Yale Carbon Containment Lab

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To:
Office of Air Policy and Program Support
Office of Air and Radiation
Environmental Protection Agency

From:
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Response to "Request for Information – Funding for Implementation of American Innovation and Manufacturing Act"

We appreciate the opportunity to provide information on funding for the implementation of the American Innovation and Manufacturing (AIM) Act. We believe that this funding can help maximize the benefits of the AIM Act and mitigate the potential climate damages of hydrofluorocarbons (HFCs) currently in use and HFCs that have yet to enter the market. We have responded to each of the Office of Air Policy and Program Support's questions below.

I) What innovative destruction technologies listed under 40 CFR 84.29 are commercially available or under development?

As of 2016, several destruction technologies have been used to destroy ozone-depleting refrigerants in the United States. These technologies include argon plasma arc, rotary kiln, gas/fume oxidation, fluidized bed incinerators, catalytic destruction, and fixed hearth incineration. In other countries, cement kilns have been used to destroy ozone-depleting refrigerants and HFCs.[1]

We are most familiar with the use of cement kilns and argon plasma arc technology to destroy refrigerant gases, including HFCs. We believe that these technologies are the most widespread and commercialized destruction technologies in use. Both technologies satisfy Montreal Protocol Technology & Economic Assessment Panel (TEAP) guidance for destruction and removal efficiency (DRE) of fluorocarbons and limits on pollutants from exhaust gases.[2]

- Cement kilns have been used for decades to destroy ozone-depleting substances (ODS) and other high potency greenhouse gases. These kilns typically operate at temperatures exceeding 1500 °C, permanently incinerating refrigerant gases within seconds. Cement kilns typically destroy refrigerants with a DRE of 99.9999 percent.
- Destroying refrigerants in cement kilns has the added benefit of requiring little additional energy use, since cement kilns can operate at standard conditions even when co-processing refrigerants. Furthermore, the alkaline environment inside the kiln neutralizes acidic byproducts from refrigerant destruction, such as hydrochloric and hydrofluoric acid. Cement kilns can be easily retrofitted with refrigerant feeders and appropriate emissions control technologies.

[1] ICF. "ODS Destruction in the United States and Abroad." Environmental Protection Agency, February 2018. https://www.epa.gov/sites/default/files/2018-03/documents/ods-destruction-in-the-us-and-abroad_feb2018.pdf.
[2] ICF. "ODS Destruction in the United States and Abroad."

- Argon plasma arc technology, unlike cement kilns, was developed specifically with the destruction of hazardous waste in mind. Companies such as PLASCON produce argon plasma arc technology. [3] This technology incinerates refrigerant gases at or above 10,000 °C, pyrolyzing the refrigerant gas and achieving a DRE exceeding 99.999999 percent. Acids produced from pyrolysis are subsequently neutralized in an alkaline solution, which can then be discharged into the municipal wastewater system as brine.

II) What do you see as important components of a grant program consistent with Section 60109(a)(3) to support reclaim and innovative destruction technologies?

We believe that the greatest challenges with refrigerant reclamation moving forward will be reclaiming highly contaminated refrigerants and mixed gases. We use "mixed gases" to refer to both HFC blends, such as R-404A, and cylinders of refrigerant that have been unintentionally mixed during the refrigerant recovery or aggregation process. Reclaiming mixed gases requires fractional distillation technology, which separates refrigerant species in a blend or mixture based on boiling points. Given that many common species of HFCs are blends – as compared to previous generations of single molecule chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) – advanced fractional distillation technology will be a requirement to building national reclamation capacity during HFC phasedown.

Several refrigerant reclamation companies, including A-Gas and Hudson Technologies, are already using advanced fractional distillation technology to reclaim HFC blends. It is our impression, however, that the approximately 40 smaller reclaimers across the country do not yet possess the technology (nor the investment capital) to reclaim more chemically complex, mixed, or contaminated gases.

We therefore believe that grant funds can best support the *scale-up*, rather than new development of, refrigerant reclaim technology capable of processing HFC blends. Grants could also support the development of new fractional distillation technology suitable for the operational scale of smaller reclaim companies. To our knowledge, most fractional distillation technology used by larger reclaimers has been developed in-house, or specifically for their own operations.

We also see some opportunities to substantially improve existing reclamation technology. Currently, refrigerant reclaimers "bulk up" reclaimed refrigerant with virgin refrigerant gas such that reclaimed refrigerant reaches or exceeds virgin purity standards. As HFC phasedown progresses and the cost of virgin gas rises, this practice will become more expensive for refrigerant reclaimers. Furthermore, it is preferable from an environmental perspective to reduce the amount of virgin gas added to refrigerant being sold as reclaimed. Refrigerant reclaimers appear to use the bulking up strategy as a cost-saving measure. High purity could be achieved without bulking up reclaimed gas, but at the cost of running recovered gases through fractional distillation towers many times. Competitive grants could support the development of more efficient fractional distillation towers capable of purifying recovered refrigerant with higher contamination levels.

On the destruction side, we believe that funds could support the retrofits of operating cement kilns with feeders for refrigerant gases. These retrofits tend to be relatively inexpensive – on the order of

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[3] PLASCON. "PLASCON Technology Overview." Process Overview. Accessed January 17, 2023. http://www.plascon.com.au/technology-overview.html.

$100,000 – especially compared with the million-dollar investment required for plasma arc technology.

We also believe that competitive grants should support development of faster recovery equipment, which supports refrigerant reclamation and destruction at scale. Recoveries of refrigerant – especially from large compressor racks or chillers – can take entire days to complete, posing large and often insurmountable costs that prevent contractors from responsibly recovering refrigerant. The capability to recover refrigerant faster is one reason behind the success and competitive advantage of Rapid Recovery, the refrigerant recovery contractor owned by A-Gas. Given that refrigerant recovery technology enables reclaim and destruction, we believe that such grants for recovery technology development would satisfy a grant program meant to support reclaim and destruction and to enable more competition.

Lastly, we are interested in ensuring that there is sufficient laboratory testing capacity to support foreseeable carbon credit generation from HFC destruction. Currently, methodologies approving destruction of ozone-depleting substances require that project developers receive third-party testing of refrigerant bound to be destroyed. This process ensures that project developers are accurately credited for the refrigerant that they destroy. We are aware of only a few facilities in the United States that test refrigerants prior to destruction, but we expect that demand for these services will grow in the coming decade.

III) What sort of new implementation and compliance tools should EPA deploy to maximize the benefits of the AIM Act?

We believe that EPA should develop and deploy software that creates a chain of custody for refrigerant, from cradle to grave. EPA proposed creating a similar electronic-based data collection approach in its HFC Allocation Rule.

Currently, there is a dearth of data and information about refrigerant recovery across the United States. Although the EPA publishes annual data on reclaimed refrigerant each year, it is unclear how much refrigerant should be available for recovery nationwide, and how much refrigerant is recycled back into equipment or vented to the atmosphere each year.[4] We know of several large refrigerant reclaimers, carbon credit project developers, and fluorocarbon manufacturers already using proprietary software to track refrigerants throughout their value chains. But since these software platforms are not public, they cannot coordinate a national HFC phasedown strategy.

We believe that more robust data can support EPA in maximizing the benefits of the AIM Act and help downstream actors such as refrigerant reclaimers in designing appropriate incentives to boost refrigerant recovery rates.

We also believe that refrigerant tracking software could function as an additional safeguard against the illegal import of HFCs. Although we commend the Interagency Task Force on preventing substantial illegal imports of HFCs over this past year, we believe that EPA should build tools that anticipate more sophisticated efforts to illegally import HFCs in the future. Ideally, this software

[4] US EPA, OAR. "Summary of Refrigerant Reclamation Trends." Data and Tools, August 5, 2015. https://www.epa.gov/section608/summary-refrigerant-reclamation-trends.

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could store data that guarantees to buyers that the HFCs that they purchase are legal, the same species of HFC as labeled, and at AHRI 700 purity standards.

EPA can also take steps to support robust reporting of HFC emissions within the WRI/WBCSD GHG Reporting Protocol. We believe that better reporting of HFC emissions can incentivize equipment owners and operators to reduce leaks, transition to climate-friendlier refrigerants, and properly recover refrigerants at equipment end of life. As we learned from refrigerant inventory efforts on Yale University's campus, refrigerant emissions from small appliances (window air conditioners, laboratory refrigerators, and dining hall equipment) are significant, even though this equipment is excluded from recordkeeping requirements under the Clean Air Act.

Furthermore, although outside the direct scope of the AIM Act, EPA should also support mandatory reporting of gases such as CFCs and HCFCs that are not covered under the Kyoto Protocol. Emissions of these gases are currently marked as optional reporting under the GHG Reporting Protocol. Under OMB Circular A-119 Policy, EPA is empowered to use and support voluntary consensus standards. The GHG Reporting Protocol is widely adopted and referenced by the U.S. Federal Government, including in its own Federal Sustainability Plan, and by reference in the new proposed climate disclosure requirements placed on U.S. Federal Suppliers.

Lastly, EPA should work with the General Services Administration (GSA) to ensure that federal footprint and procurement meet the AIM Act and ensure that federally owned facilities and assets using refrigerants also meet or exceed AIM Act goals.

We are grateful for the opportunity to provide information for this funding allocation to AIM Act implementation. We would be happy to connect further with OAR on these questions.

Respectfully submitted,

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About the Carbon Containment Lab:

Part of the Yale School of the Environment, the Yale Carbon Containment Lab (CC Lab) researches, develops, implements, and teaches low-cost, safe, and scalable approaches to carbon removal and containment. The CC Lab works with academic advisors, students, technical experts, and other collaborators to pursue concrete quantitative goals: 30 million metric tons of carbon dioxide equivalent (tCO_2e) contained by 2030, and 500 million tCO_2e by 2050. The CC Lab's Anthropogenic Program includes a project on refrigerant emissions, focusing on refrigerant recovery from end-of-life cooling equipment. The CC Lab is funded by charitable gifts from individuals and foundations.