Refurbishment of large air-conditioned buildings using HFCs
Maximising emission reductions

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There are many large air-conditioned buildings that currently have central CFC or HCFC chillers providing air-conditioning. Typically the lifetime of building stock is longer than the lifetime of existing air-conditioning systems. Eventually, under the Montreal Protocol the chillers will have to be replaced using non-ozone depleting alternatives. Options include HFCs, ammonia, and hydrocarbons. At the time of replacement of the air-conditioning system there is the option to review the air-conditioning needs, energy loading and energy use. This allows the development of a building refurbishment plan with the objective of reducing energy use and therefore greenhouse gas emissions.

A well accepted method of comparing the options for replacement of the air-conditioning chiller is to use LCCP or TEWI. This enables the various options to be compared in terms of overall emissions. In practice with modern chillers which have very low refrigerant losses (typically less than 1% annually) the LCCPs tend to fall within a narrow range.

Chiller selection may then be based factors such as load requirements (full and part load), location within the building, local codes for refrigerants. The use of ammonia and hydrocarbons may be prevented by local codes due to their toxicity or flammability. Where they are allowed, significant building modifications may be required for an existing building in order to meet the safety requirements for these refrigerants. This may be the provision of a more complex machinery room, with explosion proofing and which may also need to be relocated, leading to significant costs.

For a major building refurbishment, where one of the objectives is to reduce overall energy use, there will almost certainly be a fixed budget to ensure a cost effective refurbishment. Energy reduction options include energy load control reducing the air-conditioning demand, lighting and lighting controls, energy management systems for summer and winter building use, heating improvements and insulation improvements.

Investing in the necessary safety requirements for the use of ammonia or hydrocarbon chillers reduces the investment available for other energy saving measures within a fixed budget.

In contrast, the use of modern low refrigerant loss HFC chillers of comparable LCCP performance does not require the same extensive safety features, meaning that the chiller can be installed at lower cost, allowing investment in energy saving measures as part of a building refurbishment project.

Therefore, for the overall building refurbishment project delivered at equivalent cost, the use of HFC chillers with building energy saving measures can provide a significantly better LCCP than the use of ammonia or hydrocarbon chillers.

It is difficult to accurately quantity the possible environmental benefit of using HFC chillers for refurbishment of air-conditioned buildings that currently have CFC or HCFC chillers. This is because each refurbishment and chiller replacement will have specific requirements and different energy saving opportunities. Even so an estimation of the possible environmental benefit of using HFC chillers is appropriate so that scale of the benefit can be appreciated.

In order to develop an estimate, United Kingdom data was used. However the nature of the available data means that a number of assumptions have to be made. Firstly it is assumed that UK fully air-conditioned offices over 1000 m^2 are likely to have chillers (chilled water loops) rather than another type of air-conditioning. Even if this is not the case the general principles still apply.

UK Offices with full air-conditioning [1]

size range (m2)	Number of premises	Area premises 1000m2	Age	Premises	total area 1000m2
0-30	659	12	unknown	6	13
30-100	1913	128	pre 1900	1564	852
100-300	4282	806	1900-1918	472	221
300-1000	4998	2752	1919-1939	735	539
1000-3000	2340	4012	1940-1954	287	249
3000-10000	1007	5224	1955-1964	1068	1091
10000 plus	221	3803	1965-1970	1096	1302
All	15420	16737	1971-1980	2692	3233
			1981-1990	5372	6488
			1991 onwards	2128	2750
			All ages	15420	16738

From the data on offices with full air-conditioning, those large offices of a size suitable for chillers can be extracted. The average penetration rate for HFC/HC chillers is known and these can be excluded from the total to give an estimate of those large air-conditioned offices that should require the existing chillers to be replaced or retrofitted as Montreal Protocol phase-out is completed. It is worth pointing out that the 4% penetration of HFC/HC chillers in the UK is virtually all HFC chillers.

Fully Air-Conditioned UK Offices over 1000m^2 (size suitable for chiller air-conditioning)

	Number of premises	Area premises 1000m2	Average Area m2
1000 m2 plus	3568	13039	3654
Average penetration rate of HFC/HC chillers in 1998 was 4% approx [2], excluding HFC/HC chillers			
1000 m2 plus	3425	12517	3654

The replacement costs for CFC/HCFC chillers for the average large office area of 3650 m^2 can be estimated. These costs are indicative and will be different in practice, but the trends are valid.

Replacement of CFC/HCFC chillers for office area of 3650 m^2

air conditioning load (typical)	100	W/m2
air conditioning chiller size for 3650 m2 office	365	KW aircon system
chiller cost	34	£k
Total installation cost		
HFC Chillers	85	typically 2.5 times chiller cost
HC/ammonia chillers (*see note*)	127.5	typically cost at least 1.5* HFC cost
cost saving with HFC chillers	42.5	£k

Note: HC/ammonia chiller installation typically require relocation of plant room & services, explosion proofing, and other safety costs

Investment in energy saving measures

The cost saving (or part of the cost saving) from the use of HFC chillers can be invested in energy saving measures of the building being converted or in other building projects. These can include energy load control : lighting and lighting controls, energy management systems for summer and winter building use, heating improvements and insulation.

It is possible to estimate a wide range of emissions savings based on investment in energy saving measures. This will depend on the energy source being reduced (gas or electricity), its emission factor, and the energy reduction achieved. If the energy source is electricity and setting a project payback period of 4 years to recoup the investment, allows the estimation of emission reductions achievable. This emission reduction would be achieved by investing the difference in cost of HFC chiller installation compared to hydrocarbon or ammonia chiller installation.

Electricity price	40	£/MWhr
Investment in energy saving measures	42500	£
Energy saving based on 4 year payback	10625	£/yr
Electricity use reduction	266	MWhr/yr
Electricity emission factor	0.5	kg CO2/kWhr
Emissions reduction from energy savings	133	tes CO2/yr

These emissions savings assume that all the difference in cost is invested. It would be possible to achieve emission reductions by investing only a part of the saving from using HFC chillers.

for each office	Investment £	42500	21250	10625	592
	Emissions Reduction tes CO2/yr	133	66	33	2
	Electricity Consumption Reduction GJ/yr	956	478	239	13
for 3425 UK offices	Investment £ Million	146	73	36	2
	Emissions Reduction ktes CO2/yr	455	227	114	6

Office energy consumption

The Non Domestic Building Fact File [reference 1] page 89 gives details of office energy consumptions, including air-conditioning. An indicative energy consumption range can then be calculated for UK offices (over 1000 m^2 area) with full air conditioning and with an average floor area of 3654 m^2. The range of energy consumptions for 90% of 64 offices is greater than reductions that typically might be achieved through investment in energy saving measures.

	GJ/m2/yr	Average office area	3654	m2
Mean energy consumption of 64 offices	0.68	energy consumption	2485	GJ/yr
Range for 90% of the 64 offices	0.3 to 1.05	energy consumption range	1096 to 3837	GJ/yr
Average for sample of Commercial Offices	1.3	energy consumption	4751	GJ/yr

Emission Savings using HFC Chillers

The LCCPs of HFC, ammonia , and hydrocarbon chillers are comparable because these are available at essentially equivalent energy efficiency. The emissions of HFCs due to refrigerant loss are of the order of 1% for a modern chiller. This is equivalent to about 2 tes of CO_2 per year for the average office (3654 m^2 area) under consideration. The chiller size required would be about 365 kW with a typical charge size of 0.23 kg refrigerant/kW, giving a refrigerant charge of 84kg. Annual emissions of 1% are 0.84 kg per year (approx 2 tes CO_2 equivalent).

This direct refrigerant emission of 2 tes CO_2/year can be compared with the saving of 133 tes CO_2/year from investment in energy saving measures, made possible by using a HFC chiller.

Applying these savings to all the large (>1000m^2) fully air-conditioned offices in the UK (approximately 3425 using CFCs or HCFCs) allows the possible total emissions savings to be estimated.

The costs and savings are illustrated in the chart which shows the emission reduction potential if all the cost savings from using HFC chillers was invested in energy saving measures.

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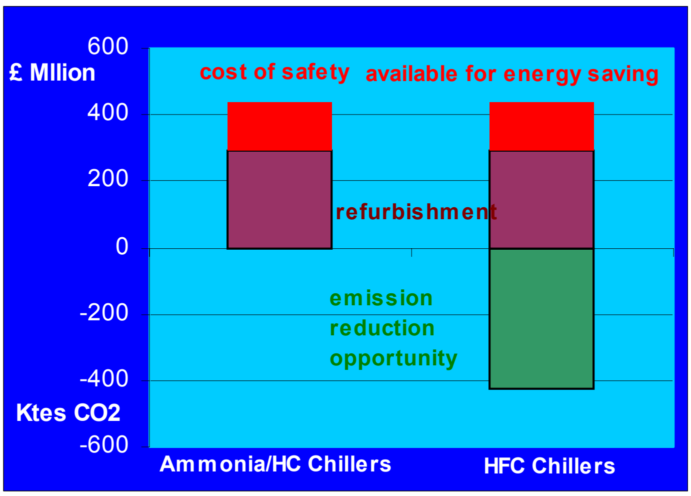
ESTIMATE of Emission Reduction Potential



For existing large air-conditioned offices estimate *additional* £150 million cost if alternatives to HFCs, this is the cost of safety. Using HFCs and investing *up to* £150 million in general energy saving measures up to 400 ktes carbon dioxide emission reductions.

References

[1] Non Domestic Building Fact File January 1998 BRE, pages 76 & 77.
[2] The Future of the UK Market for Air-Conditioning By Refrigerant Type March 1999 BSRIA page 43 Installed Base.
[3] Oak Ridge National Laboratory 1991 Energy and Global Warming Impacts of CFC Alternatives, & 1997 Energy and Global Warming Impacts of HFC Refrigerants