Institute for Governance & Sustainable Development

Testimony of Durwood Zaelke
the U.S. Senate Environment and Public Works Committee
In Support of the Super Pollutant Act

Introduction

This testimony is submitted in support of the Super Pollutants Act (the Act),[1] which aims to promote interagency cooperation in regard to super pollutants, methane, black carbon, and hydrofluorocarbons (HFCs), and to help prioritize emissions reduction strategies using existing federal authority and programs. The Act would enable federal agencies to work with business and non-profit communities to speed the adoption of super pollutant-reducing technologies and policies, all while supporting US technology innovations and investments to reduce these pollutants at home and abroad.

The Act would establish an interagency task force to review policies and measures to promote, and to develop best practices for, the reduction of these super pollutants. The task force would coordinate and optimize the federal government's existing efforts to address these super pollutants; reduce overlap and duplication of such efforts; and encourage federal operations, programs, policies, and initiatives to reduce super pollutants. The task force proposal is supported by a broad group of U.S. non-governmental organizations (NGOs).[2] The Act will make a significant contribution to climate protection, public health, and agriculture productivity in the US and abroad, and will help spur US innovation and investment in control technology markets at home and abroad.

Background

Reducing HFCs, black carbon, and methane can cut the rate of global warming in half for the next 40 years (more than 0.6°C in cumulative warming by 2050 and up to 1.5°C by 2100).[3] This will significantly reduce near term climate impacts, including reducing the rate of sea-level rise. It also will save millions of lives every year and improve public health, while also increasing agricultural yields.

Because these super pollutants are cleared from the atmosphere in a short period of time, they are also know as "short-lived climate pollutants" or SLCPs. Their short lifetime means that reducing them can produce fast benefits for the climate, for public health, and for agriculture. This is in contrast to carbon dioxide, approximately a quarter of which remains in the atmosphere for thousands of years.[4] Both the super pollutants and carbon dioxide must be cut as quickly as possible to protect the climate system from the growing impacts already occurring, although they deliver their climate benefits on different time scales, with the super pollutants being able to avoid significantly more warming in the near term than carbon dioxide.[5]

One of the super pollutants, black carbon soot, is a traditional air pollutant, and another, methane, contributes indirectly to air pollution as the principal precursor to local photochemical smog.[6] Reducing these pollutants will save millions of lives every year, protect tens of millions of tons of crop yields, and contribute to sustainable development.[7] The U.S. has a number of opportunities domestically to achieve fast, low-cost reductions in super pollutants using existing authorities, as well as procurement policy, voluntary industry agreements, public-private partnerships, and other strategies described below. The importance of mitigating each of the super pollutants is summarized below, along with an overview of select mitigation opportunities the task force might consider.

HFC Mitigation

HFCs are factory-made gases with a warming effect hundreds to thousands of times that of CO_2.[8] The average atmospheric lifetime of the mix of HFCs currently used is 15 years.[9] HFCs are produced as substitutes for ozone-depleting substances (ODSs) in air conditioning, refrigeration, insulating foams, solvents, aerosol products, and fire protection.[10] Unless a production and consumption phase-down of HFCs is implemented in the near-term, HFC emissions will increase dramatically and undermine efforts to curb the long-term driver of climate change—CO_2 emissions.[11] If not controlled, HFC emissions could correspond to up to 20% of CO_2 forcing under the IPCC business-as-usual scenarios in 2050.[12] If CO_2 was constrained from business-as-usual to a 450 ppm stabilization pathway, the radiative forcing of uncontrolled HFCs in 2050 could be as much as 40% of the CO_2 forcing, which would cancel nearly the entire benefit gained from controlling CO_2.[13]

Phasing down HFC production and consumption globally would provide climate protection equivalent to preventing between 87-146 billion tonnes of CO_2 emissions by 2050.[14] Phasing out HFC production would also avoid the build-up and eventual emissions of HFCs contained in existing refrigeration and air conditioning equipment, chemical stockpiles, foams, and other products, collectively known as 'HFC banks.' A fast phase down of HFCs by 2020 would avoid an additional 39–64 $GtCO_2$-eq of emissions.[15] The U.S. and many other countries have proposed phasing down HFC production and consumption under the Montreal Protocol, widely regarded as the most efficient and effective environmental treaty yet created.[16] The treaty has not only put the stratospheric ozone layer on the path to recovery by mid-century, it also has provided the most climate protection to date by phasing out CFCs, and now HCFCs, for a net of 135 $GtCO_2$-eq.[17] More than 100 countries now support phasing down HFCs under the Montreal Protocol, including China and India.[18]

Historically, refrigerant transitions under the Montreal Protocol are accompanied by significant improvements in the energy efficiency of the refrigerators, air conditioners, and other products and equipment using the refrigerants.[19] The phase-out of CFCs under the Montreal Protocol, which began in the mid-1980s, catalyzed substantial improvements in air conditioning and refrigerant energy efficiency—up to 60% in some subsectors.[20] These efficiency improvements were the result of replacing old products and equipment with a new generation of higher efficiency machines utilizing next generation refrigerants.[21] When refrigeration and air conditioning manufacturers redesigned their systems to be CFC-free, many took the opportunity to improve the efficiency of their designs.[22] For example, the U.S. EPA estimated that CFC-free chillers were up to 50% more energy efficient in the U.S. and over 30% more efficient in India than the CFC-based machines they replaced.[23] Similar improvements are expected with an HFC phase down, which will contribute significantly more climate mitigation, while also reducing consumers' operating costs for their air conditioners and other appliances. Currently, low-GWP alternatives exist for all major sectors.[24]

Select U.S. HFC Mitigation Options

- *Develop HFC industry partnership/coalitions to support the adoption of low-GWP alternatives.*

The Task Force could develop public-private partnerships modeled after the *Industry Cooperative for Ozone Layer Protection (ICOLP)* with ad-hoc working groups of experts that can quickly identify, develop, perfect and implement substitutes for high-GWP HFCs worldwide.[25] This could include the *Consumer Goods Forum*, comprised of 400 retailers, manufacturers, and service providers who have committed to begin phasing out HFC refrigerants beginning in 2015, and Refrigerants Naturally!, comprised of global refrigerated beverage and food marketers, working to replace high-GWP HFCs with low-GWP substitutes for new purchases of point-of-sale units and large refrigeration installations.[26]

- *Update Environmentally Preferable Purchasing (EPP) standards to exclude high-GWP HFCs.*

The Environmentally Preferable Purchasing (EPP) program was created by the EPA in 1993 to help U.S. agencies meet their obligations for green purchasing.[27] The EPP program could update its list of designated green products and develop purchasing guidelines to help eliminate products made with and containing high GWP HFCs.

- *Update voluntary green certification and rating standards to eliminate high-GWP HFCs.*

The Task Force could work with certification programs, such as the Energy Star Building program and LEED, to reduce or eliminate the use of high GWP HFCs in new building construction and remodels.

- *Reduce HFC emissions from mobile air conditioning.*

The Task Force could propose improvements to refrigerant containment with better parts and manufacturing quality control, by shifting from do-it-yourself to professional refrigerant servicing, by requiring use of improved recovery and recycle machines, and by creating incentives for refrigerant destruction when vehicles are dismantled at the end of useful life.

- *Prioritize utilization of low-GWP HFC insulation and refrigerants through Federal Housing and Energy Efficiency Loan Programs.*

The Task Force could work with these loan programs to ensure that, where possible, the programs eliminate the use of high-GWP HFCs and promote the adoption of efficient low-GWP alternatives in construction or improvements that they fund or support.

- *Reduce HFC emissions from supermarket refrigeration.*

The EPA could encourage more stringent voluntary standards for the maximum acceptable GWP for refrigerants in the supermarket sector, and work to expand the coverage of the GreenChill partnership, particularly within the companies that make up the Consumer Good Forum.

- *Reduce access to, and non-essential use of, HFC aerosol products.*

The Task Force could expand the list of prohibited non-essential and frivolous aerosol products and establish industry-government partnerships with manufacturers to agree on standardized warning labels highlighting concern for climate and permitting use of high-GWP HFC aerosol products only where technically necessary.

- *Align minimum efficiency standards for refrigeration and air conditioning with HFC reductions.*

The EPA and the Department of Energy (DOE) could work together to phase down HFCs and secure significant gains in energy efficiency in air conditioning and refrigeration by aligning their timetables.

- *Remove barriers to the adoption of low-GWP alternatives in the air conditioning and refrigeration sectors.*

The DOE could work to remove barriers to the adoption of low-GWP alternatives in the air conditioning and refrigeration sectors by supporting research and development, technical validation, and market introduction programs for low-GWP HFC alternatives.

Methane Mitigation

Methane is a powerful greenhouse gas with a 100-year global warming potential 28 times that of CO_2 and an atmospheric lifetime of approximately 12 years.[28] In 2011, the U.S. is estimated to have emitted 567.3 MMt CO_2-eq of methane, down from 578.3 MMt CO_2-eq in 2011.[29] Methane accounted for approximately 8.6% of all U.S. CO_2-eq emissions in 2012.[30] Significant reductions of methane emissions can be achieved quickly and cost-effectively utilizing currently available technologies. In the U.S., the greatest opportunities for methane mitigation come from: 1) recovery of emissions from the oil and natural gas sectors; 2) landfill gas capture and utilization; and 3) the recovery of coal mine ventilation gases. Further emissions mitigation opportunities exist in the capture and utilization of emissions from manure, and the control of enteric fermentation. A number of methane reduction opportunities were identified in the 2014 U.S. Climate Action Plan Strategy to Reduce Methane Emissions.[31]

Select U.S. Methane Mitigation Options

- *Promote methane capture for oil and gas production leases on public lands.*

Federal land management agencies and the Bureau for Land Management, in particular, could encourage the use of all technically and economically viable control technologies for oil and gas production, including hydraulic fracturing ("fracking"), on public lands.

- *Expand composting and zero-waste programs.*

The Task Force and the EPA could work with municipalities and businesses with existing zero-waste and composting programs that include methane capture to develop best practice models for expanding these programs and to support other municipalities and businesses setting zero-waste or composting goals.

- *Capture coal mine ventilation gas.*

The EPA could promote the capture of coal mine emissions by establishing federal standards for performance for coal mine emissions.

- *Control methane emissions from anaerobic digestion of manure.*

The EPA could work to expand information exchanges with key stakeholders regarding the cost-effectiveness and availability of technologies to control and utilize emissions from the anaerobic digestion of manure, through its AgSTAR program.

- *Remove regulatory barriers for development of methane-based renewable energy.*

The Task Force could work with expert organizations and agencies to remove regulatory barriers to deployment of methane-based renewable energy by continuing to expand and standardize grid interconnection rules and modern net metering laws for small clean energy generators.

- *Capture and combust methane emissions at dairies.*

The EPA could expand existing voluntary measures in the AgSTAR program to provide dairy farms with the technical expertise and information necessary to implement methane control technologies where they are effective.

- *Capture and utilize methane emissions from wastewater treatment.*

The Task Force could work with the Department of Energy Office of Energy Efficiency and Renewable Energy to expand energy production from biogas at all technically feasible wastewater treatment facilities and increase access to technology and financing through programs such as the Federal Energy Management Program's Super Energy Savings Performance Contracts (ESPC).

- *Improve rice field management to reduce methane emissions.*

Emissions of methane from rice fields can be reduced through a number of management techniques such as dry seeding and post-harvest rice straw removal and bailing. The EPA should develop a voluntary program, similar to the successful AgSTAR program, to educate farmers on cost-effective rice field management techniques.

- *Study anti-methanogen vaccines and feed supplements for livestock.*

To achieve near-tern reduction of methane emissions from livestock, the Super Pollutant Tack Force could support research into safe and cost-effective methods for reducing enteric fermentation including anti-methanogen vaccines and modified feed mixes.

Black Carbon Mitigation

Black carbon is a potent climate-forcing aerosol that remains in the atmosphere for only a few days or weeks.[32] Black carbon is a component of soot and is a product of the incomplete combustion of fossil fuels, biofuels, and biomass.[33] Black carbon contributes to climate change in several ways: it warms the atmosphere directly by absorbing solar radiation and emitting it as heat; it contributes to melting by darkening the surfaces of ice and snow when it is deposited on them; and it can also affect the microphysical properties of clouds in a manner than can perturb precipitation patterns.[34] Recent estimates of black carbon's radiative forcing confirm that it is the second leading cause of global warming after CO_2.[35] The total climate forcing of black carbon is 1.1 W m^{-2}, second only to CO_2 (1.7 W m^{-2}).[36]

The main sources of black carbon are open burning of biomass, diesel engines, and the residential burning of solid fuels such as coal, wood, dung, and agricultural residues.[37] In 2000, global emissions of black carbon were estimated at approximately 7.5 million tons, with a large uncertainty range.[38]

Thanks to modern pollution controls and fuel switching, black carbon emissions in North America and Europe were significantly curbed in the early 1900s.[39] However, the U.S. is still estimated to be the source of approximately 8% of all global black carbon emissions.[40] Approximately 50% of these emissions come from the transportation sector, primarily mobile diesel engines.[41] Open biomass burning constitutes the second largest source of black carbon in the U.S., at 35% of total emissions.[42] To address these and other sources of black carbon emissions in the United States, the Super Pollutant Task Force could focus on: continuing to reduce transportation particulate emissions particularly from super-emitting on- and off-road vehicles; expanding the use of battery and grid power for parked highway trucks; encouraging a switch to low-lack carbon fuels; requiring shore-power for at-berth ocean-going vessels and vessel speed reduction (VSR) near port; and banning open burning of agricultural biomass.

Select U.S. Black Carbon Mitigation Options

- *Reduce transportation particulate emissions.*

The task force could review the Diesel Emission Reduction Act (DERA), with an aim to produce vehicle turnover as soon as feasible.

- *Expand the use of battery and grid power for parked highway trucks.*

The EPA could work with state and local authorities to identify and support opportunities for expansion of truck stop electrification projects and provide incentives for truck owners to retrofit existing trucks compatible with electrification technologies.

- *Require shore-power from at-berth ocean-going vessels.*

The EPA could work with State Port Authorities to support the implementation of at-berth short power regulations similar to California's.

- *Reduce port congestion.*

The Task Force could work with industry associations and port authorities to develop and implement best practices for improving on- and off-short port efficiency including expanding the use of virtual arrival systems.

- *Require vessel speed reduction (VSR) near port.*

The EPA could work with other coastal states and port authorities to facilitate the expansion of VSR guidelines, priorities, and regulations for all coastal waters, including the Great Lakes.

- *Control open burning of agricultural biomass.*

The Task Force could develop training and outreach programs for farmers and land managers to educate them on techniques and best practices for eliminating the need to burn agricultural biomass, and develop tools to expand the use of biochar technologies.

- *Set stronger standards for wood-burning stoves and fireplaces.*

The Task Force should explore opportunities to expand the U.S. EPA BurnWise program, identify technical options to improve existing EPA standards both in the Residential Wood Heater program and through the voluntary Fireplace Partnership Program, and encourage states and local regulatory agencies to adopt equal or better standards for wood burning stoves and fireplaces.

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[2] Zaelke D. & Borgford-Parnell N. (2014) ADDRESSING SHORT-LIVED CLIMATE POLLUTANTS: U.S. SLCP CLIMATE ACTION SUPPLEMENT; *see also* The Connect U.S. Fund (2012) *A Call to the President to Sustain and Enhance U.S. Global Leadership*; Bachmann J. & Seidel S., DOMESTIC POLICIES TO REDUCE THE NEAR-TERM RISKS OF CLIMATE CHANGE (2013) ("As a first step under this initiative, the Administration could issue a new Executive Order, direct agencies to begin advancing the regulatory and program actions identified below, and establish an interagency Short-Lived Climate Pollutant Task Force to coordinate and monitor implementation of this effort and to identify additional actions going forward."); *and* World Resources Institute (2013) CAN THE U.S. GET THERE FROM HERE? USING EXISTING FEDERAL LAWS AND STATE ACTION TO REDUCE GREENHOUSE GAS EMISSIONS.

[3] Xu Y., Zaelke D., Velders G., Ramanathan V., *The role of HFCs in mitigating 21st century climate change,* ATMOSPHERIC CHEMISTRY AND PHYSICS 13:6083-6089, 1 (2013).

[4] Solomon S. *et al.,* CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (2007); *see also* Archer D *et al., Atmospheric lifetime of fossil fuel carbon dioxide*, ANNU. REV EARTH PLANET. SCI. 37:117-34 (2009); *and* Matthews H. D. & Caldeira K. *Stabilizing climate requires near-zero emissions*, J. GEOPHYSICAL RES. 35:4 (2008); *and* Hansen J. *et al., Climate change and trace gases*, PHIL. TRANS. R. SOC. 365:1925-1954 (2007).

[5] UNEP/WMO (2011) INTEGRATED ASSESSMENT OF BLACK CARBON AND TROPOSPHERIC OZONE; Xu Y., Zaelke D., Velders G., Ramanathan V., *The role of HFCs in mitigating 21st century climate change,* ATMOSPHERIC CHEMISTRY AND PHYSICS 13:6083-6089, 1 (2013) (calculating that cutting the short-lived pollutants can avoid up to 0.6C of warming by 2050, compared to 0.1C for aggressive mitigation of carbon dioxide).

[6] UNEP/WMO (2011) INTEGRATED ASSESSMENT OF BLACK CARBON AND TROPOSPHERIC OZONE, 57; *see also* UNEP (2011) NEAR-TERM CLIMATE PROTECTION AND CLEAN AIR BENEFITS: ACTIONS FOR CONTROLLING SHORT-LIVED CLIMATE FORCERS ("Methane contributes around 50 per cent of the increases in background ozone, with smaller contributions from non-methane volatile organic compounds and carbon monoxide"); *and* Royal Society (2008) GROUND-LEVEL OZONE IN THE 21ST CENTURY: FUTURE TRENDS, IMPACTS AND POLICY IMPLICATIONS: SCIENCE POLICY REPORT.

[7] Shindell D. *et al., Simultaneously mitigating near-term climate change and improving human health and food security*, 335 SCI. 183, 183 (2012); *and* UNEP/WMO, INTEGRATED ASSESSMENT OF BLACK CARBON AND TROPOSPHERIC OZONE (2011); *see also* Lim S. *et al.*, *A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010*, 380 THE LANCET 9859 (2012) ("The joint effects of air pollution are also likely to be large. Household air pollution from solid fuels accounted for 3.5 million (2.7 million to 4.4 million) deaths and 4.5% (3.4–5.3) of global DALYs [disability-adjusted life years] in 2010 and ambient particulate matter pollution accounted for 3.1 million (2.7 million to 3.5 million) deaths and 3.1% (2.7–3.4) of global DALYs…. The effects of ambient ozone pollution, which increases the risk of chronic obstructive pulmonary disease, were smaller than those of household air pollution from solid fuels or ambient particulate matter pollution (0.2 million [0.1 million to 0.3 million] deaths and 0.1% [0.03–0.2] of global DALYs in 2010).") Total annual deaths from air pollution is 6.8 million.

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[10] UNEP, HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER, 10 (2011).

[11] Velders G., *et al.*, *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, 335 SCI. 922 (2012); *see also* TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL, TASK FORCE DECISION XX/8 REPORT, ASSESSMENT OF ALTERNATIVES TO HCFCS AND HFCS AND UPDATE OF THE 2005 TEAP SUPPLEMENTAL REPORT DATA 2009); and Velders G., *et al.*, *The Large Contribution of Projected HFC Emissions to Future Climate Forcing*, PROC. NAT'L. ACAD. SCI. Early Ed. (2009).

[12] Velders G. *et al.*, *The large contribution of projected HFC emissions to future climate forcing*, 106 PROC. NAT'L. ACAD. SCI. 10949 (2007) ("Global HFC emissions significantly exceed previous estimates after 2025 with developing country emissions as much as 800% greater than in developed countries in 2050. Global HFC emissions in 2050 are equivalent to 9–19% (CO_2-eq. basis) of projected global CO_2 emissions in business-as-usual scenarios and contribute a radiative forcing equivalent to that from 6–13 years of CO_2 emissions near 2050. This percentage increases to 28–45% compared with projected CO_2 emissions in a 450-ppm CO_2 stabilization scenario business-as usual scenarios from 2010 to 2050"); *and* UNEP, HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER (2011) ("In a further comparison, the HFC radiative forcing in 2050 (not shown) of 0.25-0.40 W m^{-2} corresponds to 7–12% of the CO_2 values."); *see also* Velders G. *et al.*, *Preserving Montreal Protocol Climate Benefits by Limiting HFCs*, 335 SCI. 922 (2012).

[13] UNEP, HFCS: A CRITICAL LINK IN PROTECTING CLIMATE AND THE OZONE LAYER (2011) ("The increase in HFC radiative forcing from 2000 to 2050 can also be compared to the radiative forcing corresponding to a 450 ppm CO_2 stabilization scenario. The reduction in radiative forcing necessary to go from a business-as-usual scenario (as in IPCC-SRES, Figure 3.3) to such a stabilization scenario is of the same order of magnitude as the increase in HFC radiative forcing. In other words, the benefits of going from a business-as-usual pathway to a pathway in which CO_2 stabilizes at 450 ppm can be counteracted by projected increases in HFC emissions. "); *see also* Velders G., *et al.*, The large contribution of projected HFC emissions to future climate forcing, PROC. NAT'L. ACAD. SCI. Early Ed. (2009).

[14] *See* Velders G., *et al. The large contribution of projected HFC emissions to future climate forcing*, PROC. NAT'L. ACAD. SCI. USA 106:10949 (2009) (Dr. Velders' updated calculations show that as of 2013 the amendments can provide 76 to 134 billion tonnes CO_2-eq. by 2050.).

[15] Velders G. J. M., *et al.* (2014) *Growth of climate change commitments from HFC banks and emissions*, ATMOS. CHEM. PHYS. DISCUSS. 14:4563-4572

[16] Proposed amendment to the Montreal Protocol submitted by the Federated States of Micronesia, UNEP/OzL.Pro.WG.1/34/5 (16 May 2014); *and* Proposed amendment to the Montreal Protocol submitted by Canada, Mexico and the United States of America, UNEP/OzL.Pro.WG.1/34/4 (10 May 2014).

[17] Velders G. J. M., *et al.* (2007) *The importance of the Montreal Protocol in protecting climate*, PROC. NAT'L. ACAD. SCI. U.S.A. 104:4814-4819.

[18] UNEP (2010) DECLARATION ON THE GLOBAL TRANSITION AWAY FROM HYDROCHLOROFLUOROCARBONS (HCFCS) AND CHLOROFLUOROCARBONS (CFCS). There are a number of agreements between the U.S. and China and the U.S. and India on the phase down of HFCs, *see* Zaelke, D. & N. Borgford-Parnell (2014) *Primer on Hydrofluorocarbons* for a full list of policy statements supporting the phase down of HFCs.

[19] Speech, Shende R. *2009 USEPA's Stratospheric Ozone Protection and Climate Protection Awards* (21 April 2009) ("Humanity has already benefited by about 60% improvement in energy efficiency in domestic refrigerators since the industry started looking at their design in order to change from CFC-12."); *see also* U.S. Envtl. Prot. Agency (2002) BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR-CONDITIONING CHILLER, 7 ("The most energy-efficient new chillers will reduce electric generation and associated greenhouse gas emissions by up to 50% or more compared to the CFC chillers they replace."); U.S. Envtl. Prot. Agency (2002) BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR-CONDITIONING CHILLER, 2 ("Building owners around the world have saved millions of dollars in electricity bills by upgrading air conditioning chiller installations and through concurrent investments to reduce building cooling load. Today's chillers use about one-third or less electricity compared to those produced just two decades ago. Building owners can typically pay back the investment cost of replacing an old CFC chiller in five years or less in virtually all locations that cool for more than three months a year."); *and* Todesco G. (2005) CHILLERS +LIGHTING + TES: WHY CFC CHILLER REPLACEMENT CAN BE ENERGY-SAVINGS WINDFALL, ASHRAE JOURNAL, 10 ("These CFC chillers serve an estimated3.4 billion to 4.7 billion ft² (315 million to 440 million m²) of commercial floor space with a total electricity consumption of 49,000 to 66,000 GWh/year, and an annual electricity operating cost of $3.4 billion to $4.8 billion. In addition, the cooling and lighting loads in these buildings contribute an estimated 3,600 to 9,200 MW to the summer peak demand of North American utilities. The electricity consumption and peak electrical demand can be reduced significantly by replacing the remaining CFC chillers with new efficient plants. The performance of chillers has improved significantly in the last 12 years compared to chillers manufactured in the 1970s and 1980s.").

[20] Shende R., *2009 USEPA's Stratospheric Ozone Protection and Climate Protection Awards* (2009) ("Humanity has already benefited by about 60% improvement in energy efficiency in domestic refrigerators since the industry started looking at their design in order to change from CFC-12."); *and* U.S. Envtl. Prot. Agency BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR CONDITIONING CHILLER, 7 (2002) ("The most energy-efficient new chillers will reduce electric generation and associated greenhouse gas emissions by up to 50% or more compared to the CFC chillers they replace.").

[21] U.S. Envtl. Prot. Agency, *Building owners save money, save the earth: replace your CFC air conditioning chiller*, 2 (2002) ("Building owners around the world have saved millions of dollars in electricity bills by upgrading air conditioning chiller installations and through concurrent investments to reduce building cooling load. Today's chillers use about one-third or less electricity compared to those produced just two decades ago. Building owners can typically pay back the investment cost of replacing an old CFC chiller in five years or less in virtually all locations that cool for more than three months a year."); *and* Todesco G. CHILLERS +LIGHTING + TES: WHY CFC CHILLER REPLACEMENT CAN BE ENERGY-SAVINGS WINDFALL, ASHRAE JOURNAL, 10 (2005) ("These CFC chillers serve an estimated 3.4 billion to 4.7 billion ft² (315 million to 440 million m²) of commercial floor space with a total electricity consumption of 49,000 to 66,000 GWh/year, and an annual electricity operating cost of $3.4 billion to $4.8 billion. In addition, the cooling and lighting loads in these buildings contribute an estimated 3,600 to 9,200 MW to the summer peak demand of North American utilities. The electricity consumption and peak electrical demand can be reduced significantly by replacing the remaining CFC chillers with new efficient plants. The performance of chillers has improved significantly in the last 12 years compared to chillers manufactured in the 1970s and 1980s.").

[22] York International, *Taking the bite out of CFC replacement by improving air conditioning efficiency* (press release 14 February 1996) ("Now that production of chlorofluorocarbons (CFCs) has ended, the majority of commercial and institutional building owners and industrial plant managers have a chance to turn adversity into opportunity. That's the premise of a white paper being offered by York International Corp., a major manufacturer of chillers -- the large refrigeration machines at the heart of most large-building air conditioning systems. While there's no escaping eventual replacement or conversion of the 60,000 or more air conditioning systems in the U.S. that use CFCs as refrigerants, the good news, according to York International, is that the energy efficiency of these systems can be dramatically improved with new technology, meaning quicker paybacks and long-term cost savings. The savings, in fact, have been calculated to range between $200,000 and $2 million, depending on local weather conditions, over a 25-year operating life.").

[23] U.S. Envtl. Prot. Agency, BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR CONDITIONING CHILLER, 7 (2002).

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[33] U.S. Envtl. Prot. Agency, REPORT TO CONGRESS ON BLACK CARBON, xxi (2012).

[34] Bond T. C. *et al., Bounding the role of black carbon in the climate system: a scientific assessment*, Accepted for publication in the J. OF GEOPHYS. RES. –ATMOS., doi:10.1002/jgrd.50171 (2013).

[35] Bond T. C. *et al., Bounding the role of black carbon in the climate system: a scientific assessment*, Accepted for publication in the J. OF GEOPHYS. RES. –ATMOS., doi:10.1002/jgrd.50171 (2013) *(*"We estimate that black carbon, with a total climate forcing of +1.1 W m^{-2}, is the second most important human emission in terms of its climate-forcing in the present-day atmosphere; only carbon dioxide is estimated to have a greater forcing.") (This study confirms earlier estimates by Jacobson (2001) and Ramanathan and Carmichael (2008), which also concluded that BC is the second largest contributor to global warming after CO_2); *and* Jacobson M. Z., *Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols,* NAT. 409:695–69 (2001); *and* Ramanathan V. & Carmichael G., *Global and regional climate changes due to black carbon*, NAT. GEOSCI. 1:221 (2008); *see also* U.S. Envtl. Prot. Agency, REPORT TO CONGRESS ON BLACK CARBON 4, 18 (2012) ("The sum of the direct and snow/ice albedo effects of BC on the global scale is likely comparable to or larger than the forcing effect from methane, but less than the effect of carbon dioxide; however, there is more uncertainty in the forcing estimates for BC….").

[36] Bond T. C. *et al., Bounding the role of black carbon in the climate system: a scientific assessment*, Accepted for publication in the J. OF GEOPHYS. RES. –ATMOS., doi:10.1002/jgrd.50171 (2013).

[37] U.S. Envtl. Prot. Agency, REPORT TO CONGRESS ON BLACK CARBON, 4, 18 (2012).

[38] Bond T. C. *et al., Bounding the role of black carbon in the climate system: a scientific assessment*, Accepted for publication in the J. OF GEOPHYS. RES. –ATMOS., (2013) ("With this method, a bottom-up estimate of total global emissions in the year 2000 is about 7500 Gg BC yr-1, with an uncertainty range of 2000 to 29000 Gg yr-1."); *see also* U.S. Envtl. Prot. Agency, REPORT TO CONGRESS ON BLACK CARBON, 4, 18 (2012).

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