Reducing your carbon footprint…? Think fluorine first.

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Companies may be able to achieve greenhouse gas emission savings of staggering effectiveness by minimizing usage or emissions of fluorinated compounds (FCs)[1]. This is especially true if one recognizes that some FC molecules will stay in the atmosphere for several thousands of years.

Fluorinated compounds are strong infrared absorbers and some of the most potent greenhouse gases (GHG) known to man. The two champions in the GHG league are tetrafluoro methane (CF_4) and sulfur hexafluoride (SF_6). CF_4 has an atmospheric life of 50,000 years and a Global Warming Potential (GWP)[2] of 5,700. SF_6 has an atmospheric life of 3,200 years and a GWP of 22,200. This means that preventing emissions of one kilogram of SF_6 in the atmosphere is equivalent to saving 22.2 tons in carbon dioxide equivalent.[3]

FCs are found in a large variety of industrial applications. For example, FCs are used for refrigeration and air conditioning,[4] electrical transmission and distribution, fire suppression and explosion protection, aluminum and magnesium production, and in the electronics industry (semiconductor, flat panel display and photovoltaic manufacturing). FCs are used as propellants in many personal care products (e.g., deodorant, shaving cream), household products (spray bottles of air 'fresheners'), in some insulating foams where FCs are used as blowing agents, in chillers, heat exchangers, heat pumps and the air conditioning unit in cars. If you are a manufacturer, some of the parts or materials you may be buying to build your own products may have been produced using FCs.

FC emissions savings may be achieved by optimizing manufacturing processes, and also by paying close attention to the supply chain, carefully selecting raw materials and inquiring into the specific processes used to manufacture them. FC molecules can be emitted during their manufacture, their use, through fugitive emissions, or as byproducts from the production of other fluorinated compounds.

Sources of FC emissions are not hard to identify, and several measures can be taken to minimize them. For example, you may be able to help reduce CF_4 emissions by 1.2 kg (or over 6 tons in CO_2

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[1] Fluorinated compounds (FCs) include hydrofluorocompound (HFC) and perfluorocompond (PFC) molecules such as CF_4, C_2F_6, C_3F_8, c-C_4F_8, C_6F_{14}, NF_3, SF_6, CHF_3, CH_2F_2, $C_2H_2F_4$… Most FCs are non-toxic and present unique chemical properties that make them valuable chemicals (heat transfer, dielectric properties, ability to safely deliver fluorine, etc.). While the vast majority of FC molecules are gaseous at room temperature and atmospheric pressure, some FCs such as C_2F_{12} and C_6F_{14} are used as liquids for heat transfer applications.
[2] Global warming potential (GWP) is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas in question to that of the same mass of carbon dioxide (whose GWP is by definition 1). A GWP is calculated over a specific time interval and the value of this must be stated whenever a GWP is quoted or else the value is meaningless. Typically a 100-year GWP is used in calculations for determining CO_2 equivalents.
[3] using a GWP value calculated with a 100 year time horizon
[4] Many HFCs such as HFC-134a ($C_2H_2F_4$), HFC-227ea (C_3HF_7) are used a substitutes for ozone depleting substances such as chlorofluorocarbons (CFC). Substitution of ODS with FC molecules is the fastest growing segment among all FC industrial applications.

equivalent), for every ton of aluminum used to fabricate your product or the products you buy. Just make sure that your aluminum supplier uses the Center Worked Pre-Bake (CWPB) method as opposed to the Side Worked Pre-Bake (SWPB), and the job is done. Selecting the right supplier with the lowest emissions technologies will not only reduce your carbon footprint or that of your products, it will also accelerate market transition towards usage of better manufacturing technologies. Other examples of possible actions include minimization of the use of FC propellants for personal care, household or industrial products; ensuring that the air conditioning units in homes, offices or factories are properly serviced and that the refrigerant is recycled. An analysis of the carbon footprint of a supply chain will often reveal ways to reduce FC emissions, and provide opportunities for an effective contribution in reducing greenhouse gas emissions.

Companies that are significant users or producers of FCs are likely to find that a large fraction of their carbon footprint originates from these molecules. Of course, each industry may have different requirements and each factory or business may require a tailored approach to reduce FC emissions, but solutions exist. A good example can be found in the semiconductor industry, where technologies have been developed to reduce FC emissions by one to two orders of magnitude per substrate pass.[5] The gains in productivity (better FC utilization efficiency, lower gas usage, faster throughput) offered by these newer and more efficient technologies result in a win-win scenario for the environment and the industry: semiconductor manufacturers can save money while reducing FC emissions. When the FC-based processes are not amenable to change, or when fluorocompounds are byproducts of a manufacturing operations, you may be able to use alternate chemicals (or at least use 'better' FCs), possibly capture and recycle them, or destroy the FC molecules prior to their release in the atmosphere. Advanced combustion technologies, or abatement solutions based on plasma or catalytic processes have been developed and are available today in the market place. Some FC abatement solutions can be implemented at relatively low costs. For example, abatement of FCs from chemical vapor deposition (CVD) processes in semiconductor applications can be achieved for less than 2$ per ton CO_2 equivalent saved (100 years GWP).

Fluorinated compounds are chemicals of great importance to many industries. FC molecules have unique properties that make them some of the most effective compounds in many industrial applications. There would be no computers or cell phones without FCs, air conditioning units would be less effective or more expensive or more hazardous, and electrical power distribution systems would be affected if SF_6 usage was banned. But responsible use of FCs and application of the precautionary principle require that we minimize emissions of such potent greenhouse gases. With respect to implementation of FC emissions reduction programs, some case studies have demonstrated that FC emissions can be reduced at net savings, due to productivity improvements. When the economics of FC alternatives is not favorable, the emergence of greenhouse gas emission trading schemes, at the international, regional, and state levels will provide an incentive to trade emissions credits from FC emissions reduction projects. Because of their high global warming potential, FCs molecules also have a rather dense monetary value. Should a company be able to trade its FC emissions savings, it could trade a ton of C_2F_6 emission credits for nearly $60,000 (at $5/ton CO_2 equivalent), which is more than the price of the material itself. Indeed, one can buy a ton of high-purity C_2F_6 for less than $50,000 if one buys it in large quantity. So, will you be prepared when these FC emissions trading markets take off?

[5] S. Raoux, *Solid State Technology,* Implementing technologies for reducing PFC emissions – Jan. 2007

About the Author

Dr. Raoux is the founder of Transcarbon International Corporation, an independent consulting firm dedicated to implement sustainable development practices and to help various industries reduce their carbon footprint at the lowest possible cost. Dr. Raoux is the inventor of 20 patents, the author of 30 articles in technical journals and he has presented over 100 communications at international conferences. His areas of expertise include high global warming potential gas emissions, environmental technologies, environmental impact valuation, design for environment, life-cycle analysis as well as environmental strategies and management systems. In 1999, Dr. Raoux was the recipient of an R&D 100 Award for the development of the Remote CleanTM. He also received, on behalf of Applied Materials, the Climate Protection Award from the US EPA for environmental leadership in the semiconductor industry. Dr. Raoux is a co-author of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.