; this element was combined into one piece of legislation with the non-MAC sections, but is not discussed in this paper.

The rapporteur for the first reading in the European Parliament (Robert Goodwill, EPP, UK) proposed a number of changes to the Commission's proposal, none of which were particularly consequential in the non-MAC sections. During the debate in Parliament's Environment Committee, there were two major areas of discussion: first were amendments to introduce new restrictions under 'Annex 2' of the Regulation, which deals with phaseouts; although some votes were very close, no amendments were passed. Second was a significant objection to the use of an internal market legal base, Article 95 of the EC Treaty, instead of Article 175, environment. The impact of the former would be to eliminate the option of member states to enact national regulations more stringent than the EU Regulation, which is what Denmark and Austria already had done; they would see their legislation overturned. That the measure was primarily one with an environmental aim seemed obvious to many on the Environment Committee, which voted for a dual legal basis as a compromise, in April 2004. However, the plenary opted to continue with the internal market in its vote at the end of March. Subsequently, the Council legal service argued that a single environment legal base was appropriate, and environmental NGOs and the Member States Denmark, Austria and Sweden continued to argue for this option. In Council discussions in October of 2004, the dual legal basis was reintroduced as a compromise, and the MAC section was split into a separate legislative effort – an amendment to the vehicle type approval directive[5].

Although all was ready for Parliament to begin its second reading in the Spring of 2005, this was delayed until summer, until after the UK assumes the presidency of the Council. The UK has had significant influence on the process until now through its active government and industry representatives and may have wanted to help shape the remaining steps.

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[3] Documentation is available on the Commission's website at http://europa.eu.int/comm/environment/climat/eccp.htm

[4] COM 2003(492), OJ C/2004/96 13. Full Prelex history at http://europa.eu.int/prelex/detail_dossier_real.cfm?CL=en&DosId=184911

[5] 70/156/EEC, as amended by 92/53/EEC

Requirements under the proposed Regulation

The Regulation as it stands focuses on containment and improved handling of refrigerants, with limited marketing and use restrictions in other minor applications. Requirements include:

- *Containment*: an obligation to use all measures that are ‘technically feasible and do not entail disproportionate cost’ to prevent leakage and repair any detected leakage.
- *Inspection*: by certified personnel, annually for systems with 3kg or more, more frequently for larger systems, less frequently for hermetically sealed systems.
- *Leakage detection systems:* for equipment with charges over 300kg.
- *Record keeping:* of F-gases installed, added or recovered during maintenance, servicing and final disposal.
- *Recovery:* of F-gases at end of life ‘to the extent that it is technically feasible and does not entail disproportionate cost’.
- *Labelling:* F-gases containing equipment shall have the substance identified on the equipment
- *Training and certification:* programmes will be required, and personnel will have to be trained
- *Reporting:* producers, importers an exporters who handle over 1 tonne/year will have to report quantities handled.
- *Control of use:* i.e. bans: on the use of SF_6 in magnesium die-casting from 2008, except in small installations; on the filling of tyres with SF_6.
- *Placing on the market:* i.e. bans: on F-gases in non-refillable containers; directly emitting refrigeration (e.g. ‘self-chilling cans’); perfluorocarbons in fire protection; F-gases in windows, footwear, tyres, and gap-filling ‘one-component’ foams (except where required for safety standards); and HFCs in novelty aerosols (e.g. ‘fake snow’, ‘silly string’). All of these on different time scales.

Analysis of the assumed effectiveness of the Regulation

During the ECCP working group, a number of options for reduction of emissions from F-gases were discussed, including everything from voluntary codes of conduct to phase-out regimes on strict timetables. However, attention quickly focused on containment measures like those being pursued under the Dutch ‘STEK’ system. At the time of the ECCP, STEK had nearly a decade of experience and results were reported to be positive. As part of the ECCP process, the Commission commissioned two consultant reports on emissions reduction potentials related to the proposed measures; while there are no estimates of the impact of the proposed Regulation as it stands, the ECCP studies are the basic underpinning for the assumed effectiveness of the Regulation.

In the report on the potential impact of containment measures[6], the estimates rest heavily on information about STEK, with estimates about what the impact of a similar system would be on a European level. The report concluded that the EU-15 could find 15MT CO_2 equivalent savings per year by 2012 at a cost of €18.32/tonne.

There are reasons to doubt that reductions will be this great due to the Regulation. First is that the study analysed a full equivalent of the Dutch system, which is probably more comprehensive and rigorous than systems that are likely to be put in place in other member states due to the Regulation. Second is that it is difficult for the EU to police the proper implementation of such a Regulation at national level. Indeed, one reason why costs of implementing a STEK-like system is estimated to be so much higher in some member states than others is that some have yet to even meet the requirements imposed by the ozone Regulation (2037/2000), which would provide a good basis for HFC regulation (as the STEK system did).

[6] Enviros, 2003.

A third factor calling potential emissions reductions levels into question is what is explored in more detail in this paper - the assumed reductions brought about by the STEK system itself. As these underpin assumptions about the Regulation and informed the decision to choose containment as a primary method of controlling F-gases, the reductions due to STEK are important to understand. However, the estimates reported to the ECCP are based on only partial results from a study of leak rates, which upon further study are not easily interpreted.

The STEK system may be significantly less effective than thought

During development of the Regulation it was widely cited that the Netherlands had managed to reduce its refrigerant emissions to 4.5% per year of the total bank of installed refrigerants, through use of the STEK system. This low figure was presented as evidence of the success of the containment strategy, and became the backbone of the EU proposal. However, there was never any further investigation of the leak rate. It isn't surprising that these results have not been widely discussed, however: the report upon which the figure is based is only available on paper, by request to STEK, and only in Dutch[7]. It was not corroborated by more recent or independent study as part of the Regulation's development.

If one examines the studies upon which the 4.5% figure is based, a complicated picture emerges. That figure was picked out of one of four studies completed together (by STEK, ITM, KPMG, and TNO), which were supposed to approach the issue from different angles. The study, by ITM Research, was a survey of users and their logbooks of system servicing. It showed that there was an estimated 13,500 KT of refrigerants in use, and 604 KT of emissions, hence a leak rate of 4.5%. However, the 4.5% includes non-fluorinated gases, in particular ammonia. If both banks and emissions from these sources are removed, as well as 'unknowns[8],' then the leak rate is 5.2%; if 'unknowns' are included, the leak rate is 4.8%. If one looks only at the HFC-containing equipment (non-mobile air conditioning), the rate is 5.8% for known emissions coming from known banks, or 5.3% if unknowns are included (Table 1).

Table 1: various ways of re-calculating the STEK leak rate using the ITM report alone[9]

		Bank	Emitted	Leak rate[10]
HFCs	Known amounts	1847	107	5,8%
	Including unknowns	2151	115	5,3%
ALL FCs	Known amounts	10890	568	5,2%
	Including unknowns	12681	609	4,8%

These results are viewed separately from information in the KPMG study, which calculated the total amount of F-gases sold in the Dutch market in the same year, corresponding to use for filling of new installations, and re-filling needed as a result of leakage. The impact of comparing across the two studies is presented in Table 2. The table is complicated, due to the need to interpret the published results. An explanation row by row follows:

Row 1 shows the bank of gases estimated by the ITM report, 12681 KT, the amount of sales reported by the KPMG report, 1848 KT, the amount of f-gas reported as being used in 'new' installations, 235

[7] 'Koudemiddelgebruik in Nederland: Rapportage op basis van het Nationaal onderzoek Koudemiddelstromen Nulmeting over 1999 voor het HFK-beleid in de koudetechniek' Stek, Utrecht, 29 mei 2002. This study comprised several elements: an investigation of net sales volumes (by KPMG), a survey of installers about emissions volumes (by STEK), a study about causes of emissions (by TNO), and a survey of users and their log books (by ITM Research), wherein all system servicing/maintenance events are recorded.
[8] Quite a large volume of total coolants was reported as being of 'unknown' type. When included in the leakage figures here, HFCs separately and FCs together, in the two respective sections of the table, are proportionally represented among the unknowns in equal amounts to their representation in known quantities.
[9] Taken from the ITM study, with unknowns calculated as in the previous footnote.
[10] Annual emissions as a percentage of the bank

KT, the difference between sales and new use that are therefore reported as emissions, 1613 KT, and the resulting leak rate comparing this amount to the estimated bank, 12.7%.

Row 2 reduces the KPMG sales amount by 194 tonnes, which were reported as having been sold to a single large automotive cooling manufacturer that was not included in the STEK survey, rather STEK states it was confirmed by cross checking with its database[11]. Given that the ITM survey shows only 249 tonnes of HFC-134a are found in installations, it certainly seems unlikely that there could be 227 tonnes sold[12] in 1999 alone. Still, there is a range of problematic issues with this adjustment[13]. Removing the 194 tonnes yields an 11.3% leak rate

Row 3 uses the sales figures of row 1 and recalculates two things: the total bank is only for known gases and amounts. Also, new systems are not the figure reported as 'new' in the ITM report and the executive summary, but the figure calculated from the table 'year of delivery' as being from 1999[14], also only for known gases and amounts. This yields a 10.1% leak rate.

Row 4 calculates the same as row 3, but with the inclusion of 'unknown' gases. This yields an 8.4% leak rate.

Row 5 is as in row 4, but minus the 194 tonnes as in row 2. This yields a 6.9% leak rate.

Table 2: leak rates comparing measured emissions to sales amounts (in KT)[15]

Row #	Description	Bank	Sales	New	Emitted	Leak rate[16]
1	KPMG sales minus ITM 'new' installation	12681	1848	235	1613	12,7%
2	As previous, minus 194 tonnes of HFC ascribed to automobile comfort cooling	12681	1654	235	1419	11,3%
3	KPMG sales minus 'system delivery in 1999' using known types and amounts	10890	1848	748	1100	10,1%
4	As previous, including unknowns proportionally	12681	1848	779	1069	8,4%
5	As previous, minus 194 tonnes HFC ascribed to automobile comfort cooling	12681	1654	779	875	6,9%

[11] Page 30, executive summary – and not mentioned anywhere else in the report, or in tables. This makes it extremely difficult to track, and to know if it has been separated out anywhere else.

[12] After subtracting the 56 KT reported as going to mobile air conditioning

[13] The first problem is that the KPMG survey notes which applications used the HFCs in question - it separates out 56 tonnes for mobile air conditioning, and the rest among four other sectors. The implication is that this is wrong – by a very large margin. Given that this is an annual survey, one has to question how they could have been so wrong given their experience. Further, the STEK and ITM surveys scale up the survey responses (i.e. multiply by some factor) to reflect an estimate of the whole population. To some degree, therefore, lacking the 194 tonnes is covered by the scaling up factor from those data points that were included – many other specific uses weren't included either, as this is a statistical sample. The 194 tonnes just happen to be a particularly big use and skew the results by not being included, but can't simply be added back in without first de-scaling, adding it in, and re-scaling from the survey response to the estimate of the full population. Simply adding it back in, as has been done here for simplicity, would tend to overstate its influence somewhat – i.e. the figure should be lower. Finally, it is not assumed that the 56 tonnes reported as being for the mobile sector in the KPMG were included in the 194 tonnes, though they may have been. There is no way of knowing, given that the STEK report implies that KPMG is wildly inaccurate in their apportioning of 134a to different sector uses.

[14] ITM, page 33, table 2.16. What the difference would be between 'new' systems and those installed in 1999 is unclear, which is why both approaches have been reported separately here.

[15] Banks are from the ITM study. Sales are from the KPMG study, as summarised in the executive summary: this figure is calculated as 700 tonnes minus 56 tonnes of HFC-2134a dedicated to mobile air conditioning. All pre-filled systems and canisters for mobile air conditioning are left out. 'New' uses are recorded in the ITM study.

[16] Annual emissions as a percentage of the bank

The figures listed above are not claimed to be more accurate than the 4.5% and 4.8% leak rates frequently reported by STEK – nor is it to be read that STEK has misrepresented its work. What should be inferred, however, is the immense complexity of interpreting the data resulting from such a study. There are clearly different ways of looking at the data that imply significantly different emissions levels, anywhere from 6.9% to 12.7%, or between about 1.5 and 2.5 times as high as the rates widely mentioned as STEK's result.

Reported emissions may have been low due to response bias

There are a number of possible explanations for the discrepancy between the 4.5% figure, and the rates revealed by looking across the studies. The ITM study notes that only 10.8% of installations recorded any emissions – which indicates that leakage isn't an evenly spread phenomenon, but rather, the majority of emissions are accounted for by a smaller group of installations. One might well ask, given the importance of a few installations to the overall leak rate, whether the sampling methodology was likely to capture a representative group of installations.

The studies themselves call the representativeness into question. The ITM survey of users managed to get written responses from 12% of the companies initially contacted by telephone, which were themselves supposed to be a random sample of the relevant sectoral uses. The STEK survey of installers and technicians went to all 2140 registered companies, of which 334 were returned, or 16%. These levels of response would easily be statistically significant in a random survey. However, the response wasn't random – there was no obligation to respond, and there is no way of knowing whether those who responded were responsible for equipment with more or less emissions than those who did not. Significantly, the STEK report itself finds that 'the level of coverage is generally not high. The impression is consistently that installers are reluctant to share their insights when it is unclear what the policy changes could come as a result…the response from STEK-recognised businesses is disappointing.' TNO found that 'the delivery of data ran up against, in particular in larger companies, resistance by management'.[17]

Given the fear of potential implications for policy, one might suspect that reporting high emissions could be seen as unwise, as it might lead to tougher controls. If anything, the tendency may well have been for those with less to worry about to be the most willing to return the forms.

It is hard to know how well containment works

The STEK study notes the difficulty of any real accuracy in the estimates. 'It must be recognised that the picture we have gotten can diverge from reality. There is a significant level of uncertainty in the extrapolations, given that the standard deviation from the mean was regularly 100% or more.[18]'

After six years of experience with STEK at the time, the ITM study found 'it is notable that a review of the logbooks shows that the interventions are often not completely recorded. About 50% of the interventions turned out not to be (fully) traceable.[19]' In its study of the reasons for leakage, TNO learned that 'fully 40% of the interventions with coolant re-filling and almost 35% of the total re-filling amount fall under the cause of emissions category 'unknown''[20].

A tremendous amount of effort went into STEK's set of studies, building on six years of experience. That these levels of uncertainty remain goes to show the inherent difficulty of attempting to monitor the impact of containment on this incredibly diverse and dispersed sector. However, effective monitoring and oversight of servicing practice are the main tools for ensuring compliance with containment measures, making the difficulty of doing so a real concern for any policy that relies on

[17] TNO report, pg. 4
[18] STEK Annex 2 'methodology', pg. 10
[19] ITM report, pg. 29
[20] TNO report, pg. 45

containment – policymakers are unlikely to be given a true picture of emissions, and technicians are unlikely to feel pressure to use best practices and technologies simply by having record keeping requirements.

The proposed European Regulation has a monitoring and data collection system at its heart, which should give incentives to best practices that will reduce emissions. But given that there is no explicit requirement for this information to be submitted for analysis – it only needs to be made available if someone happens to ask for it – it is a fairly notional requirement, which even in the best case, as in Holland, yields incomplete information.

Total HFC emissions will continue to rise even as leak rates fall

Leak rates have very likely dropped in the Netherlands due to the STEK system, though it is very difficult to say by how much, and what the absolute levels now are. However, while there has been a probable drop in the *rate* at which HFC equipment leaks, overall leakage from stationary cooling will still more than triple between 2000 and 2010 because more systems will use HFCs[21]. This is due both to replacement of other FCs by HFCs, and by market growth.

Table 4: leak rates and total leakage projections from stationary sectors

Year	Leak rate	total leakage (tonnes HFC)
1995	10%	32
1999	5%	107
2010	5%	430

Table 4 indicates the evolution of leak rates and total leakage amounts, where the data for 1999 are the same as in the studies mentioned above. Future projections take this 1999 level as a baseline, upon which future amounts are predicted. The Dutch annual inventory of greenhouse gas emissions similarly uses the same 1999 figure, and scales up emissions by an assumed growth rate. Note that if the leak rates are incorrect and are in fact higher, the possibility of which was indicated above, the percentage growth rate would stay the same, but the absolute amounts would be significantly higher. Because national reporting to the European Commission and the UN relies on the same figures, there are ongoing repercussions for assumed emissions until another survey is done.

STEK leak rates in international perspective

Globally, top-down estimates using sales data from manufacturers indicate that refrigerants of all sorts leak on average 30% per year[22]. The refrigeration application of most importance to HFCs is supermarket refrigeration, where traditional 'direct expansion' systems use large charges and generally have high leakage.[23] A review of leakage rates from such systems around the world shows emissions in the range of 3.2 to 22% of charge per year, with the lowest figure being an estimate of the STEK results for this specific sector (Table 5).

[21] Beker, D. and C.J. Peek, 2002
[22] Palandre *et al*, 2004
[23] In these systems, the refrigerant runs throughout the supermarket in pipes, leading to cooling units. Due to the longs runs, charges are high, and leakage can occur through the many joints in the piping.

Table 5: supermarket leak rate estimates around the world

Country	Year(s)	Annual leakage
The Netherlands[24]	1999	3.2%
Germany[25]	2000-2002	5-10%
Denmark[26]	2003	10%
Norway[27]	2002-2003	14%
Sweden[28]	1993 1998 2001	14% 12.5% 10.4%
United Kingdom[29]	1998	14.4%

That the STEK figure is so low could be taken to be a sign of its success compared to the efforts of other countries. However, the sharp divergence between Dutch and international results in such a traditionally emissive technology raises questions about the accuracy of the figure. Countries like Sweden have instituted aggressive control programmes of their own; they lead the way, for example, in low charge, low leakage 'secondary loop' systems, as well as having a containment strategy very similar to that in the Netherlands. It seems highly unlikely their supermarkets emit three times those in Holland, while using techniques similar to those in Holland that are designed to reduce emissions[30] (on the other hand, if these techniques are so variable in their impact, it raises further questions).

The implications of potentially higher leak rates for the costs of abatement

In the Enviros report issued through the ECCP working group on F-gases, it was assumed that the current annual leak rates under the STEK system was 4.8%. It also estimates that a similar system applied in the rest of the union may only achieve a 5.5% leak rate due to the time the Dutch have had to implement the system, the small size of the sector there, and the degree of cooperation between government and industry.

Given the reduction from estimated business as usual (BAU) emissions levels in 2012 to the 5.5% figure, and the costs of doing so, the report states that there will be a possible reduction of 15 MT CO_2 eq. at a cost of €18.32/tonne in the EU-15. The costs of implementing a 'STEK' system are relatively fixed - if we assume that the emissions reductions resulting from this level of effort are in fact less than expected, then the costs per tonne abated increase. An example is reported in table 6 – it shows the implications of any less effective result than the ones assumed, whatever the reason. Costs rise from €18.32/tonne to €52.57/tonne if abatement is about half as effective as anticipated.

24 Hoogen et al., 2003; STEK, 2001
25 Birndt et al., 2000; Haaf, 2002
26 Pedersen, 2003
27 Bivens et al., 2004
28 Bivens et al., 2004
29 Radford, 1998
30 The Enviros study commissioned for the ECCP describes the Swedish system this way (Enviros 2003, pg. 32), which is very similar to STEK:

> 'Servicing and installation of refrigeration and air-conditioning systems may only be carried out by accredited enterprises, these must have certified and trained personnel (re-examination every 5 years) and are liable for audit. There are technical requirements on design…plus an operating manual and further specifications. Plus requirements on inspection, record keeping and reporting, upon installation (all refrigeration and air-conditioning systems except unitary stationary systems with less than 3kg refrigerant). The Swedish Refrigeration Association has a code of how often a system may leak, and what should be checked.'

Table 6: the impact of less effective mitigation on costs/tonne

BAU Leak rate in the EU-15, 2012	Total BAU leakage in 2012 (tonnes CO_2 eq.)	Leak rate under the Regulation	Leakage reduction achievable in 2012 (tonnes CO_2 eq.)	Cost per tonne
11%	35,111,837	5.5%	14,953,001	€18.32
11%	35,111,837	6.5%	11,590,603	€22.07
11%	35,111,837	7.5%	8,228,204	€31.09
11%	35,111,837	8.5%	4,865,805	€52.57

Conclusions

Analysis of the conceptual underpinnings of the proposed EU Regulation, drawn from the Dutch STEK system, shows that emissions reductions attributable to containment in Holland may well be less than reported. By comparing end-user surveys with top-down sales figures, much higher derived leak rates result than the 4.5% and 4.8% figures widely cited. Depending on how the published study results are interpreted, comparing bottom-up and top-down surveys shows the implied leak rates could be anywhere from 6.9% to 12.1%.

While the specific achievement of STEK in limiting leak rates is difficult to pin down quantitatively, there have likely been reductions, and the system has many benefits for the professionalism and environmental awareness of the sector in Holland. It is in fact probably more effective than any system that would be likely to result from the requirements of the Regulation. STEK's requirements are more detailed than those under the Regulation, and as the Netherlands has a small market, tight cooperation between regulators and industry, and an environmentally conscious population, poorer results in many other member states are to be predicted. Emissions reductions under such an approach are largely due to good monitoring, technician training, and technicians' willingness, essentially voluntarily, to make leak avoidance a priority. However, the European Regulation makes no specific requirements on data gathering and reporting, no specific technical requirements to avoid leakage, and no specific obligation to report, avoid or repair leakage – the blanket obligation to avoid it where possible has no measurable objective parameters.

The result is that one should not be surprised if emission reductions are less effective than anticipated under the Regulation. Given that implementation will have real costs, the effect of poor results would be to raise the price of mitigation – based on ECCP study results of an estimated cost for an expanded STEK system of €18.32/tonne CO_2, if mitigation were about half as effective as anticipated costs would rise to above €50/tonne.

Given concerns about the potentially limited effectiveness of containment, other options could be considered. These include means of limiting demand for cooling, and switching to alternative technologies or refrigerants with lower climate impacts. The former is a general goal outside the scope of the Regulation, but the latter is central to the kinds of phaseouts of minor applications in Articles 7 and 8 of the Regulation.

Alternatives to F-gases and associated equipment in refrigeration are increasingly popular; the question is how to introduce them into the market. Containment regulations do little to promote alternatives in the market when these are subject to similar requirements – as they ought to be, given they have safety considerations that require oversight. Other major possibilities include taxes and charges on F-gases that make alternatives more attractive, and phaseouts of F-gases. The former have been applied in Denmark and Norway with success – however, taxes are difficult to agree at European level and are unlikely to be considered. Phaseouts, on the other hand, are already part of the Regulation under consideration, albeit for minor applications. The question is whether the same approach would be appropriate to major uses in refrigeration and air conditioning.

Policies in Denmark and Austria were designed phase out HFCs in a period of time meant to keep pace with technical improvements among alternatives. In Austria, for example, HFCs are banned in refrigeration and air conditioning from the beginning of 2008, but with the option for exemptions where needed. Denmark has a range of phaseout dates differentiated among applications – for example, HFCs in commercial refrigeration are banned in five steps over a period of four years, depending on system size.

While these policies came in for criticism from the ECCP working group on F-gases as too aggressive to consider at the European level, this is essentially exactly what is being done to phase out HFC-134a in mobile air conditioning under the proposed amendment of the vehicle type approval directive. In that case, the alternative systems, transcritical CO_2, have proven themselves but are farther from the market than systems already widely used in stationary applications. Thus, logic would seem to dictate that a similar approach could be at least considered in stationary sectors.

Annex 1: Global warming potentials

Different substances have different impacts on the climate, due to their inherent physical properties and the length of time they stay in the atmosphere. The global warming potential (GWP) is a metric devised to compare substances' impact, where the GWP of CO_2 is set equal to 1. The GWP is defined over a set time horizon—the impact relative to that of CO_2 over a 100 year period (GWP-100) is most often used[31].

Substance	Composition	GWP-100
Carbon dioxide	CO_2	1
SF_6	SF_6	22200
Hydrofluorocarbons (HFCs)		
HFC-23	CHF_3	12000
HFC-125	CHF_2CF_3	3400
HFC-134a	CH_2FCF_3	1300
HFC-143a	CF_3CH_3	4300
HFC-152a	CH_3CHF_2	120
HFC-245fa	$CHF_2CH_2CF_3$	950
HFC-365mfc	$CF_3CH_2CF_2CH_3$	890
Common blends		
R-404A	143a/125/134a	3784
R-407A	32/125/134a	1990
R-407C	32/125	1653
R-410A	125/143a	1975
Perfluorocarbons (PFCs)		
Perfluoromethane	CF_4	5700
Perfluoroethane	C_2F_6	11900
Chlorofluorocarbons (CFCs)		
CFC-11	CCl_3F	4600
CFC-12	CCl_2F_2	10600
Hydrochlorofluorocarbons (HCFCs)		
HCFC-22	$CHClF_2$	1700
HCFC-141b	CH_3CCl_2F	700

[31] Chart data source: IPCC 2001.

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