An Analysis of Emission Trading in Fire Protection:

HCFCs for Halons

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ABSTRACT

Replace halons with HCFC for a Net Environmental Benefit

A very significant reduction in damage to the stratospheric ozone layer **can** be realized if halons, used for fire protection, **are** removed **from** service and securely stored or, preferably, destroyed, and **replaced** with HCFCs. If HCFCs are produced for fire protection, and a weight of **halons qual** to *5%* of the HCFCs produced are destroyed, the **net emissions** of ozone depleting **substances** for fire protection will be **negative 198,000** equivalent tomes. ***An*** equivalent tonne **being** the weighted ozone depletion potential of one tonne of CFC-11.

Ozone depletion not only environmental impact

To evaluate the environmental effect of a **substance** it is **necessary** to look ***at*** all potential impacts not simply one aspect. For halon alternatives global warming potential (GWP) and atmospheric lifetime (ALT) are of great concern.

ENVIRONMENTAL CONCERNS ARE NOT LIMITED TO OZONE DEPLETION

When examining the environmental effect of a substance one should not look at one aspect, in this case ozone depletion potential **(ODP),** in isolation. The total cradle to grave environmental effect should be examined. Of particular concern with regard to halon replacements are global warming potential **(GWP)** and atmospheric lifetime **(ALT).** Also of concern is the pollution associated with the production of the agent and the pollution caused by installing a system. Production of systems will invariably produce some pollution. Replacement of existing systems will produce waste material from the old systems as well as pollution generated when producing the new systems. In some cases considerable quantities of potentially contaminated construction debris may have to be landfilled.

Damage to the Ozone Layer is Self-Healing

Ozone depleting substances (ODS) do not destroy ozone rather they interfere with the production of ozone. Stratospheric ozone is constantly being created and destroyed according to the following simplified reaction scheme.

$O + O_2 \longrightarrow O_3$
$O_3 + h\nu \longrightarrow O + O_2$
$O_2 + h\nu \rightarrow 2O$
$O + O \rightarrow O_2$

Of course in reality, even in the absence of anthropogenic influences, there are many other reactions happening in the stratosphere: some of these involve species from the above reactions and may reduce the equilibrium for that which could be calculated using only the above reactions.

ODS interfere with the equilibrium established above by removing **O** from the system according to the simplified reaction scheme shown below.

$O + X \longrightarrow XO$
$XO + O \longrightarrow X + O_2$

where **X** is a halogen or similar species

These reactions decrease the concentrations of **O** which in turn decreases the concentration of O_3 When **X** is removed from the stratosphere it is removed from the equation and the previous equilibrium **is** re-established and thus stratospheric ozone is replenished and the ozone layer will have healed itself

Climate Change

"**OZONE** is only one problem and is **RELATIVELY MINOR**

A potentially **MORE SERIOUS** example is **GLOBAL WARMING** and this will have to be tackled early"

Dr. Brian Gardiner, head of the ozone section of the British Antarctic Survey is reported to have made the above statements [3].

There *are* a great many uncertainties associated with global climate change. The Global Warming Potential (GWP) of a substance does simply measure how much it would cause the earth to warm a better term would be Climate Change Potential. It is thought that there will be very significant shifts in climate associated with "Global Warming"; storms will become more severe, rainfall will decrease in some areas and increase in others, winters may actually become colder as the summers become hotter The great uncertainties associated with climate change however are a number of potential positive feed-back mechanisms. Will warming release methane from the perma-frost causing more warming? will it cause higher levels of water vapour (a greenhouse gas) in the atmosphere? will rising sea-levels cause a decrease in planetary albedo causing further warming? **Are** any of these reversible? Is the earth at present in an unstable equilibrium with respect to climate? Can we tip the balance and cause massive irreversible changes? Unlike ozone depletion, **global climate change** may be **irreversible.**

Atmospheric Lifetime (ALT)

Are we passing environmental problems on, not just to the biblical tenth generation, but even unto the fiftieth generation?

The ALT of a substance is important because it is an indicator of the certainty we have about the fate of the substance. If a substance has a short ALT this indicates that the substance will take part in a known set of reactions and its effect is well characterized. It may turn out that the substance participates in other reactions and it has fates other than the known ones but even if the unknown reactions turn out to have serious deleterious environmental consequences **we** have an upper bound on the time over which these consequences will be spread. If a substance has a very long ALT this may indicate that the we have missed the main fate of the substance. It is likely taking part in unknown reactions. What are the reactions? Do they have harmful consequences? Will the consequences be suffered for generations? In the case of PFC with ALT of thousands of years we may be handing severe environmental problems down for millennia.

Other Environmental Impacts

As well as the above noted atmospheric impacts the impact on soils and waters of the agents, their manufacturing processes, and the production and installation of systems utilizing the agents should be examined.

If extensive retrofit of existing systems is required the environmental impact of the retrofit could be substantial. *As* well as the pollution associated with producing a new system there may be considerable quantities of construction debris generated in installation process. This is because some fire protection systems are highly integrated into the building in which they are installed and removal of an old system and installation of a new may involve significant renovations. In the specific case of nuclear power plants not only would considerable construction be required but quantities of radioactively contaminated waste would be generated.

HCFC as a Halon 1301 Replacement

Halon 1301 systems have traditionally been over designed. Various design criteria (see for example **NFPA** 12A *[5]* state:
i) that a demonstrated extinguishing concentration plus twenty percent safety factor shall be used as a minimum design concentration
ii) that in no case shall a design concentration of less than 5% be used.
Many installed halon 1301 systems have sufficient halon 1301 to achieve a concentration well in excess of *5%* in the enclosure they were designed to protect.
For other clean agents the minimum design concentration, as stated by NFPA 2001 [6], is a demonstrated extinguishing concentration plus 20%. Using the above criteria, on a weight basis, approximately 10% more NAF S-III than halon 1301 (360 g/m^3 vs. 331 g/m^3 under standard conditions), is required for a minimum design concentration for n-heptane (the "standard" **fuel).** Because halon 1301 systems frequently have more halon than required it is often possible to replace halon 1301 on kilogram for kilogram basis with NAF S-III.

The Factory Mutual Research Corporation [4] identify the various characteristics that affect the flow of halon-like agents in piping systems. I have summarized their findings, in table form, below.

If Property increases	then Flow rate	Property NAF S-III vs. halon 1301	Flow NAF S-III vs halon 1301
vapor pressure	decreases	lower	higher
gas density	decreases	lower	higher
liquid density	minimal effect	lower	
heat of vapourization	decreases	higher	higher
gas viscosity	no significant effect		
liquid viscosity	no significant effect		

In **summary** they found that there were three important factors influencing flow rate; vapour pressure, gas density, and heat of vapourization. In all cases the properties of NAF S-III are favouring higher flow rates. **A** higher flow rate leads to a shorter discharge time. Note that more NAF **S-111** is required than halon 1301 but the factors which increase the flow rate of the NAF S-111 should more than compensate for the 10% extra mass of NAF **S-III.**

While some modifications to systems will be required when converting from halon 1301 to NAF S-III the piping can remain the same and thus with respect to piping NAF S-III is a drop-in replacement for halon 1301 in real halon 1301 systems.

Restrictions on halons

While halon production is banned effective December 31, 1993, there is no requirement, under the amended Montreal Protocol, for the removal of halons from use. nor for the destruction of the existing stock of halons. It is estimated that there is a **3%** to **5%** annual emission of the halon stock, to the atmosphere, due to leakage and other factors [1] Many countries have gone beyond the letter of the protocol in curtailing the use of halons. Australia, for example, has announced that the possession of halons after January 1, 1996 will require an "Essential Use Permit". "**4.4** Experience relating to the issue of 'Essential Use Permits' ... shows that few, if any, will be issued for ground based total-flooding Halon installations. This is because alternative protection strategies are available .." [7]. One of the accepted alternatives is NAF S-III. Production of HCFCs is also limited under the Montreal Protocol, and there have been suggestions, in some jurisdictions, that they should be banned for fire fighting purposes. The model presented below show that this is short sighted and that significant benefits can be gained by replacing halons with HCFC.

Emission Trading: the Concept

Replace highly impacting emissions with emissions of lower impact

Emission trading is a well established concept in air pollution control. With emission trading the market-place encourages the destruction of highly polluting sources in favour of those which are cleaner. The basic concept is to allow a new source of a pollutant (in this case an ODS) in an airshed (for ODS the entire world) only if replacing an existing source which would have produced more pollution than the new source. ***An*** example, for acid rain control, would be to allow the construction of a factory producing 9 tonnes/day of sulphur dioxide (SO_2) if sources producing 10 tonnes/day of SO_2 are eliminated. This concept can easily be extended to ozone depleting substances.

Produce low ODP ODS (HCFC) to Replace High ODP ODS

Production of an ODS with a low ODP could be allowed if an ODS with a higher ODP were destroyed. Even if the amount of the substance destroyed was less than the amount of the new substance produced a net reduction in ozone depletion can be achieved due to the higher ODP of the substance destroyed. (**As** discussed below, if 1 tonne of halon 1301 were destroyed and 40 tomes of an HCFC with an ODP of 0.04 were produced, the potential ozone depletion would be one tenth that which would result if no halon were destroyed and no HCFC produced.)

Weighted Emissions and Equivalent Tonnage

Different compounds have different ODP and are produced at different rates. To compare the potential effect of various compounds we can use *weighted* emissions. We can define the ***weighted*** emissions as the ODP of the substance multiplied by the weight of the substance. One tonne of halon 1301 (with an ODP of 16) would cause the same damage to the ozone layer as 16 tonnes of CFC-11 (ODP are measured relative to CFC-11 which by definition has an ODP of 1) or 400 tonnes of HCFC (ODP of 0.04). Weighted emissions are expressed in equivalent tonnes relative to CFC-11.

Modeling the Environmental Effect of Replacing Halons with HCFC

Background and Calculations

The Halons Technical Options Committee (HTOC) of the United Nations Environment Program (UNEP) [1] has examined historical use of halon 1211 and halon 1301, present stocks of these materials and future emissions. These data combined with knowledge of the Ozone Depletion Potential (ODP) of the substances allow us to calculate the relative potential damage to the ozone layer caused by these substances.

It was estimated that, in 1986, halons were responsible for 23% of the total estimated ozone depletion potential (ODP) of CFCs and halons combined [2]. **As** mentioned above HCFC can also be used as clean, fire extinguishing agents with low toxicity. HCFCs have a small, but non-zero, ozone depletion potential.

If emission trading in ODS were allowed, it would be possible to accelerate the phase-out and destruction of halons and other ODS with high ODPs, with a considerable reduction in damage to the ozone layer.

Ozone Depletion Potentials (ODP) and Production Limitations

While severe limitations on hydrochlorofluorocarbon (HCFC) production are mandated by the amended Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) at present there is no requirement for the destruction of existing stocks of the far more harmful CFCs and halons. HCFCs used for fire protection have ozone depletion potentials (ODPs) of 0.05 or less while CFCs typically have ODPs of about 1 and halons have ODPs of up to 16. In the past, virtually all of the ozone depleting substances (ODS) used for fire protection purposes have been halons. In this paper we explore the potential benefit to the ozone layer of replacing halon 1211 and halon 1301 with HCFCs.

An ODP of 16 for halon 1301 and **4** for halon 1211 [2] is used for these calculations. The North American Fire Guardian Technology Inc. replacement for halon 1301, **NAF** S-III, has an ODP of 0.04: its newly announced replacement for halon 1211, NAF P-III, has an ODP of 0.02. To be conservative calculations were run assuming an ODP for HCFC of 0.05

Emission Data

HTOC [1] presents data on emissions of halons 1211 and 1301 in use as well as on halon stocks. The halon stock data is conservative. Their data states that the United Kingdom, Sweden, Japan and India have an installed base of about 30,000 tonnes ofhalon 1301 while the worldwide total is estimated to be between 60,000 and 70,000 tonnes. It seems likely that the rest of the world, including most of the heavily industrialized and oil producing nations, would have stocks considerably in excess of those found in these four countries, and thus the total stocks are severely underestimated.

Anecdotal evidence also suggests that the HTOC data is very conservative and that the data grossly underestimates halon 1301 production to date. Manufacturers may have under-reported production in the past for commercial or other reasons and may continue to do so now to, in the public eye, minimize their contribution to a growing environmental problem. **A** more realistic estimate of the existing stock of halons is; 350,000 tonnes of halon 1301 and 150,000 tonnes of halon 1211.

HTOC estimates that post-1993 the halon 1301 stock will be released to the atmosphere at the following fraction of the existing stock per year: 1.5% to extinguish fires, and 1% for leakage and false discharges. **In** addition 2.5% of the supply will be used for testing and training. Pre-1988 leakage and false discharge rate was estimated to be 2.5% per year. We feel that the leakage figures are conservative.

HTOC estimates that post-1993 the halon 1211 stock will be released to the atmosphere at the following fraction of the existing stock per year: 2% to extinguish fires, 1% for testing and training, and 2.5% for leakage and false discharges.

To supplement the very conservative HTOC emission estimates we constructed a very simple model using the more realistic estimates of halon stocks, for 1993, of 350,000 tonnes of halon 1301 and 150,000 tonnes of halon 1211. We calculated emissions assuming that a fixed fraction of the stock would be emitted each year: this was done for a 2% (a highly conservative figure) and a 4.5% per year emission rate.

An emission rate of 2% of the halon stock per year is very low: this is less than the emissions HTOC predict for fire extinguishment and leakage with no allowance for training and testing. We believe that while emissions due to training and testing may well drop below the HTOC estimates, emissions due to leakage will be much higher. Informal discussions with persons experienced in the maintenance of halon 1301 systems lead us to believe that leakage alone cannot be below 2% of the stock per year and is likely higher. ***An*** emission rate of 4.5% of the stock per year is a fairly conservative. but realistic, estimate. The overall conclusions of this paper are not very sensitive to the exact emission rate used.

Production, Reduction, and Destruction

We developed a model for HCFC use for fire protection purposes similar to the model used by HTOC. The following assumptions were made:

- for halon 1301 replacement by HCFC

1. -production starts in 1993 at 3000 tonnes per year;

2. -production grows at 50% per year from 1993 to 1995;
3. -production grows at 20% per year in 1996;
4. -production grows at 10% per year in 1997;
5. -production grows at 5% per year in 1998;
6. -production is stable from 1999 to 2001;
7. -production decreases 5% per year from 2002 to 2004;
8. -production decreases 10% per year from 2005 to 2007;
9. -production decreases 12% per year from 2008 to 2010;
10. -production decreases 5% per year from 2011 through 2019 when production halts;
11. recovery efficiency on recycle;
12. -one fifteenth of existing stock is recycled each year;
13. -emission assumptions are the similar to those made by HTOC for halon 1301 i.e.
    1.5% per year of existing stock to fires;
    2% to training and testing;
    1% to other emissions.;

- for halon 1211 replacement the model was identical to that outlined above except that production did not start until 1994 and it was 24% of the production used for halon 1301 replacement.

We used the above models to calculate the tonnage of halons that would be destroyed in various emission trading scenarios. The scenarios calculated were that a weight of halon equal to 5%, 10%, 40%, or 80% of the weight of HCFC, produced for fire protection, would be destroyed.

RESULTS and DISCUSSION

Halon Emissions in Terms of Ozone Damage

Table **la** presents a summary of the weighted ODP of emissions of halons, as derived from HTOC data [1] expressed as thousand equivalent tonnes. **As** can be seen it is expected that if no action is taken **Halon emission of 1.5 million equivalent tonnes** can be expected in the future. **As** discussed above, it is likely that halon stocks, and thus emissions, are underestimated. Weighted emission data for a 500,000 tonne (350,000 tonnes of 1301 and 150,000 tonnes of 1211) halon base with a 2% per year and a 4.5% per year emission rate are presented in Tables Ib and 1c, respectively. In Figure la and lb the cumulative weighted emissions of halons 1211 and 1301, for the period 1993-2019, are shown for the HTOC data and a 500,000 tonne base, respectively. ***Also*** shown on these graphs are the weighted emissions of HCFCs expected.

Table la. Weighted emissions of halons 1301 and 1211 (HTOC data).

Halon	1301	1211	Combined 1301 and 1211
	(in 1000 equivalent tonnes)		
emissions to 1990	808	370	1178
emissions 1990-95	428	197	625
emissions 1993-2019	913	307	1220
emissions 1996-2000	249	111	359
emissions after 1996	944	221	1165
peak production	201	81	282
peak emission	98	41	140
1993 emissions	64	30	94

Table lb. Weighted emissions of halons 1301 and 1211
(500,000 tonne halon base: 2%/yr emissions).

Halon	1301	1211	Combined 1301 and 1211
	(in 1000 equivalent tonnes)		
1993 emissions	112	12	124
emissions after 1993	5600	600	6200
emissions 1993-2019	2354	252	2606
emissions 1996-2000	298	54	352
emissions after 1996	5264	565	5829

Table 1c. Weighted emissions of halons 1301 and 1211
(500,000 tonne halon base: 4.5%/yr emissions).

Halon	1301	1211	Combined 1301 and 1211
	(in 1000 equivalent tonnes)		
1993 emissions	252	27	279
emissions after 1993	5264	565	5829
emissions 1993-2019	3985	427	4412
emissions 1996-2000	820	107	927
emissions after 1996	4880	523	5403

Weighted Emissions (1993-2019)
based on UNEP halon stock data

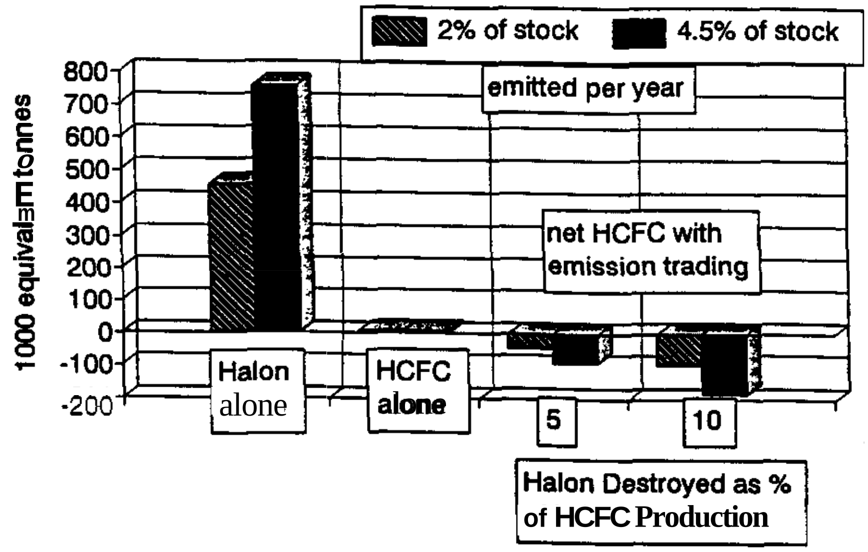
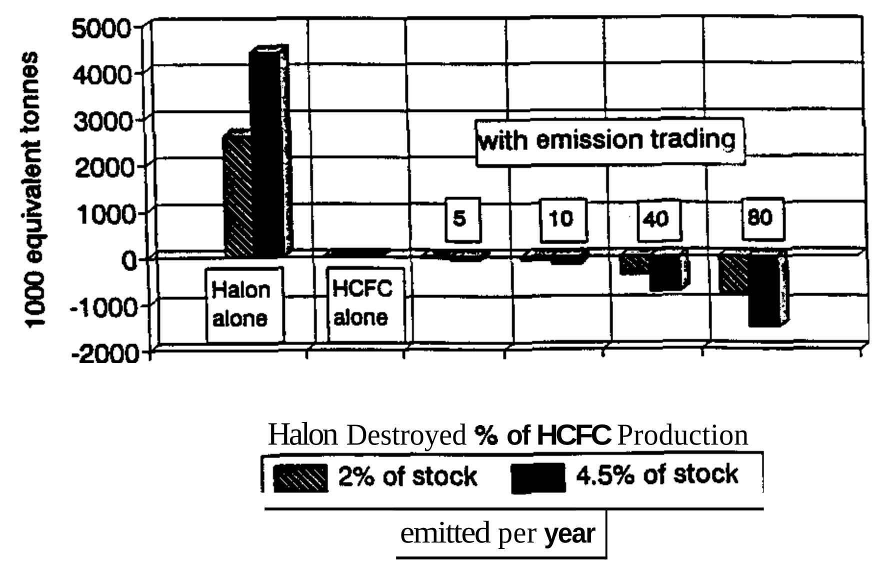


Figure 1a. Total weighted halon emissions, for the period 1993- 2019, are calculated using HTOC data for the amount of halons present, worldwide, in 1993, . Emissions are calculated assuming either 2% or 4.5% of the stock at the beginning of year, is emitted in a year. The stock of halons is also reduced each year by 0%, 5%, or 10%, of the weight of HCFCs produced for fire protection. Also shown is the estimated weighted emissions of HCFC for this period.

Net Weighted Emissions (1993-2019)
500,000 T halon base (1993)



HCFC Production in Terms of Ozone Damage

Table 2 gives the net total equivalent tonnage of HCFCs expected, under different scenarios, to be produced for fire protection. Production is expected to cease in the year 2019. The first scenario is explained above: it is the maximum amount of HCFCs that it is expected might be used for fire protection purposes. This results in total weighted production of 13,100 equivalent tonnes compared with a historical total weighted production ofhalon 1211 and 1301 of almost 3 million equivalent tonnes based on HTOC data (136,271 tonnes of halon 1301 with an ODP of 16 plus 197,055 tonnes of halon 1211 with an ODP of 4).

Table 2. ODP Weighted HCFC Production for Fi Protection.

Halon Destruction (%)	Flooding Agent	Streaming Agent	Combined
	(in thousand equivalent tonnes)		
0	3.8	9.3	13.1
5	-17	-181	-198
10	-36	***-367***	-403
40	-150	-1481	-1631
80	-303	-2966	-3236

The remaining scenarios allow for emission trading and will be discussed below

Comparison of Ozone Damage Due to Halons and HCFCs

Figures 1a and 1b show the cumulative weighted emissions of halons and HCFCs during the period 1993-2019: Figures 2a and 2b show the expected weighted emissions of halons and HCFCs in the year 2020. **As** can be seen, the weighted emissions of HCFCs is insignificant relative to weighted halon emissions These graphs also illustrate the reduction in weighted emissions that can be achieved with emission trading at various levels. Figure 3a, 3b, 3c, and 3d show the remaining stocks of halons, in 2020, under various scenarios. It is evident that if emission trading were implemented, the stocks, and hence future emissions would be significantly reduced.

Emission Trading

HCFCs will be used, in part, to replace halons in existing systems and the halons replaced can be effectively destroyed in an environmentally acceptable manner. Figures 4a and 4b graphically illustrates the net ODP weighted emissions of HCFCs, for fire protection, for the period 1993-2019 (the total expected production period), also graphed are expected weighted emissions of

Halon Emissions 2020
with Emission Trading (based on HTOC)

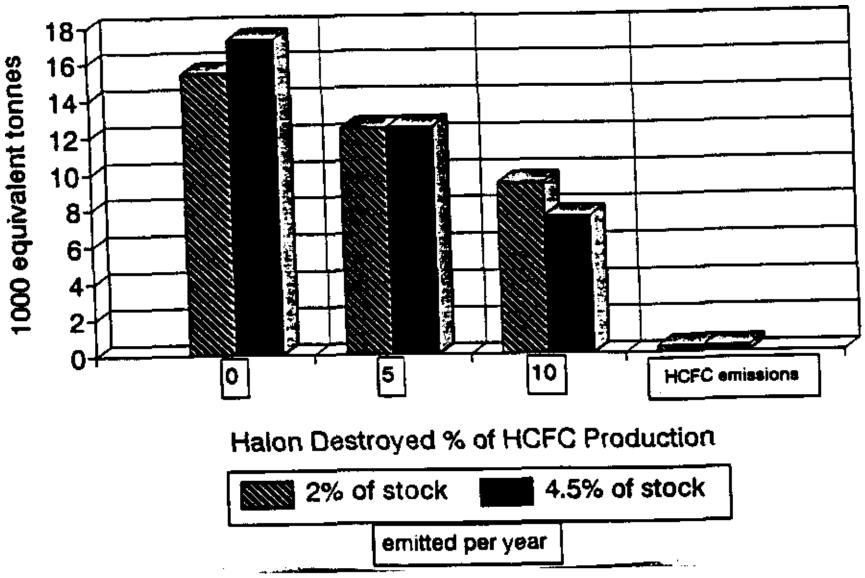


Figure 2a. **Total** weighted halon emissions in the **year 2020, are** calculated **using** the HTOC **data** for the amount of halons present, worldwide, in **1993** Emissions **are** calculated **assuming** either **2% or 4 5%** of the stock at the **beginning** of **year,** is emitted each **year from 1993** through **2020** **The** stock of halons is also reduced each **year by** 0%, **5%, or** 10% of the weight of HCFCs produced for **fire** protection. Also shown is ***the*** estimated weighted emissions of HCFC for **this** period.

Halon Emissions (2020)
with Emission Trading (500,000T base)

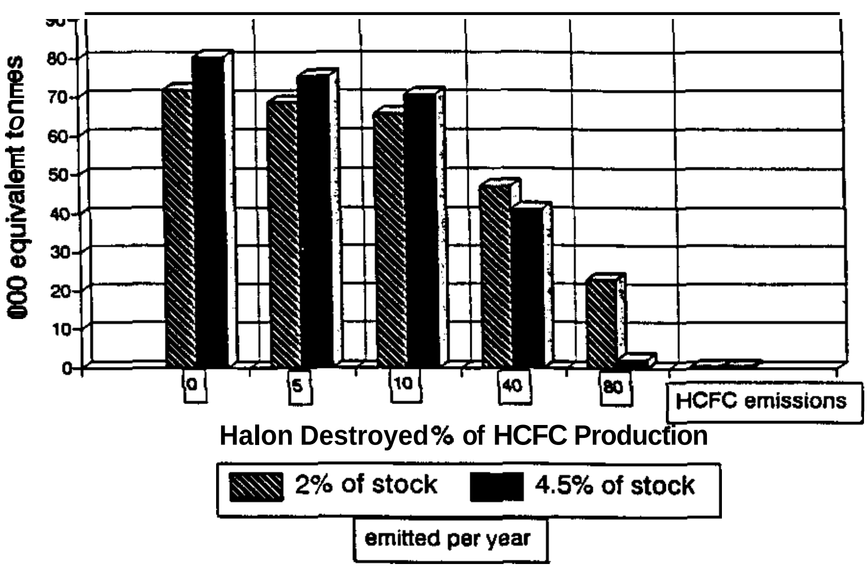


Figure **2b. Total** weighted **halon** emissions in the **year** 2020, **are** calculated **using a** 500,000 tonne, **in 1993, halon base.** Emissions **are** calculated **assuming** either **2%** or **4.5%** of the stock, ***at*** the **beginning** of **year,** is emitted each **year from 1993** through **2019** The stock of halons is also reduced each **year by 0%,** 5%, **10%, 40%** or 80% of the weight of HCFCs produced for **fire** protection. Also **shown** is ***the*** estimated weighted emissions of HCFC for **this** period.

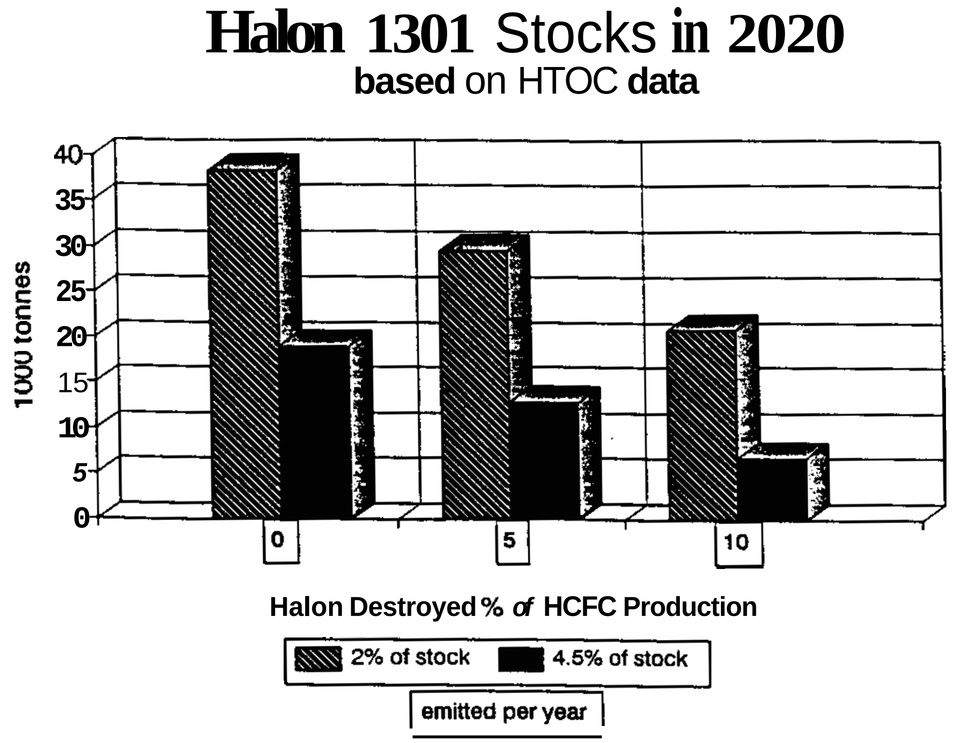


Figure 3a. Halon 1301 stocks are calculated by subtracting emissions plus halon destroyed from **existing stocks.**

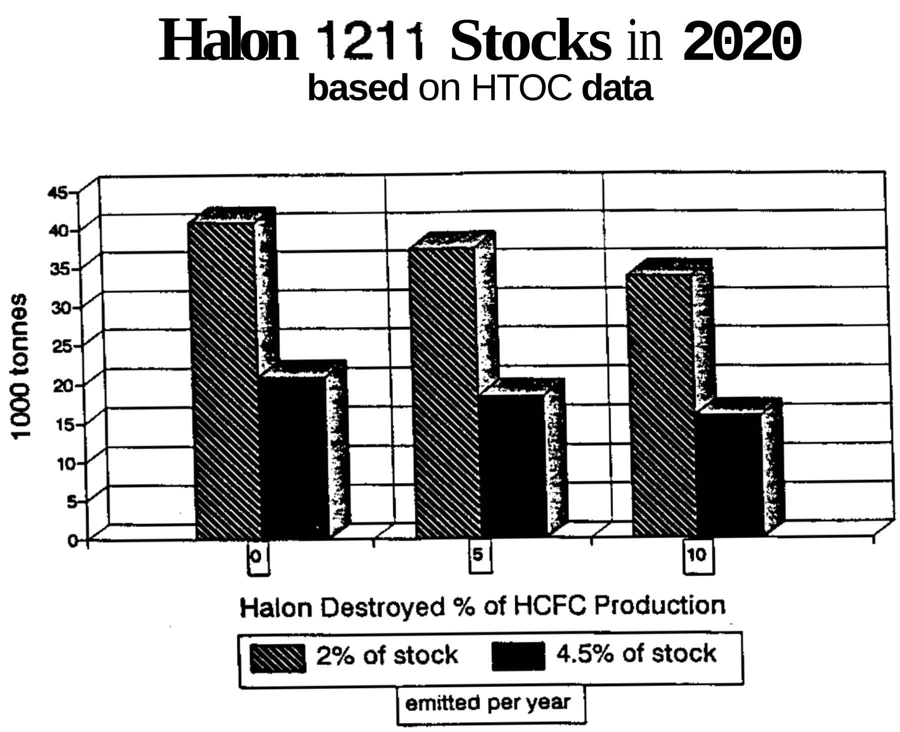


Figure 3b. Halon **1211 stocks *are* calculated by subtracting emissions plus halon destroyed** from **existing stocks.**

Halon 1301 Stocks in 2020

350,000T base in 1993

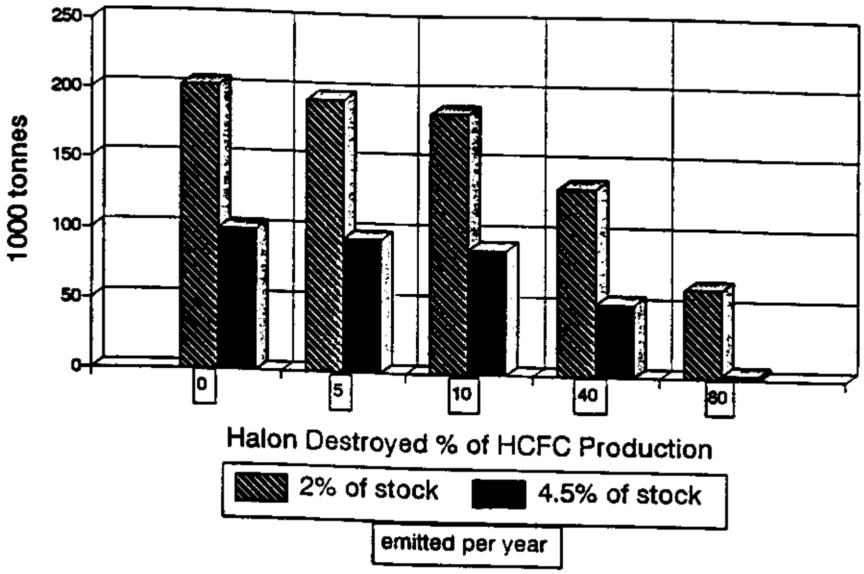


Figure 3c. Halon 1301 stocks are calculated by subtracting emissions plus halon destroyed from existing stocks.

Halon 1211 Stocks in 2020

150,000T base in 1993

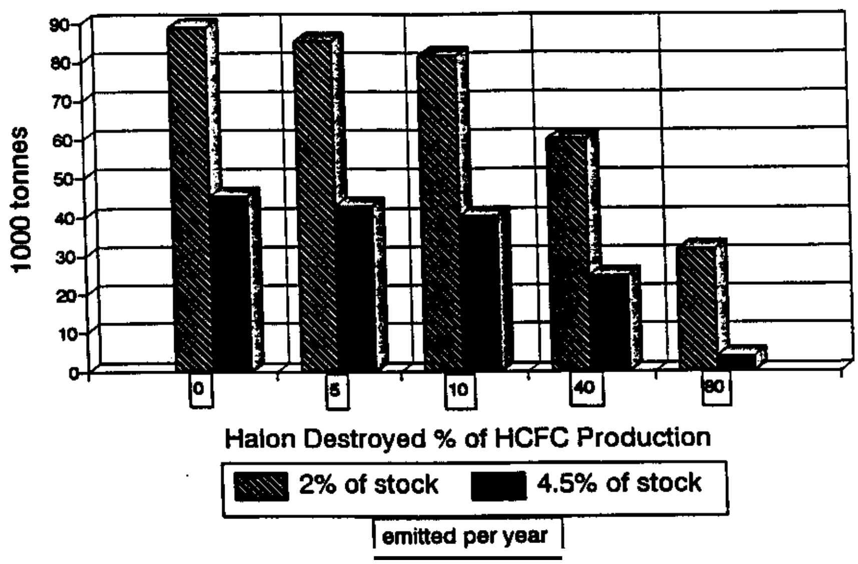


Figure 3d. Halon 1211 stocks are calculated by subtracting emissions plus halon destroyed from existing stocks.

Halon Emissions (1993-2019)
with Emission Trading (HTOC data)

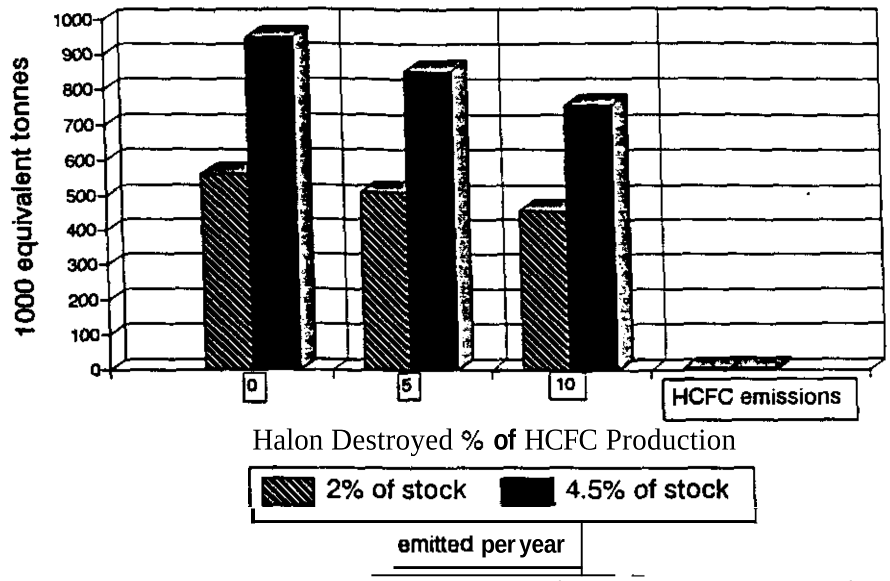


Figure 4a. Weighted halon emissions are those expected if there is no production of HCFCs for fire protection and no halon destruction Weighted HCFC emissions are the gross weighted emissions of HCFCs expected. Net weighted HCFC emissions are the weighted emissions of HCFCs expected plus the weighted emissions of halons expected, under the various scenarios, minus the weighted emissions of halons expected if there is emission trading,

Halon Emissions (1993-2019)
with Emission Trading (500,000T base)

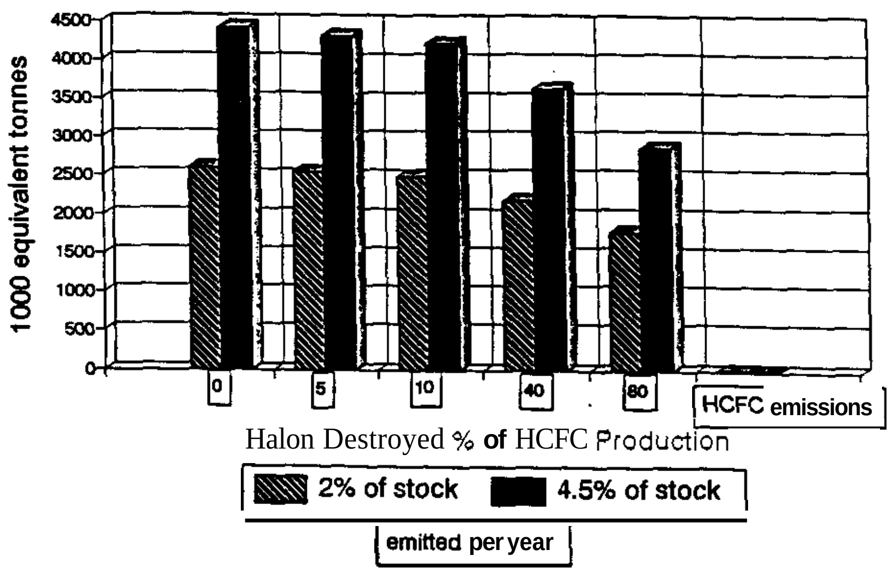


Figure 4b. Weighted halon emissions are those expected if there is no production of HCFCs for fire protection and no halon destruction. Weighted HCFC emissions are the gross weighted emissions of HCFCs expected. Net weighted HCFC emissions are the weighted emissions of HCFCs expected plus the weighted emissions of halons expected under the various scenarios, minus the weighted emissions of halons expected if there is emission trading.

halons if emission trading is not implemented. We can see From this that there could be a significant net **environmental benefit if emission trading in ODSs** were implemented. With emission trading, even at very low levels, it could said that **HCFCs have a negative effective ODP.**

Figures la, lb, **2a**, and 2b further illustrate the benefits of emission trading. These show the expected weighted emissions of halons under various emission trading scenarios. With destruction of halon equal to only **5%** of the weight of HCFC produced, the reduction in weighted halon emissions is far greater than the weighted emissions of HCFCs. In fact, the **total weighted emissions of HCFCs for the period 1993-2019 is much lower than the amount weighted halons emissions could be reduced, in the single year 2020,** if HCFCs are used for fire protection and the weight of halon destroyed equals 5% of the weight of HCFCs produced.

Figures 3a, 3b, 3c, and 3d also illustrate the benefits of emission trading. Emissions of halons are a function of the stock of halons. If the stock is reduced then the future emissions will also be reduced.

Not shown on the figures or tables is a break even point: **if a weight of halon 1301, equal to 0.25% of the weight of HCFCs produced, were destroyed there would be no net effect on stratospheric ozone.**

To implement the accelerated destruction of halons it is necessary to have a replacement for halons that can be used in existing installations with little or no modification: that is a drop-in replacement. At the present, HCFCs are the only halon replacements that can utilize existing halon systems. Emission trading would give incentive for the destruction rather than the release of halons, and other high ODS substances, and much ofthe future emission of these substances, to the atmosphere, could be avoided. Emission trading in ODSs would lead to much less ozone depletion than will otherwise be the case.

In Terms of Years of Production of HCFCs

For Table 3 we have calculated the ozone depletion caused by one year's production of HCFCs, for fire protection, if they were produced at the peak level of the combined halon 1211 and 1301 production of 32,732 tonnes (1309 equivalent tonnes). Using this high production level, we have compared the damage that might be done by HCFC to the damage that has been done in the past and that which, if destruction of halons is not implemented, will be done in the future, by halons. In fact, it **is** unlikely that HCFCs would be used at this high rate for fire protection, and it is likely that the average ODP of HCFCs used for fire protection would be lower than the 0.04 estimated, **and** thus these numbers are low.

Table 3. HCFC Production to Equal Ozone Depletion Caused by Halons.

Halon Scenario	HTOC	500,000 tonne base Emissions per year 2%	4.5%
	(years of HCFC production [1])		
emissions to 1990	900		
emissions in 1993	72	95	213
emissions 1993-2019	932	1991	3371
emissions 1996-2000	274	269	708
emissions after 1996	890	4452	4127

[1] If HCFCs for fire protection are prr ce it the **peak** rate for halon 1211 **and** 1? combined of **32,732** tomes per year

HCFCs could be produced (at 32,723 tonnes per year):

- for 900 years to cause the same ozone depletion expected to be caused by total halon emissions up till **1990** (HTOC data);

- for between 890 years (HTOC data) and **4452** years **(500,000** tonne base, 2% emissions per year) to have the same ozone depletion as halon emissions after **1996** if there is no destruction of halons.

CONCLUSIONS

Use of **HCFCs** for fire protection purposes produces insignificant damage to the ozone layer compared to the continued recycle, recovery and re-use of existing halon products. If legislative bodies controlling the consumption of ODS allow emission trading in **ODSs** the net benefit to the environment could be tremendous. The total weighted emissions of HCFCs for the period 1993-2019 is much less than the amount that annual weighted halon emissions could be reduced with even very limited emission trading. Because there is a very great difference in **ODP** between halons and HCFCs used for fire protection, it is possible to require a very high ratio for emission trading (say ten to one). As an example, if it were required to destroy 10 equivalent tomes of **ODS** for each equivalent tonne of ODS produced (a 10:1 ratio), then one could produce 40 tomes of HCFCs for every tonne of halon 1301 destroyed, and there would still be a 90% reduction in ozone damage.

Global climate change and atmospheric lifetime are very important environmental considerations. Either high global warming potential or long atmospheric lifetime can render an substance unsuitable for widespread use. In addition considerable environmental impact can be avoided by utilizing existing systems.

HCFCs can be a valuable transitional substance. If CF_3I becomes commercially available for fire protection purposes it will probably be able to utilize existing halon 1301 piping systems. To remove these and install systems for other agents only to remove the new systems and re-install halon-type system would be extreme folly. To utilize HCFC now to speed the transition from halon and to provide a bridge to the next generation agents seems to be the prudent course. The damage to the ozone layer which might be caused by HCFCs used for fire fighting becomes insignificant when viewed next to the damage caused by existing halons. When all environmental effects are considered **HCFC** are, on the balance, arguably the environmentally friendliest alternatives to halon 1301 for many applications.

A clear message to both producers and end-users must be sent as to the lifetime of HCFCs for fire protection. **As** can be seen from this analysis, there is a net benefit to the environment to guarantee HCFCs a reasonable lifetime for fire protection in order to speed-up the phase-out and destruction of halons.

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