Replace CFCs, assess the trade-off

Core idea: replacing ozone-depleting substances with non-ozone-depleting chemicals can protect the stratosphere. HFCs are one replacement, but some strongly warm the climate.

1. KEEP THESE CHEMICAL FAMILIES DISTINCT

Family / elements	Ozone effect	Climate trade-off
CFCs Carbon, chlorine, fluorine	Chlorine can drive ozone destruction.	Strong greenhouse gases.
HCFCs Hydrogen, chlorine, fluorine, carbon	Lower ozone impact than many CFCs, but not zero.	Also greenhouse gases; transitional substitutes.
HFCs Hydrogen, fluorine, carbon	No chlorine or bromine; zero ozone-depletion potential.	Some have high global warming potential.

HFCs = hydrofluorocarbons. HCFC comparison is supporting context: adding hydrogen to a chlorine-containing chemical does not make it ozone-safe.

2. WHY AN HFC CAN HELP THE OZONE LAYER

CFC emissions can eventually supply reactive chlorine to the stratosphere. Substituting an HFC avoids that chlorine source because the HFC contains no chlorine. The replacement prevents additional ozone-destroying chemistry; it does not directly add ozone or remove CFCs already in the atmosphere.

3. WHY "OZONE-SAFE" IS NOT "CLIMATE-SAFE"

A chemical does not need chlorine to act as a greenhouse gas. Some HFCs absorb outgoing infrared radiation strongly and persist long enough to have a large warming effect. Replacing a CFC with an HFC therefore addresses ozone depletion but can leave a climate problem. The preferred substitute must be evaluated for both impacts.

Required HFC benefit and greenhouse-gas trade-off: College Board APES CED, STB-4.B.1.
CFC, HCFC and HFC properties: US EPA, Ozone-Depleting Substances.
Halogen sources, alternatives and climate: NOAA, Twenty Questions (2022), Q6 and Q18.

Core scope: College Board APES CED, Topic 9.2, STB-4.B.1, p. 183.

Choose a substitute carefully

Supporting application: compare ozone protection, climate effects and safe operation. No chemical is automatically the best choice for every cooling system.

1. TWO DIFFERENT MEASURES

ODP: ozone-depletion potential

Relative ozone loss per mass emitted, compared with CFC-11. CFC-11 has ODP = 1; HFCs have ODP = 0.

GWP: global warming potential

Relative warming impact per mass emitted, compared with CO_2, over a stated time horizon. CO_2 has GWP = 1. Compare values using the same time horizon and assessment.

2. LOWER-CLIMATE-IMPACT OPTIONS EXIST

Examples used in appropriate refrigeration systems include carbon dioxide, ammonia, hydrocarbons and hydrofluoroolefins (HFOs). These offer options beyond high-GWP HFCs; the choice depends on the specific application.

HFOs generally have shorter atmospheric lifetimes and lower GWPs than many traditional HFCs. Blends may contain both HFOs and HFCs, so a blend name alone does not establish its climate impact.

3. CHECK THE WHOLE SYSTEM

Evaluate toxicity, flammability, equipment compatibility, energy efficiency and likely leakage, as well as ODP and GWP. Refrigerant emissions create a direct climate impact; electricity use can create an indirect impact depending on the energy source. A low-GWP option still needs safe design and proper servicing.

ODP and GWP reference values: US EPA, Ozone-Depleting Substances.
CO2, ammonia, hydrocarbons and HFO alternatives: US EPA, Relevant EPA Programs.
Safety and environmental screening: US EPA, SNAP Program Overview.
Climate metrics and indirect energy effects: NOAA, Twenty Questions (2022), Q18.

Core scope: College Board APES CED, Topic 9.2, STB-4.B.1, p. 183.

Reduce releases, allow recovery

Supporting context: changing new products is only part of the solution. Existing equipment and chemical stores can continue to release refrigerants.

1. CONTROL EMISSIONS THROUGH THE LIFE CYCLE

New equipment	Select suitable non-ozone-depleting alternatives, considering climate and safety.
During use	Maintain equipment and repair leaks to reduce refrigerant losses.
At servicing	Recover refrigerant into appropriate equipment instead of venting it.
At disposal	Use qualified recovery and recycling services; refrigerant should be captured before dismantling or shredding.

2. INTERNATIONAL COOPERATION

The Montreal Protocol, adopted in 1987, established international controls to phase out ozone-depleting substances. Its framework combines national action, reporting, trade controls and financial or technical support for transitions.

The Kigali Amendment, adopted in 2016, adds a phase-down of specified HFCs because of their climate impact, not because HFCs deplete ozone.

3. WHY RECOVERY TAKES TIME

Many ozone-depleting gases remain in the atmosphere for decades. Additional emissions can come from "banks": chemicals still held in old equipment, foams or stockpiles. Ending new production therefore does not instantly end emissions or remove past pollution. Sustained reductions, management of existing stores and atmospheric monitoring support long-term recovery.

Recovery during maintenance: US EPA, Stationary Refrigeration Service Practice Requirements.
Capturing refrigerants before disposal: US EPA, Appliance Disposal.
Montreal Protocol and Kigali Amendment: UNEP, About Montreal Protocol.
Long lifetimes, banks and recovery: NOAA, Twenty Questions (2022), Q6 and Q20.

Core scope: College Board APES CED, Topic 9.2, STB-4.B.1, p. 183.