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Urgent, Collaborative, Sustainable, Impact

October 29, 2023

Response from êffecterra on

California Air Resources Board's Request for Information for

California Senate Bill 1206 Assessment Report

Submitted online to the public comment docket here:
https://ww2.arb.ca.gov/public-comments/public-comment-request-information-california-senate-bill-1206-assessment-report

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êffecterra appreciates the opportunity to provide input to the California Air Resources Board (CARB) in response to their Request for Information (RFI) to aid the development of an assessment report on how to transition California's economy away from hydrofluorocarbons (HFCs) and to ultra-low global warming potential (GWP) or no-GWP alternatives no later than 2035, as required by Senate Bill (SB) 1206.

êffecterra is a Public Benefit Corporation that provides sustainability technical support to companies and investors, as well as government entities. One of our niche specialties is in addressing emissions of super-polluting greenhouse gases like HFCs. We applaud CARB for being climate protection leaders, particularly when it comes to reducing super-pollutant emissions. We really appreciate CARB's transparency and willingness to seek public input to develop the SB 1206 assessment report, which will undoubtedly serve as a scoping plan for eliminating HFC emissions in California and will hopefully pave the way for similar ambitious policy actions in other states, and at the federal level.

We are providing input on specific questions listed in the RFI and have included the section and question numbers below.

Section 1: Commercial and Industrial Stationary Refrigeration (Retail Food, Cold Storage, Industrial Process Refrigeration, and Ice Rinks)

1. ***What potential technological solutions are available for existing facilities and how can their adoption be accelerated?***

Response: The stationary commercial and industrial refrigeration sectors are the farthest along on the trajectory of transitioning to ultra-low and no-GWP alternatives to HFC refrigerants. From among the high-GWP HFC alternatives available today, there is currently just one category that can meet the technological needs of heating and cooling while also ensuring there is no collateral environmental damage (such as ozone depletion, global warming, PFAS pollution). That is the category of natural refrigerants or natural working fluids. Natural refrigerants like CO_2, ammonia, and hydrocarbons are generally commercially available for a wide variety of commercial and industrial refrigeration uses in the US today, and as such, are the most sustainable, environmentally friendly HFCs alternatives.

Natural refrigerants are used widely in the European Union. Even though they are used in new commercial refrigeration facilities in the US and have historically been used for large cold storage and

industrial process refrigeration, there remain barriers to adoption. Earlier this year, with support from the New York Department of Environmental Conservation, êffecterra convened a series of technical working group meetings to assess the challenges and opportunities for natural refrigerants in the US by end-use sector. The findings of those meetings are summarized in a synthesis report, which is available publicly.[1] The report contains information on the availability and barriers for natural refrigerant technologies by equipment type. The report also includes a series of recommendations for policymakers. While the report was developed for the State of New York (NY) and contains some NY state-specific information, it more broadly contains information pertinent to many of the questions contained in this RFI, and thus we are drawing your kind attention to it.

Technology development for natural refrigerants has occurred by leaps and bounds in the last decade, thanks to various international and national regulations on fluorinated greenhouse gases (F-gases). But the main challenge in commercial and industrial refrigeration facilities has been replacing existing HFC systems with those using natural refrigerants. Modular systems are being developed that will allow for partial transitions that enable facilities to remain operational during the conversions. These include CO2 condensing units, CO2 micro distributed solutions, small or distributed CO2 rack systems, as well as microdistributed and self-contained hydrocarbon systems/cases. These and other solutions will allow owner/operators to replace sections of equipment while not stranding or replacing newer assets (i.e. cases) and undergoing costly and very disruptive “gut retrofits” (complete system replacements). These types of partial or phased upgrades are not new. In fact, some of the first were performed as early as 2014 with replacements of low-temperature systems in existing stores to CO2. With the introduction of additional and more flexible technologies, such as those aforementioned as well as a better understanding of the coordination required to execute these upgrades, the barriers to adoption of these HFC alternatives in existing facilities are no longer prohibitive.

However, the existing facility conversions from HFCs to natural refrigerants remain financially and logistically challenging. We recommend that CARB continue to provide financial incentives for transitions to natural refrigerant systems in existing facilities[2] and include technical support to help the facilities that lack knowledge and experience of working with natural refrigerants.

2. What incentives are needed to transition existing refrigeration facilities and what GWP limit should be set for technologies supported through incentives?

Response: When it comes to incentives, we recommend that CARB use more decisive criteria for choosing refrigerant alternatives. We understand that the key principle behind criterion like GWP limits is technology neutrality. While technologically neutral criteria like GWP limits may be suitable for current regulations, incentive programs can and should be more ambitious. It is becoming increasingly clear that GWP alone is not a sufficient metric for limiting environmental damage. We need to ensure that this refrigerant transition is sustainable. Just using a metric of GWP for incentives would be short-sighted, given that concerns about PFAS pollution from synthetic HFC alternatives are already being highlighted around the world. While the science becomes clearer on the question of PFAS pollution from F-gas alternatives and governments gain confidence in regulating them, incentive programs should focus on promoting alternatives that are not impacted by concerns related to PFAS pollution.

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[1] êffecterra, Synthesis Report: New York State Assessment of Natural Refrigerants (September 2023). Available at: https://bit.ly/NaturalRefrigerantsAssessment23

[2] This was done in the first round of CARB’s F-gas Reduction Incentive Program (FRIP)

In short, for incentive programs, we highly recommend using multiple criteria such as "to qualify for CARB's incentives, refrigerant alternatives must meet the following criteria: zero ODP, < 10 GWP, and not considered PFAS under the OECD definition.[3]"

Financial and technical assistance are the main types of incentives necessary for existing facilities. A robust incentive program that supports both, by not only providing easily accessible funds to qualifying and well vetted projects, but also qualified and agnostic technical resources that can support the design, development, implementation, optimization and measurement/verification of these projects is critical. The latter will also require incentives for continued training and workforce development. FRIP-style programs that continue to evolve to account for best in class incentive models focused on transitioning existing facilities will be very helpful.

Technical assistance is a key missing ingredient. Most facility owners/operators lack the knowledge of available options and experience in transitioning to non-HFC alternatives. It will be prudent for CARB to invest in developing technical assistance resources for the existing facilities. One example of this is the newly launched *Cal Fleet Advisor*,[4] which is a free technical assistance program available to owners and operators of medium- and heavy-duty vehicles and aims to provide help in transitioning to zero-emission vehicles and fleets. A similar program incentive by CARB, administered by a third party would be ideal for commercial and industrial refrigeration facilities.

4. What barriers exist in bringing technologies such as ejectors, CO2 condensing units and others, to the California market, particularly for smaller refrigeration systems such as those found in convenience stores?

As a general rule, advanced efficiency technologies related to CO2 refrigeration; particularly parallel compression and ejectors are widely commercialized within the EU market with installations exceeding several thousand at this point and the technology is considered mature and commercially available. In addition, small low cost CO2 condensing units are also widely commercialized in the EU market with installations exceeding 10,000 and the system architecture is considered mature and commercially available. So the issue with these technologies is not the development or maturity of the technology, rather the availability and acceptance of the technology in the United States. The issue remains the full demonstration of these technologies in US applications to demonstrate their value. Moreover, and to be blunt, the other major issue despite increasing demand is the availability of these technologies from US equipment manufacturers. It is our opinion that incentive efforts that facilitate the deployment of pilot demonstration programs for these technologies are required.

[3] The OECD definition of PFAS can be found here: https://www.oecd.org/chemicalsafety/portal-perfluorinated-chemicals/aboutpfass/

[4] Cal Fleet Advisor is a technical assistance program administered by CALSTART on behalf of CARB, to help transition medium- and heavy-duty trucks and fleets to zero emission vehicles. It is funded by California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas emissions, strengthening the economy, and improving public health and the environment—particularly in disadvantaged communities. More information is available at: https://calfleetadvisor.org/

Section 2: Stationary Air Conditioning & Space Conditioning Heat Pumps

General comment: Following the adage, “you cannot manage what you do not measure”, êffecterra’s first recommendation is to amend CARB’s Refrigerant Management Program (RMP) regulation to include air-conditioning (AC) and heat pump (HP) systems. Even though the South Coast Air Quality Management District has an RMP-like rule for AC systems, we believe it is important to have statewide rule apply to the AC/HP systems (as is now being proposed by the state of Washington). Even as CARB pursues strategies to reduce emissions from the AC/HP systems, it is vital that the agency also collect data on those systems to track progress and emphasize the importance of refrigerant management to the users of commercial and industrial AC/HP systems.

5. There are limited ultra-low-GWP and/or no-GWP technologies for this sector. How can technological innovation be encouraged?

Response: For decades, the development of AC/HP technology in the U.S. has been guided by the federal energy performance standards set by the U.S. Department of Energy (DOE) and state standards for equipment not regulated by the DOE. As a result, the focus of the HVAC industry in the US has been to develop high energy-efficiency, low-cost AC/HP equipment. While those are commendable qualities, the issue of refrigerant emissions from those systems has been overlooked. Most AC/HP system architectures in use today are not conducive to switching from current refrigerants to ultra-low and no-GWP alternatives because of design limitations and building code challenges that are delaying the adoption of non-A1 refrigerants. êffecterra’s Synthesis Report on Natural Refrigerants for New York State (referenced earlier in this document) discusses the barriers to ultra-low or no-GWP technologies in the AC/HP sector in some detail. Broadly, we need policy mechanisms – both regulations and incentives – that address the barriers and, in some cases, a paradigm shift in system architectures that are more conducive to the use of sustainable alternatives like natural refrigerants.

6. What types of ultra-low GWP technologies for this sector are available in other markets globally, but not in the US? What do you see as the primary market barriers to the adoption of these technologies in the US?

Response: The following are excerpts from the NY Natural Refrigerant Assessment Report. The table below contains information on availability of ultra-low and no-GWP natural refrigerants for various AC/HP system types, followed by a discussion of the primary market barriers.

The following symbols are used in the table:
Y – Yes, commercially available in the US; I – Available internationally; N – Not available in the US or internationally

Equipment Type	R-744 (CO_2)	R-290 (Propane)	R-717 (Ammonia)
Commercial AC and Space-Conditioning Heat Pumps			
Chiller or Chiller-Heater System or Chiller Heat Pump	Y[e]	I	Y
Packaged Units	I[f]	N	N
Single-Split Systems	N	I[g]	N
Multi-Splits and Variable Refrigerant Flow Systems	N	N	N
Residential AC and Space-Conditioning Heat Pumps			
Ducted Central AC	N	N	N
Ductless Split Systems	N	I[h]	N
Window/Wall/Portable	N	I[i]	N
Emerging, Non-Space-Conditioning Heat Pumps			
Commercial Water Heaters	Y[j]	I[k]	Y
Residential Water Heaters	Y[l]	I[k, m]	N
Clothes Dryers	N	I[k, n]	N
Pool/Spa Heaters	N[o]	I[k, p]	N

[e] *OEM Examples: Flow Environmental Systems sells R-744 chillers for comfort cooling in the US (30 – 120 tons); Mayekawa and Carnot also each have R-744 offerings for comfort cooling.*
[f] *R-744 Package Unit OEM Examples: Clade, Unic Air*
[g] *R-290 split systems are manufactured in China and India (OEM Example: Midea); not yet available in the US for comfort cooling due to charge size limitations.*
[h] *R-290 Split System OEM Examples: Godrej, Midea*
[i] *R-290 Window/Wall AC Unit OEM Examples: LIFE ZEROGWP, KANION, Proklima*
[j] *R-744 Commercial Water Heater OEM Examples: Mayekawa, Mitsubishi/Trane, Lync, Intellihot*
[k] *R-290 is more commonly used outside of the US for these applications; availability in the US is limited due to charge size limitations. See discussion on safety standards in this section for more details.*
[l] *R-744 Residential Water Heater OEM Example: ECO2 Systems*
[m] *R-290 Residential Water Heater OEM Examples: PHNIX, GMO*
[n] *R-290 Clothes Dryer OEM Example: Siemens*
[o] *Larger-scale commercial CO_2 heat pump systems exist for swimming pools/gyms/etc., but we do not see any evidence of this being common or there being solutions dedicated to a single pool.*
[p] *R-290 Pool Heater OEM Example: PHNIX*

In addition to the space-conditioning heat pumps, information on availability of non-space-conditioning heat pumps is also included above. This is because remarkable innovation is currently underway where

combination or integrated heat pump systems are being developed that meet the needs for space conditioning as well as heating water and for thermal energy storage.

One of the main factors that slow down the progress in adopting climate-friendly alternatives to HFCs is the lengthy process of updating safety standards and integrating these into building codes. HFC alternatives like hydrocarbons possess thermodynamic qualities that make them excellent refrigerants and heat transfer fluids. But they also pose a safety risk owing to their flammability. However, over the past several decades, technological developments and robust safety standards have made it possible to leverage the benefits of these refrigerants while minimizing the risks. As discussed in the NY Report, the process to update the international and national safety standards (namely, the IEC, UL and ASHRAE standards) and obtaining EPA approval is a rigorous process – as it should be – that ensures the refrigerants can be deployed safely. However, subsequent adoption of the safety standards into state and local business codes often takes several years and leads to undue delays in the adoption of climate-friendly alternatives.

7. How can centralized ducted AC systems be transitioned to ultra-low GWP or no-GWP technologies?

Response: Common AC system architectures that are currently used in the US – for example central ducted residential AC and VRF systems – are not conducive to the use of climate-friendly natural refrigerant alternatives because none of them are "drop-in" retrofits for current high-GWP refrigerants like R-410A and possess flammability characteristics. To leap-frog to natural refrigerants as we electrify buildings and transition to heat pumps while minimizing safety risks, investments must be made in both alternative system designs (such as hydronic/secondary loop systems) as well as innovative retrofits, such as examining the reuse of existing refrigerant copper piping to be used as water piping that can be coupled with air-to-water heat pumps. [5]

As a first step, CARB should consider incentivizing the deployment of secondary loop heat pump systems that perform several heating and cooling functions and yield additional benefits, described in response to question 10 below. Even from a codes and standards standpoint, outdoor indirect systems will be able to utilize greater quantities of hydrocarbons much sooner than direct systems. The main reason the process is moving faster for these systems is that they minimize the risks related to the flammability of A3[6] refrigerants by using relatively smaller amounts of refrigerant and locating them outside the building, away from occupied spaces and dwellings.

For a full list of suggested pilot projects, please see the NY report referenced earlier in this document.

10. What are the benefits of and potential for expanding the use of integrated heat pump technology (units that provide space conditioning and water heating and/or other uses) in California?

[5] Veissmann, now owned by Carrier Corporation, has tested a retrofit application where the indoor refrigerant piping (with cleaning) can be repurposed to be used as a hydronic loop, demonstrating that indirect systems can be integrated into existing buildings and potentially use some of the existing system architecture.
[6] A3 is the safety group classification for refrigerants with higher flammability characteristics under ASHARE Standard 34.

Response: The NY report summarizes various benefits of integrated secondary loop heat pumps as given below:

The technical working group identified several key advantages of integrated/combination indirect heat pump systems, which are summarized below:

- Integrated/Combination indirect heat pump systems using natural refrigerants that perform multiple functions – such as space heating, cooling and domestic hot water – can be a great means to simultaneously reduce refrigerant impacts, replace multiple fossil-fuel based systems at once, minimize the number of electric appliances, and help potentially mitigate the urban heat island effect, as having fewer integrated units rejecting heat as well as having heating applications that are rejecting cool air in the mix would result in a net reduction in heat rejected to the local environment.
- For multifamily homes, the source of heat for integrated indirect heat pumps could be neighboring water bodies.
- Indirect systems use less refrigerant than corresponding direct expansion systems serving the same heating/cooling load, thus mitigating safety risks and direct refrigerant emissions, allowing us to leapfrog to natural refrigerants in indirect system architectures.
- Indirect systems allow for capture of waste heat which can be used when needed, for e.g., to meet simultaneous cooling and heating needs.
- Indirect systems are suitable for load shedding or demand responsiveness because the secondary loops act as “thermal energy loops” which can function even when power is shut off (for some time) and can aid load shedding by adding additional thermal storage.
- For parts of the country where radiant heating systems are still widely used (such as the Northeastern states), indirect systems are a relatively simpler retrofit solution since these can be added into existing buildings and connected with existing radiant heating systems. Thus, residential heat pumps using natural refrigerants could be incorporated into existing buildings and homes without the need for costly building retrofits or drilling.
- Some equipment manufacturers are exploring the idea of repurposing existing refrigerant piping used in centralized AC systems as water or hydronic loops, which if successful, would allow replacement of centralized AC systems with hydronic loop heat pumps.
- Use of integrated indirect heat pumps can help address workforce shortages while stimulating job growth in multiple labor sectors, for e.g., installation of indirect or hydronic loop systems requires plumbers to lay the secondary fluid loop, while the heat pump system is self-contained and relatively simpler to install and maintain, thus reducing the strain on the HVAC technician workforce.
- Often, indirect systems are assumed to be inefficient from an energy consumption standpoint. However, such comparisons must be done on a “like for like” basis. It is true that an indirect system is less efficient than a direct system using the *same* refrigerant because of the additional heat exchange with a secondary fluid. However, this blanket assumption is incorrect when comparing systems with different types of refrigerants. For example, due to their superior

thermodynamic properties as refrigerants, an indirect system using ammonia or propane can be more energy-efficient than a direct HFC system serving the same cooling load.

- Coupled with building decarbonization and electrification efforts, the use of natural refrigerants like hydrocarbons in heat pumps will help remove very large amounts of flammable fossil fuels that are continuously combusted and replace them with much smaller amounts of highly energy-efficient natural refrigerants which, if maintained well, will rarely or never need to be replenished.

Section 3: Non-Space Conditioning Heat Pumps (Water Heaters, Clothes Dryers, Pool and Spa Heaters)

13. There are limited ultra-low-GWP and/or no-GWP technologies for these equipment types. What can be done to spur technological innovation?

Response: Non-fossil-fuel-combustion technologies like heat pumps are a vital tool for building decarbonization that help reduce energy-related greenhouse gas emissions and improve air quality. However, we must remain cognizant that heat pumps currently use high-GWP HFCs or blends containing HFCs as heat transfer fluids, and we cannot ignore the potential for HFC emissions from these emerging sources. Unchecked proliferation of high-GWP heat pump technologies will offset the GHG emissions benefits expected from building decarbonization efforts. As CARB outlined in their 2022 Scoping Plan, addressing F-gas emissions from heat pumps is necessary to fully preserve the climate benefits derived from building decarbonization. Similarly, The New York State Scoping Plan also highlights the importance of reducing HFC emissions from heat pumps in tandem with building decarbonization efforts.

Under the 2022 Inflation Reduction Act, the federal government is heavily incentivizing heat pump technologies, including heat pump water heaters. We recommend CARB consider creating a “match” funding program where federal and state incentives can be stacked to provide the end-user more aid in leapfrogging to sustainable heat pump technologies. Here again, we recommend broader criteria for the incentives to address concerns about PFAS pollution, and not just using a GWP limit as the sole criterion.

Additionally, regulating the non-space conditioning heat pump sectors at the earliest — preferably placing stringent criteria for GWP and requiring non-PFAS alternatives — will be vital for adoption of sustainable, low-climate-impact heat pump technologies and pave the way for holistic building decarbonization.

Section 10: Overarching Questions

38. What factors around PFAS (per- and polyfluoroalkyl substances) should be considered as California transitions to ultra-low- and/or no-GWP alternatives?

Response: êffecterra strongly supports state and federal actions on environmental toxins like PFAS and appreciates CARB’s willingness to take feedback on this very important issue.

The first recommendation on this topic is made in the NY Assessment Report, which states that there is a need for consensus on the definition of the term 'PFAS'. Across the country, various states (including California) have enacted legislation that restricts the use of PFASs in a variety of end-uses. However, there is a lack of a uniform definition of the term that applies universally to chemical substances that meet the criteria regardless of their end-use. For scientific consistency and regulatory clarity, a clear and uniform definition should be adopted at federal and state levels.

êffecterra recommends the definition developed by the intergovernmental Organisation for Economic Co-operation and Development (OECD) published in 2021 which states, *"PFASs are defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e. with a few noted exceptions, any chemical with at least a perfluorinated methyl group (–CF3) or a perfluorinated methylene group (–CF2–) is a PFAS."* [7]

The 2021 OECD definition was developed with broad international scientific consensus including input from the U.S.EPA.[8] As stated in the OECD report, "It is key to have a coherent and consistent logic behind the PFAS definition to adequately reflect all compounds with the same structural traits, i.e., the PFAS universe." [9] The OECD definition has since been adopted by the European Chemicals Agency as part of their regulatory action on PFAS, namely the REACH Proposal, which also states that the 2021 OECD definition has been "scrutinized by the international scientific community and is widely accepted." [10]

Under the OECD definition, most HFOs and several HFCs would be classified as PFAS. While the fate of the EU's REACH regulation is yet to be determined, the environmental impacts of synthetic HFC alternatives remains unclear at best and potentially egregious to human and environmental health at worst. Given these concerns, CARB's policies aimed at transitioning away from HFCs must also aim to promote the most sustainable alternatives, especially when PFAS-free alternatives already exist.

êffecterra works with several global corporations that are keen to manage and reduce their climate footprints and be good stewards of the environment. However, a lack of legal clarity and consistency makes it very difficult for these companies to make prudent decisions relative to their investment in refrigerants and heat pump fluids. Navigating confusing and inconsistent laws, and subsequently regulations at the state and federal levels can potentially cost these companies millions of dollars. Using the established OECD definition, consistent with the international standard and US state laws already on the books, will make compliance and administration of the policies simpler for the regulated industries as well as the regulatory agencies.

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[7] Organisation for Economic Co-operation and Development, Environment Directorate Chemicals and Biotechnology Committee (9 July 2021). Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance. Available online at: https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf#:~:text=The%20rationale%20behind%20the%20revision,noted%20exceptions%2C%20any%20chemical%20with

[8] Ibid. See Acknowledgements in the document linked above.

[9] Ibid. See Executive Summary on Page 7.

[10] European Chemical Agency, Annex XV Restriction Report, Proposal for a Restriction on Per- and Polyfluoroalkyl substances (PFASs) (February 2023). Available online at: https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea

39. What types of ultra-low GWP and/or no-GWP pilot or demonstration projects from other regions or countries could be implemented in California? Please be specific as to types of equipment/applications.

Response: For a list of suggested pilot projects, please see êffecterra's NY Natural Refrigerants Assessment Report beginning on page 28. https://bit.ly/NaturalRefrigerantsAssessment23

40. Are there additional control measures for refrigerant management, such as requirements for maintenance, servicing, and leak detection/repair, that could support California's climate goals?

Response: Reiterating our general comments in Section 2 following the adage, "you cannot manage what you do not measure", êffecterra's recommendation is to amend CARB's Refrigerant Management Program (RMP) regulation to include all equipment applications regardless of charge size or sector including, air-conditioning (AC) and heat pump (HP) systems. Moreover, we'd recommend applying the same level of stringency for maintenance, servicing, leak detection/repair and reporting that is applied to, for example, large commercial refrigeration equipment containing high GWP refrigerants to all equipment/system types regardless of application, charge size, refrigerant type, and sector. The only true path to zero emissions is eliminating leaks from all equipment. This begins with better oversight and applying recognized best practices currently detailed in the RMP universally. Even as CARB pursues strategies to reduce emissions from, for example, AC/HP systems, it is vital that the agency also collect data on those systems to track progress and emphasize the importance of refrigerant management to the users of any commercial and industrial RACHP systems.

42. Do you have any other comments that would support the SB 1206 assessment report?

Response: Thank you again for the opportunity to provide input. In addition to the above, we would also like to emphasize the importance of collaboration between government, industry, academia, and the non-profit voices in developing and implementing a successful HFC transition strategy. Critical topics that should be explored collaboratively include the development and standardization of Product Category Rules (PCRs) and Environmental Product Declarations (EPDs) for both refrigerants and mechanical equipment, as well as Extended Producer Responsibility (EPR) requirements. These could further inform decision makers when procuring refrigerant containing equipment as well as encourage greater investment from equipment manufacturers toward life cycle refrigerant management.

Sincerely,

Co-Founders of êffecterra:

Tristam Coffin | Michael May | Chris Vallis