

Use of chlorofluorocarbons in refrigeration, insulation and mobile air conditioning in the USA*

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In 1985, \approx 1.54 billion lbs of chemicals which potentially deplete stratospheric ozone were produced by the USA. These chemicals were chlorofluorocarbons (CFCs), halons, carbon tetrachloride and methyl chloroform. Roughly 40% of the total production of these ozone-depleting substances, or 580 million lbs of CFC, were used in energy-related applications, namely as the working fluid in refrigeration equipment and mobile air conditioners, or as the blowing agent in foam insulations. When the production of these chemicals is weighted by their ozone depletion potential, energy-related applications again accounted for \approx 40% of the potential risk to the environment. Refrigeration, mobile air conditioning and foam insulation were all found to contribute fairly evenly to the ozone depletion problem.

(Keywords: CFCs; refrigeration; air conditioning; insulation; ozone depletion)

Utilisation des chlorofluorocarbones dans le froid, pour l'isolation et pour le conditionnement d'air des automobiles aux Etats-Unis

En 1985 environ 699 millions de tonnes de produits chimiques pouvant réduire l'ozone stratosphérique ont été produits par les Etats-Unis. Ces produits chimiques étaient des chlorofluorocarbones (CFC), des halons, le tétrachlorure de carbone et le chloroforme méthylique. Environ 40% de l'ensemble de la production de ces substances réduisant la couche d'ozone, soit 264 000 tonnes de CFC, ont été utilisés dans des applications liées à l'énergie, en particulier comme frigorigène dans les équipements frigorifiques et les conditionneurs d'air pour automobiles ou comme agent de moussage dans les isolants cellulaires. Lorsque la production de ces substances chimiques était estimée d'après leur possibilité de réduire la couche d'ozone, les applications liées à l'énergie représentaient encore environ 40% du risque possible pour l'environnement. On a trouvé que le froid, le conditionnement d'air des automobiles et les mousses isolantes contribuaient tous à peu près également à la réduction de la couche d'ozone.

(Mots clés: CFC; froid; conditionnement d'air; isolation; équipement de l'ozone)

During the last few years, there has been increased scientific evidence that the atmospheric release of certain substances can result in the depletion of stratospheric ozone¹. These substances may also have added to global warming. On 16 September, 1987, the United Nations responded to this global environmental issue by signing the Montreal Protocol on Substances that Deplete the Ozone Layer². In the USA, the Environmental Protection Agency (EPA) initiated the implementation of the Montreal Protocol by issuing a proposed rule on 14 December, 1987³. The EPA rule freezes CFC 11, CFC 12, CFC 113, CFC 114, and CFC 115 at the 1986 production levels by their relative ozone depletion potentials. The production freeze is followed by a 80% production cap by mid-1993 and by a 50% production cap by mid-1998.

This Paper examines where these ozone-depleting substances were used in the USA in 1985 and analyses, in greater detail, the applications which are energy-related.

Methodology

This Paper examines where ozone-depleting substances were used in the USA in 1985. The chemicals included in

this analysis are CFC 11, CFC 12, CFC 22, CFC 113, Halon 1211, Halon 1301, carbon tetrachloride and methyl chloroform. These chemicals are thought to be the major substances which deplete ozone and for which production data are readily available. Production data for R22 were obtained from the Air Conditioning and Refrigeration Institute (ARI)⁴. Data for the other chemicals were taken from a Rand Corporation report prepared for EPA⁵. The production data were disaggregated by end-use.

Some substances, such as CFC 114, CFC 115, and Halon 2402, which are covered by the Montreal Protocol and the EPA rule, are not covered in this Paper due to a lack of available production data. As these three substances are produced in very limited quantities, the omission of these substances in this analysis is not considered serious.

The combined effect of these substances as ozone depleters was calculated by multiplying the total production of a particular chemical by its ozone depletion factor. The ozone depletion factors are listed in *Table 1* and are from the EPA rule.

1985 production levels

Table 2 shows that 1.54 billion lbs of ozone-depleting substances were produced by the USA in 1985. These

chemicals were used as fire extinguishants, chemical solvents, blowing agents for rigid and flexible foam, aerosol propellants, and the working fluid for refrigeration equipment and mobile air conditioning. Figure 1 shows that energy-related uses accounted for 38% of the overall production. Energy-related uses of potential ozone depleters amounted to about 580 million lbs which consisted of refrigeration (63%), mobile air conditioning (19%), and insulation (18%) (Figure 2). Details on specific end-use applications are presented below.

Fire extinguishants

In 1985, the US manufactured about 6 million lbs of Halon 1211 and 12 million lbs of Halon 1301. Halon 1211 is used in hand-held fire extinguishers while Halon 1301 is used in total flooding systems to protect critical equipment⁵. As these fire extinguishants contain bromine, the halons are considered to be a more serious ozone depletor than CFC.

Chemical solvents

In 1985, the US produced a total of about 802 million lbs of chemical solvents which were used in many

manufacturing processes to clean electronic parts and other industrial products. The solvents were CFC 113 (164 million lbs), methyl chloroform (605 million lbs), and carbon tetrachloride (33 million lbs). Methyl chloroform, which has a lower ozone depletion factor than CFC 113, can replace CFC 113 to some extent. The use of carbon tetrachloride as a chemical solvent is being phased out by the industry due to its toxicity.

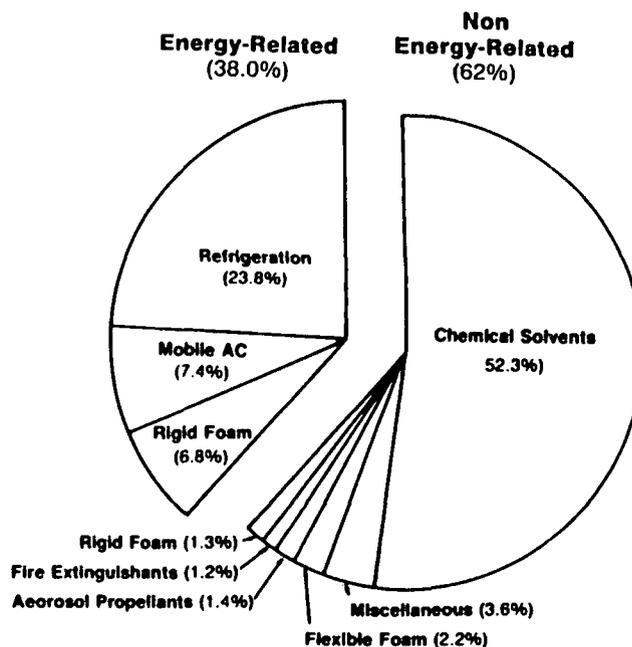


Figure 1 1985 US production of ozone-depleting substances (1.54 billion lbs)
 Figure 1 Production par les Etats-Unis en 1985 de substances réduisant la couche d'ozone (699 millions de tonnes)

Table 1 Ozone depletion factors
 Tableau 1 Facteurs d'épuisement de l'ozone

Chemical	Ozone depletion factor
CFC 11	1.00
CFC 12	1.00
CFC 22	0.05
CFC 113	0.80
Halon 1211	3.00
Halon 1301	10.00
Carbon tetrachloride	1.06
Methyl chloroform	0.10

Table 2 1985 US production of ozone-depleting substances (million lbs)
 Table 2 Production de substances réduisant la couche d'ozone (millions de livres)

Application	CFC 11	CFC 12	CFC 22	CFC 113	Halon 1211	Halon 1301	Carbon tetrachloride	Methyl chloroform	Total
Non-energy-related									
Chemical solvents	0.0	0.0	0.0	164.0	0.0	0.0	33.6	604.8	802.4
Flexible foam	33.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.2
Aerosol propellants	8.5	12.8	0.0	0.0	0.0	0.0	0.0	0.0	21.3
Fire extinguishants	0.0	0.0	0.0	0.0	6.0	12.1	0.0	0.0	18.1
Rigid foam									
Polyurethane	9.9	2.4	0.0	0.0	0.0	0.0	0.0	0.0	12.3
Polystyrene	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	8.4
Miscellaneous	11.2	44.6	0.0	0.0	0.0	0.0	0.0	0.0	55.8
Energy-related									
Refrigeration									
HVAC	19.9	80.9	130.4	0.0	0.0	0.0	0.0	0.0	231.2
Chillers	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	4.5
Room AC and retail food	0.0	10.8	113.1	0.0	0.0	0.0	0.0	0.0	123.9
Home appliances	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	5.4
Mobile AC	0.0	113.1	0.0	0.0	0.0	0.0	0.0	0.0	113.1
Polyurethane rigid foam									
Buildings	56.2	3.6	0.0	0.0	0.0	0.0	0.0	0.0	59.8
Refrigeration	14.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	20.6
Transportation	7.8	2.5	0.0	0.0	0.0	0.0	0.0	0.0	10.3
Industrial	7.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	8.3
Extruded polystyrene board	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.0	6.6
Total	168.7	302.5	243.5	164.0	6.0	12.1	33.6	604.8	1535.2

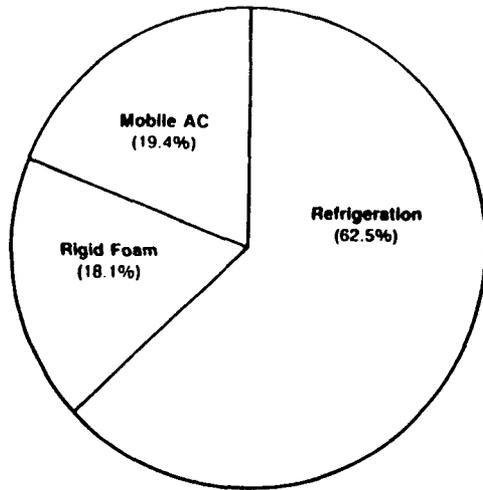


Figure 2 1985 US production of CFCs in energy-related applications (580 million lbs)

Figure 2 Production par les Etats-Unis en 1985 de CFC dans les applications liées à l'énergie (264 000 t)

Flexible foam blowing agents

In 1985, about 33 million lbs of CFC 11 were used to manufacture moulded auto seats and to produce flexible slabstock foam for furniture, bedding, packaging and carpet underlay. Both carbon dioxide and methylene chloride are widely used as blowing agents for flexible foam and can substitute for much of the CFC 11 that is currently used.

Aerosol propellants

The US used about 21 million lbs of CFC 11 and CFC 12 as aerosol propellants for essential uses. Substitute propellants, pump dispensers, and non-pressurized applicators can be used in place of some of the CFC propellants.

Rigid foam blowing agents

In 1985, about 120 million lbs of CFC 11 and CFC 12 were used to manufacture rigid foam. About 21 million lbs were used for non energy-related uses, such as packaging materials, flotation devices, and marine buoys. The remaining 99 million lbs were used as polyurethane foam insulation.

In 1985, about 86 million lbs of CFC 11 and 13 million lbs of CFC 12 were used to manufacture polyurethane foam insulation. Over 80% of all polyurethane insulation was used for buildings and appliances. Polyurethane was used in most of the 6 million refrigerators and 1.3 million freezers made in 1985. It also was used in about half of the 7 million water heaters. Specifically, polyurethane rigid foam insulation was used in buildings (59.8 million lbs), household appliances (20.6 million lbs), refrigerated trucks and rail cars (10.3 million lbs), and industrial tanks and pipes (8.3 million lbs).

The US used about 6.6 million lbs of CFC 12 to make extruded polystyrene board insulation, which was used for insulating buildings.

Refrigeration

The four refrigeration applications were heating, ventilating, and air conditioning (HVAC); chillers; room air conditioners and retail food refrigeration; and home

appliances. Room air conditioners and retail food refrigeration were combined together because the data were presented that way.

The three key ozone-depleting substances used in refrigeration applications were CFC 11, CFC 12, and CFC 22. Other refrigerants, like CFC 113 and CFC 114, are used in some centrifugal chillers. According to ARI, about 100 000 lbs total of both CFC 113 and CFC 114 were used for refrigeration applications in 1985⁴. Consequently, these refrigerants were not included in this analysis.

In 1985, about 19.9 million lbs of CFC 11, 101.6 million lbs of CFC 12, and 243.5 million lbs of CFC 22 were used for various refrigeration applications. Almost all of this was for HVAC applications (63%) and retail food refrigeration (32%). The amount used for room air conditioners is estimated as about 6 million lbs of CFC 22, or about 2% of all CFC used in refrigeration applications. This is based on about 3 million room air conditioners sold in 1985 and each unit with an average charge of 2 lbs. In other areas, about 10.8 million lbs of CFC 12 and 107 million lbs of CFC 22 were used for retail food refrigeration. Less than 10 million lbs were used for chillers and home appliances.

Mobile air conditioning

In 1985, about 113 million lbs of CFC 12 were used to air condition cars, trucks, and buses. Over 90% of this amount was for the initial charge and for recharging after refrigerant leakage and servicing. About 34% of the total quantity was for the initial charge for new vehicles. Another 25% was for recharging due to leakage, while 34% was due to recharging after servicing. The remaining 7% was due to refrigerant loss in accidents⁷.

1985 production levels – adjusted by ozone depletion potentials

In this section, the production data presented above are weighted by their ozone depletion factors to determine an adjusted production total. This number is equivalent to the number of pounds of CFC 11 that is needed to match the risk to the environment. As shown in Table 3, the adjusted production of all ozone depleters manufactured by the US in 1985 was equal to about 850 million lbs of CFC 11. As there were 238.6 million people in the US in 1985⁶, the US produced about 1.62 kg per capita of potential ozone depleters in 1985. To put this figure in perspective, the Montreal Protocol allows developing countries whose usage of controlled substances is less than 0.3 kg per capita to delay for a 10-year period in meeting protocol production restrictions. Thus, on a per capita basis, the US uses about five times more of these substances than the threshold level for developing countries.

Figure 3 shows that energy-related uses accounted for about 42% of the overall amount of substances that deplete ozone. The energy-related uses were equivalent to about 350 million lbs of CFC 11. As shown in Figure 4, refrigeration, mobile air conditioning, and insulation accounted for 38, 31 and 31%, respectively. The weighted amount of potential ozone-depleting substances used by the US in 1985 for energy-related applications is estimated to be about 0.67 kg per capita, or about twice

Table 3 1985 US production of ozone-depleting substances (million lbs equivalent CFC 11)
 Tableau 3 Production de substances réduisant la couche d'ozone (millions de livres équivalentes CFC 11)

Application	CFC 11	CFC 12	CFC 22	CFC 113	Halon 1211	Halon 1301	Carbon tetrachloride	Methyl chloroform	Total
Non-energy-related									
Chemical solvents	0.0	0.0	0.0	131.2	0.0	0.0	35.6	60.5	227.3
Flexible foam	33.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.2
Aerosol propellants	8.5	12.8	0.0	0.0	0.0	0.0	0.0	0.0	21.3
Fire extinguishants	0.0	0.0	0.0	0.0	18.1	121.0	0.0	0.0	139.1
Rigid foam									
Polyurethane	9.9	2.4	0.0	0.0	0.0	0.0	0.0	0.0	12.3
Polystyrene	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	8.4
Miscellaneous	11.2	44.6	0.0	0.0	0.0	0.0	0.0	0.0	55.8
Energy-related									
Refrigeration									
HVAC	19.9	80.9	6.5	0.0	0.0	0.0	0.0	0.0	107.3
Chillers	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	4.5
Room AC and retail food	0.0	10.8	5.7	0.0	0.0	0.0	0.0	0.0	16.5
Home appliances	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	5.4
Mobile AC	0.0	113.1	0.0	0.0	0.0	0.0	0.0	0.0	113.1
Polyurethane rigid foam									
Buildings	56.2	3.6	0.0	0.0	0.0	0.0	0.0	0.0	59.8
Refrigeration	14.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	20.6
Transportation	7.8	2.5	0.0	0.0	0.0	0.0	0.0	0.0	10.3
Industrial	7.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	8.3
Extruded polystyrene board	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.0	6.6
Total	168.7	302.5	12.2	131.2	18.1	121.0	35.6	60.5	849.8

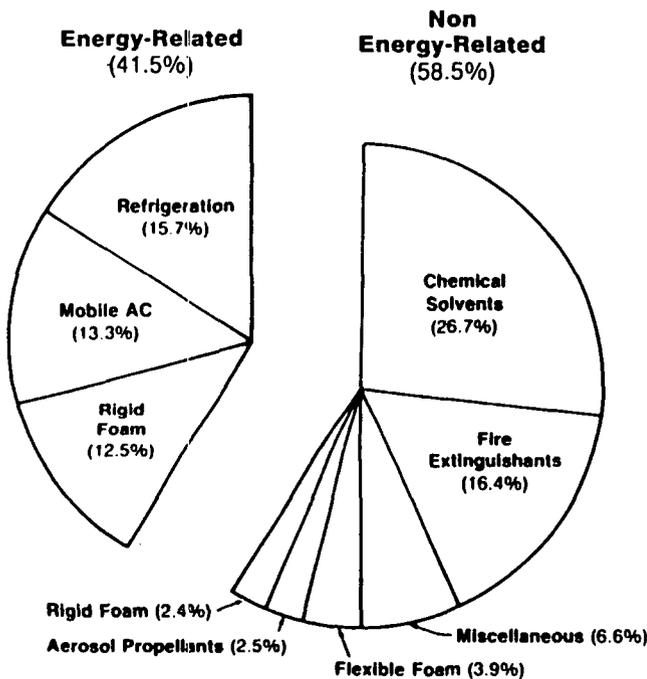


Figure 3 1985 US production of ozone-depleting substances (850 million lbs equivalent CFC 11)
 Figure 3 Production par les Etats-Unis en 1985 de substances réduisant la couche d'ozone (386 000 t équivalent CFC 11)

the Montreal Protocol threshold level for developing countries.

Conclusions

The conclusions from this analysis are:

1. The USA used about 1.54 billion lbs of ozone-depleting substances in 1985. These substances are CFCs, halons, carbon tetrachloride, and methyl chloroform.

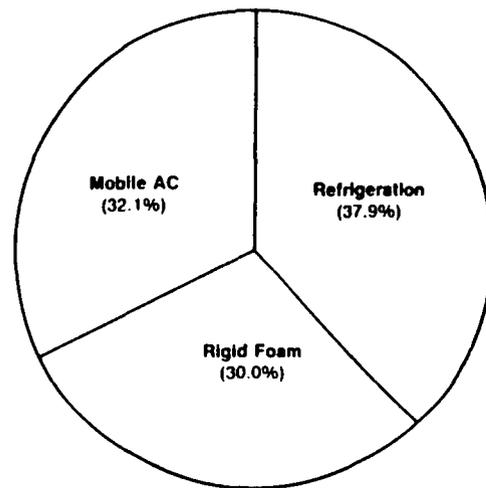


Figure 4 1985 US production of CFCs in energy-related applications (350 million lbs equivalent CFC 11)
 Figure 4 Production par les Etats-Unis en 1985 de CFC dans les applications liées à l'énergie (158 000 t équivalent CFC 11)

2. Energy-related uses, namely refrigeration, insulation, and mobile air conditioning, accounted for about 580 million lbs or roughly 40% of the total amount of ozone-depleting substances.
3. About 80.4 million lbs, or over 80% of all polyurethane foam insulation was used for buildings and appliances.
4. HVAC applications and retail food refrigeration accounted for about 95%, or about 349 million lbs of all CFC used as refrigerants.
5. Mobile air conditioning used about 113 million lbs of CFC 12 in 1985, of which over 90% was for the initial charge and for recharging after leakages and servicing.
6. On an adjusted weight basis, the total amount of ozone-depleting substances manufactured by the USA in 1985 was equivalent to about 850 million lbs of CFC 11.

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7. On an adjusted weight basis, energy-related uses accounted for about 350 million lbs or about 42% of the total.

8. On an adjusted weight basis, the energy-related uses were split fairly evenly among refrigeration (38%), mobile air conditioning (32%), and insulation (30%).

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