Enhancing Monitoring, Detection, & Mitigation of Unexplained or Illegal Sources of Emissions

- **Avipsa Mahapatra, Climate Campaign Director, EIA-US**: Overview on the Need to Enhance Monitoring and Verification of Emission Sources

- **Luke Western, University of Bristol**: Global Emissions of CFCs and Other ODS Due to Processes Not Controlled Under the Montreal Protocol

- **Christina Starr, Climate Campaign Senior Manager, EIA-US:** F-Gases at the Fenceline: Case Study on Infrared Detection of F-Gases from U.S. Production Facilities

- **Masoud Ghandehari, New York University:** Mapping Refrigerant Gases in the NYC Skyline

- **David Tratt, Aerospace Corporation:** Longwave-infrared Spectral Sensing of F-Gases: Implications for Enhanced Regulatory Monitoring

Followed by Q&A and Panel Discussion

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Need to Enhance Monitoring and Verification of Emission Sources

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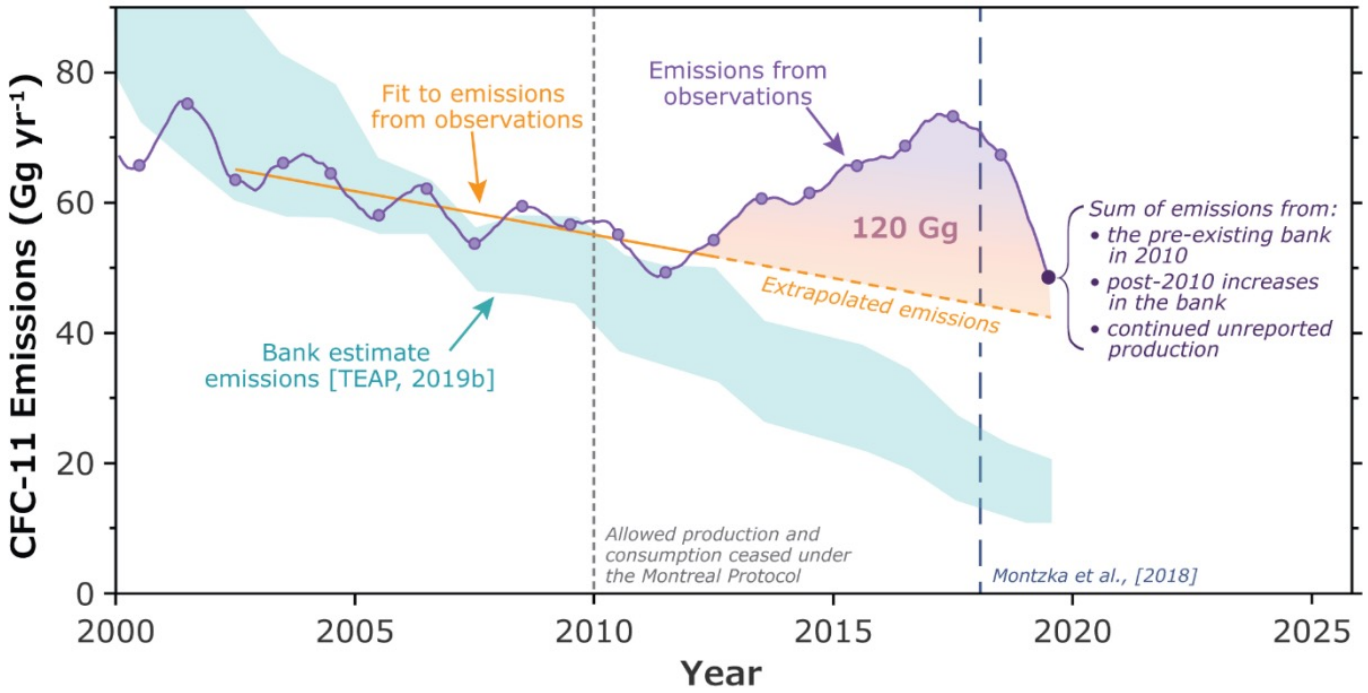
Lessons from Illegal CFC-11 Production and Use (2012-2018)

[EIA Investigative Report (2018)]



SAP Report on Unexpected Emission of CFC-11 (2021)

- **Illegal production and use went undetected for at least 6 years**
- **Emissions began to rise in 2012 (or earlier), but global community was only alerted in 2018**
- **Substantial banks of CFC-11 created**

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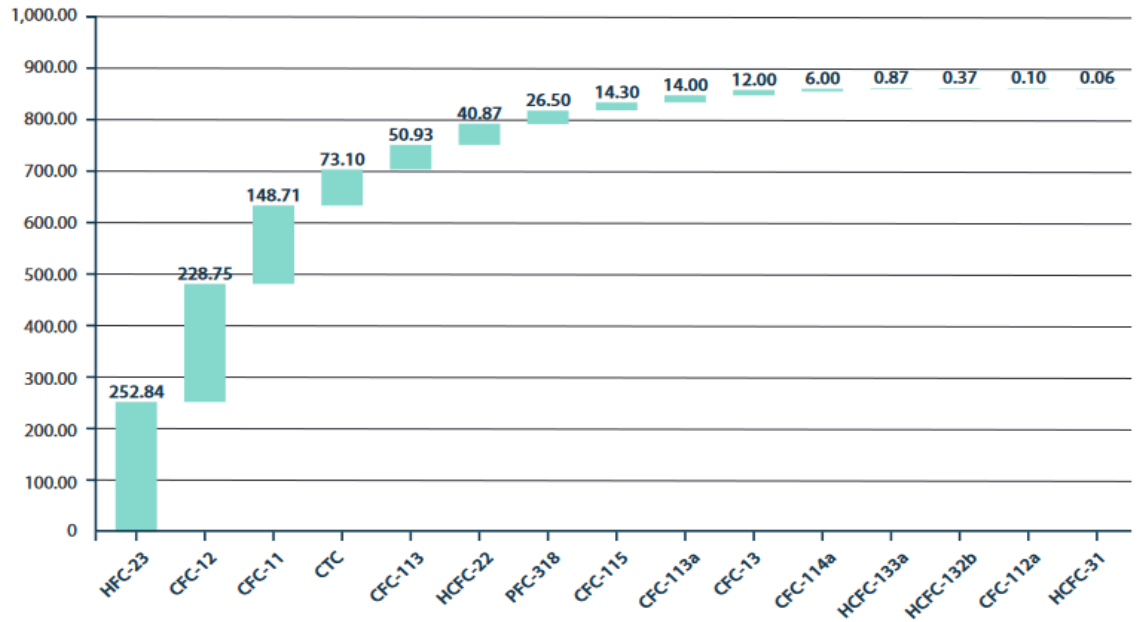
What's happening today?

Chemical	WMO 2022 GWP	Estimated Emissions (Gg/yr)	Estimated Emissions (Million Tonnes CO_2e/yr)	Year(s) Observed	Description of Emission Sources	Reference
HFC-23	14,700	17.20	252.84	2019	Top-down estimate of global emissions. By-product emissions from production of HCFC-22, as well as from pyrolysis of HCFC-22 to produce TFE and HFP. Potential by-product emissions from production of HFC-32, HFC-125 and other controlled substances. Also includes emissions from banks of niche refrigerant and fire suppression uses.	WMO (2022)[6]
CFC-12	12,500	18.30	228.75	2014-16	Top-down estimate of unexpected emissions excluding emissions from banks. Emissions are linked to illegal production and use or other unknown sources.	Lickley et al. (2021)[7]
CFC-11	6,410	23.20	148.71	2014-16	Top-down estimate of unexpected emissions excluding emissions from banks. Emissions are linked to illegal production and use or other unknown sources.	Lickley et al. (2021)[8]
CTC	2,150	34.00	73.10	2020	Top-down estimates of global CTC emissions are 44 ± 15 Gg/yr from 2016 and 2020. Once legacy emissions from landfills and contaminated soils (5-10Gg) are subtracted, total emissions from production and unexplained sources are 44 - 10 = 34Gg. Unexplained emissions are assumed to be from feedstock and chloromethane production or other unknown sources. CTC is a feedstock to various CFCs, HFCs, HFOs, and chloroform, which is used to make HCFC-22.	WMO (2022) (Update to Sherry et al. 2018)[9]
CFC-113	6,530	7.80	50.93	2014-16	Top-down estimate of unexpected emissions excluding emissions from banks. CFC-113 is a common feedstock used to make HFC-134a, TFA, pesticides and chlorotrifluoroethylene (CTFE) which is a precursor used to make fluoropolymers.	Lickley et al. (2021)[10]
HCFC-22	1,910	21.40	40.87	2019	Bottom-up estimate of emissions from feedstock production and use. Feedstock to TFE/HFP to produce PTFE and other fluoropolymers.	WMO (2022)[11]
PFC-318	10,600	2.50	26.50	2020	Top-down estimate. By-product of hexafluoro-propylene (HFP) production, which is used to make fluoropolymers including PTFE (aka Teflon).	WMO (2022)[12]
CFC-115	9,630	n/a	14.30	2020	Top-down estimate of global emissions. No significant banks from end uses. By-product of HFC-125 production.	Western et al. (2023)[13]
CFC-113a	3,930**	n/a	14.00	2020	Top-down estimate of global emissions. No significant banks from end uses. Feedstock/By-product in HFC-125, HFC-134a, HFO-1334mzz production; feedstock in production of TFA and pesticides.	Western et al. (2023)[14]
CFC-13	16,300**	n/a	12.00	2020	Top-down estimate of global emissions. Unknown sources. Potential use as a feedstock for CFC-11, however emissions have not declined in recent years with CFC-11 emissions.	Western et al. (2023)[15]
CFC-114a	7,410**	n/a	6.00	2020	Top-down estimate of global emissions. No significant banks from end uses. Feedstock/ intermediate in production of HFC-125 and HFC-134a.	Western et al. (2023)[16]
HCFC-133a	378	2.30	0.87	2016-19	Top-down estimate of global emissions. No known dispersive end-uses or banks. Feedstock to produce HCFC-123, CFC-113a.	Vollmer et al. (2021)[17]
HCFC-132b	332	1.10	0.37	2019	Top-down estimate of global emissions. No known dispersive end-uses or banks. Likely by-product of HFC production.	Vollmer et al. (2021)[18]
CFC-112a	3,550**	n/a	0.10	2020	Top-down estimate of global emissions. No significant banks from end uses. Unexplained, previous uses as a solvent and feedstock in fluorovinyl ether production.	Western et al. (2023)[19]
HCFC-31	85	.71	0.06	2016-19	Top-down estimate of global emissions. No known dispersive end-uses or banks. By-product of HFC production.	Vollmer et al. (2021)[20]
TOTAL			869.40			

Figure 1: Scientific Findings on Unexpected Emissions Linked to Production, Unknown Sources, and Illegal Production and Use*



Unexpected emissions of many gases, linked mainly to fluorochemical production or unexplained sources.

870 million tonnes CO2e annually = emissions of Germany!

What can we do to end these emissions?

- **Enhanced monitoring, reporting, & verification**
- **Control feedstocks and production sources**

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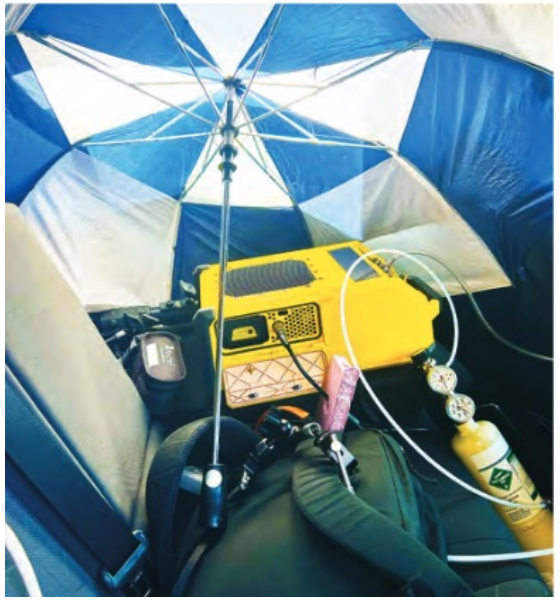
New EIA Findings

Map of U.S. Top F-Gas Emitting Production Facilities



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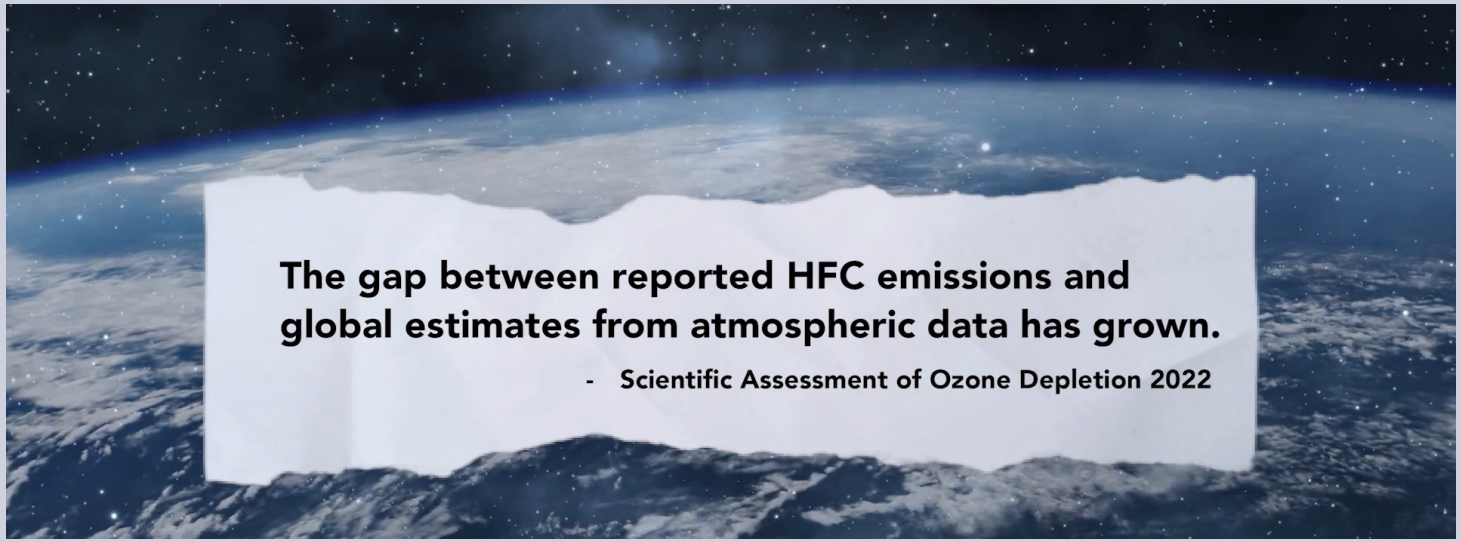
Where do we go from here?



Atmospheric monitoring of HFC emissions will be even more complex with so many blends

To pinpoint unexpected emission sources:

1. Enhanced global atmospheric monitoring:
    - Faster, more targeted approaches
2. Localized monitoring
3. Enhanced reporting
4. Tighter controls
5. Overall MRV+E

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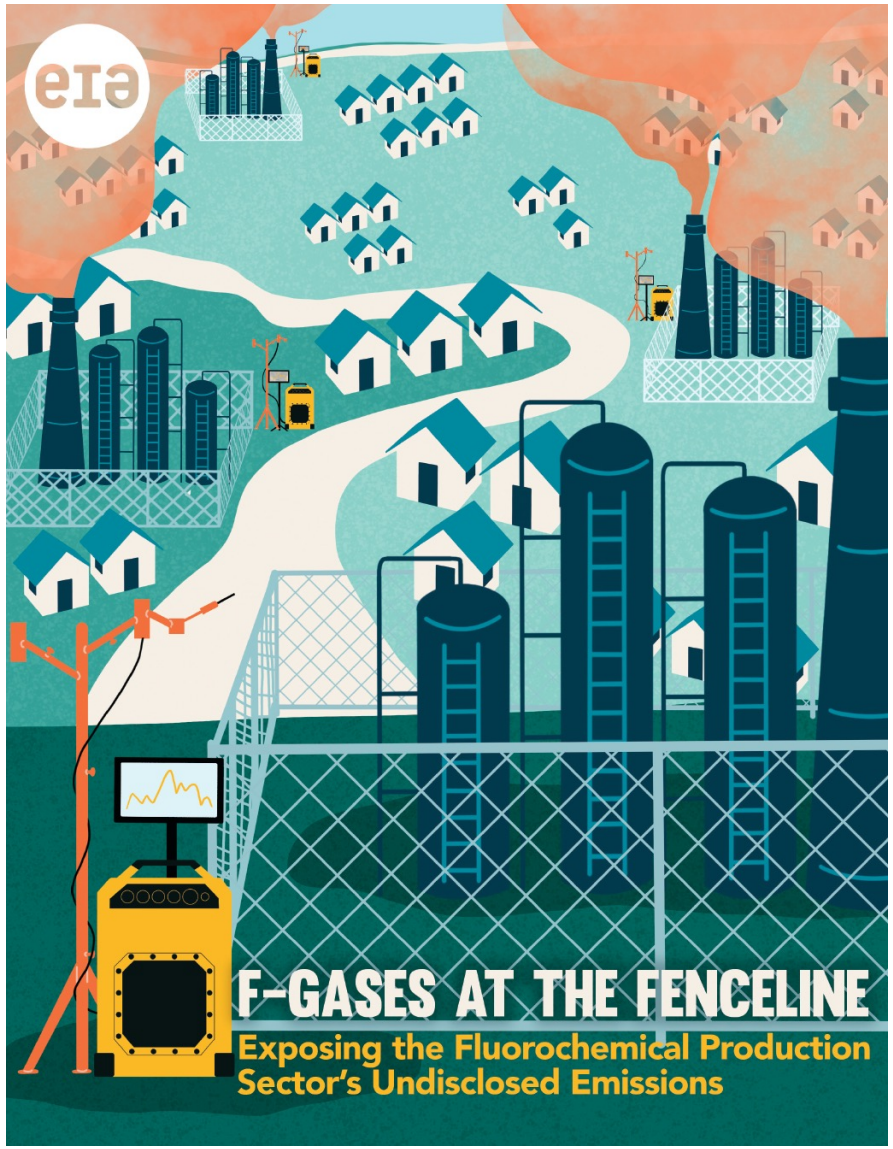
New EIA Report: Detecting F-Gases at the Fenceline



- EIA used sophisticated infrared spectroscopy equipment to collect and analyze air samples near U.S. fluorochemical production facilities in 2022 and 2023.

- Case study on fenceline detection of F-gases at two facilities:
  - Honeywell - Baton Rouge, Louisiana
  - Chemours – Corpus Christi, Texas

- Positive detection & identification of CFCs, HFCs, and HFOs at parts per million (ppm) concentrations.

- Several CFCs/HFCs from one facility had not been reported under recent years of mandatory EPA reporting.

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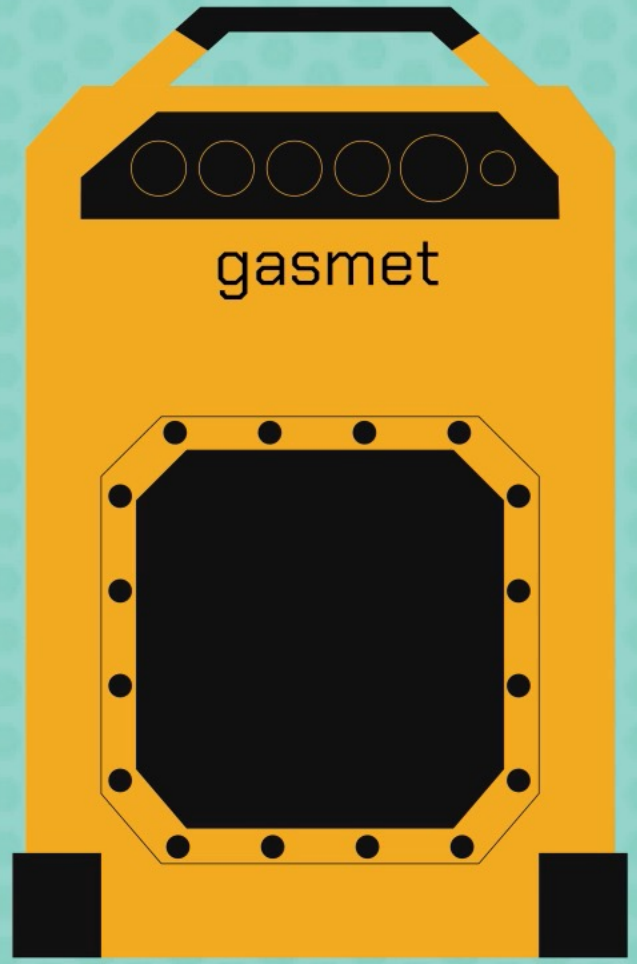
GASMET

Step 1: EIA used the Gasmet to collect air samples several hundred feet downwind of production facilities.

One sample is collected and analyzed by the Gasmet each minute for at least 30 minutes at a time.

best in-class emissions detection equipment



analyzes compostion of gases in the air

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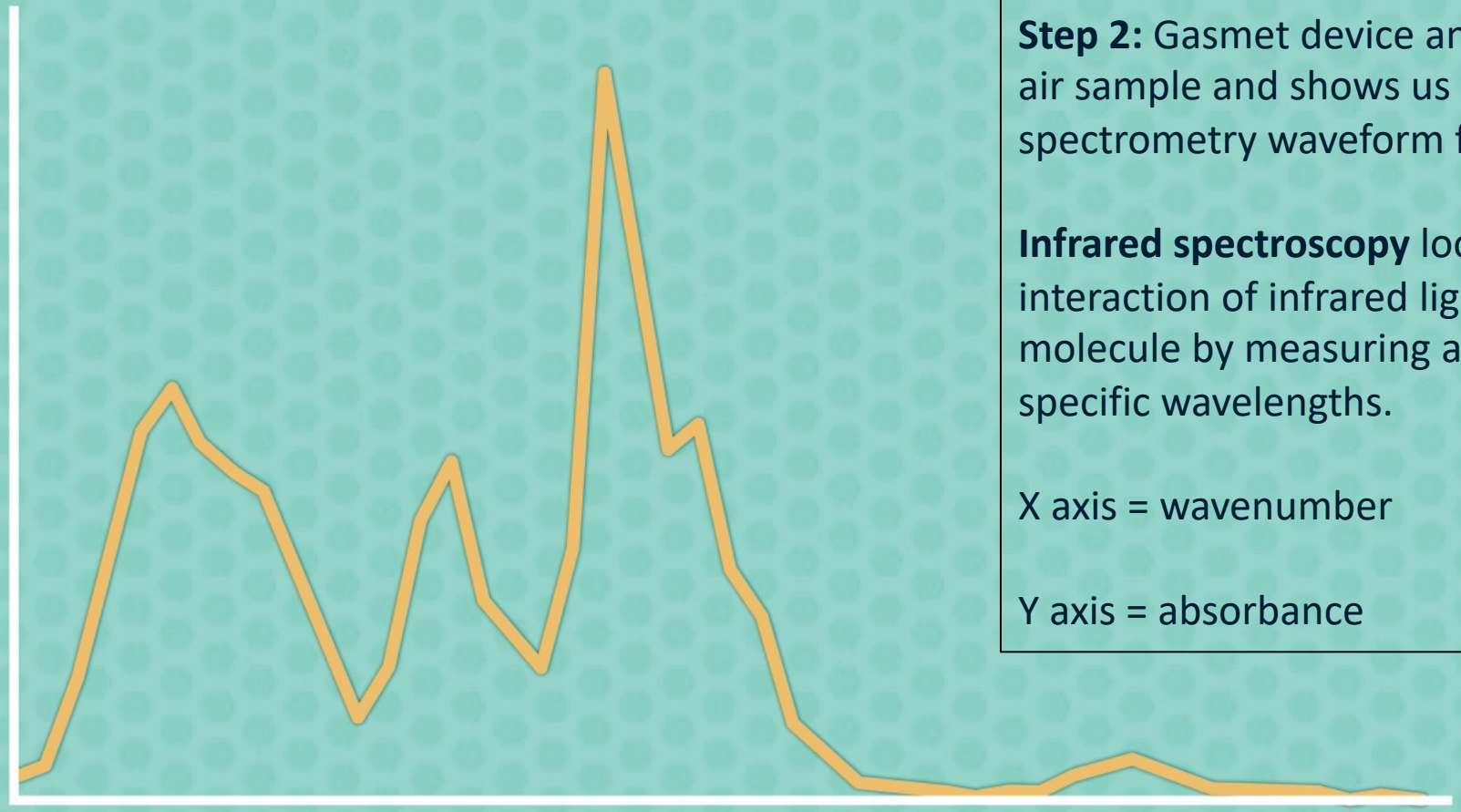
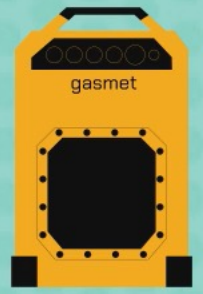


Step 2: Gasmet device analyzes each air sample and shows us the infrared spectrometry waveform for each one.

Infrared spectroscopy looks at the interaction of infrared light with a molecule by measuring absorption at specific wavelengths.

X axis = wavenumber

Y axis = absorbance



The resulting infrared spectrometry waveform of the air sample

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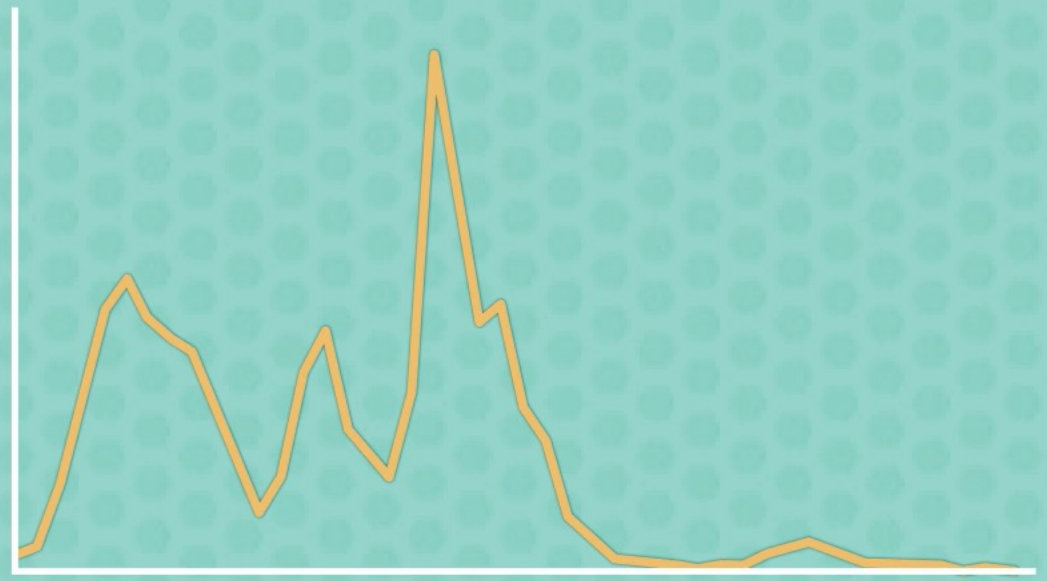
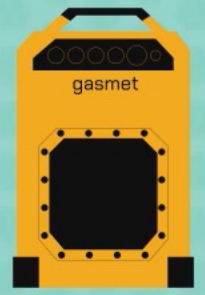
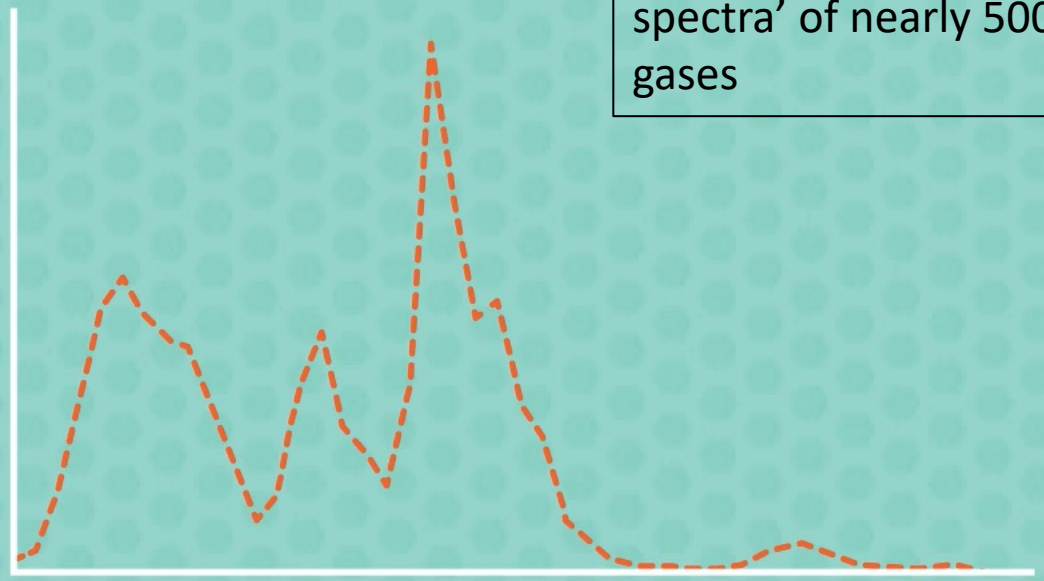
EIA sample vs reference

Step 3: EIA used sophisticated Gasmet software to compare the sample with a library of ‘reference spectra’ of nearly 500 gases







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This is like matching fingerprints

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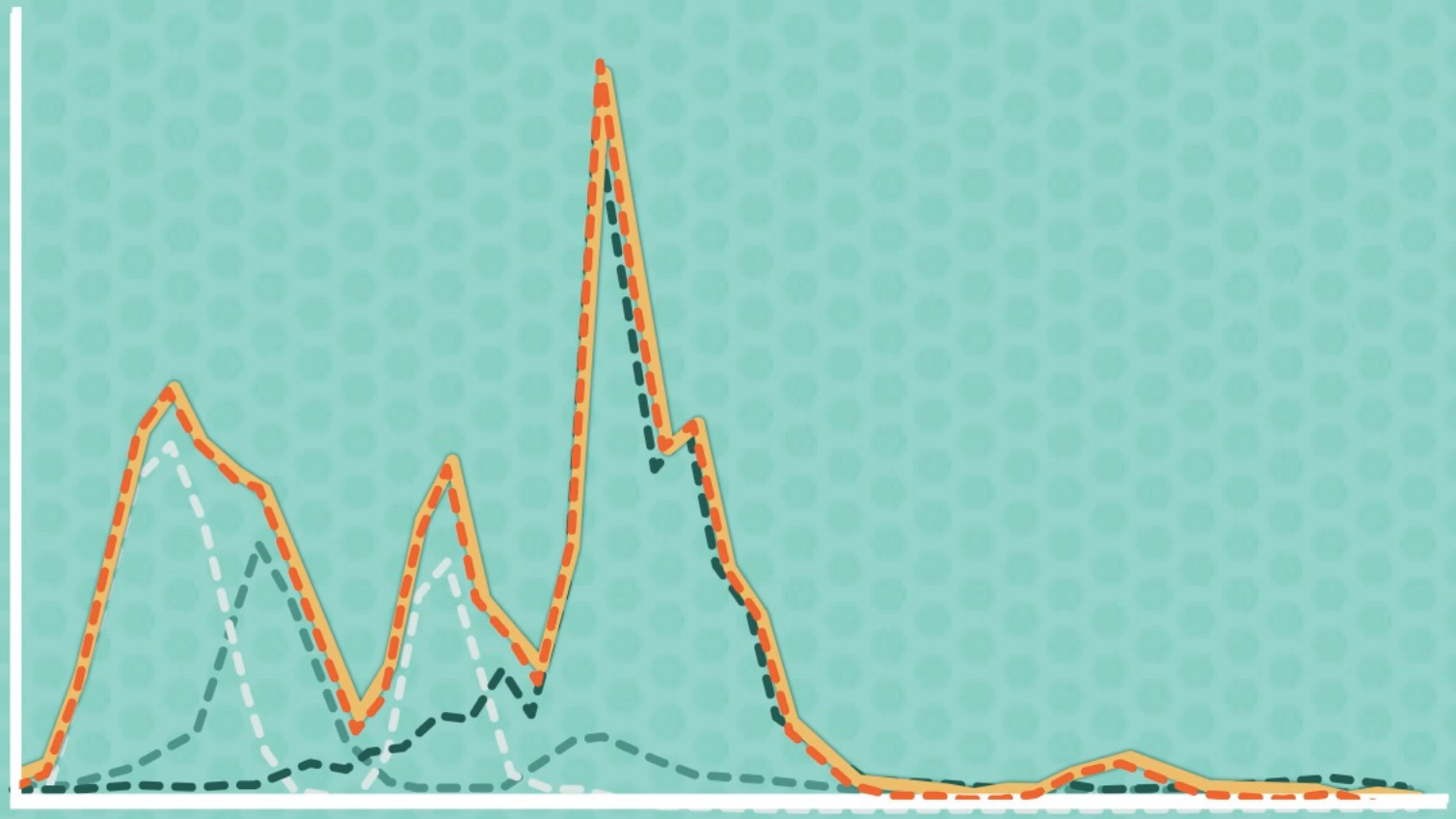
Analysis of this EIA sample confirms emissions of

Step 4: Reference spectra of individual gases add up to match the sample (yellow line), confirming the gases detected



HFC-32

HFC-134a

HFC-125

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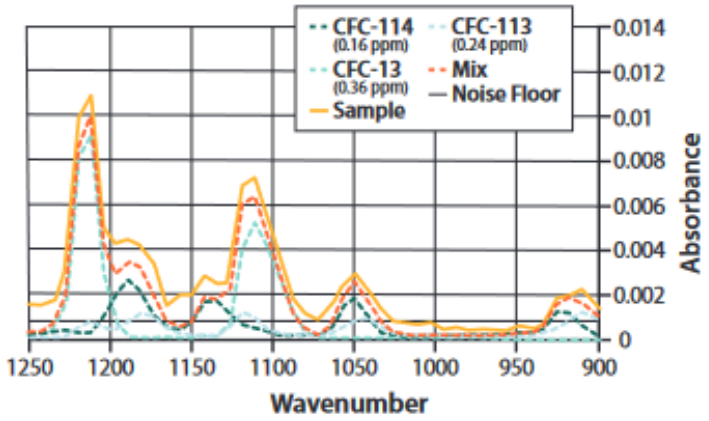
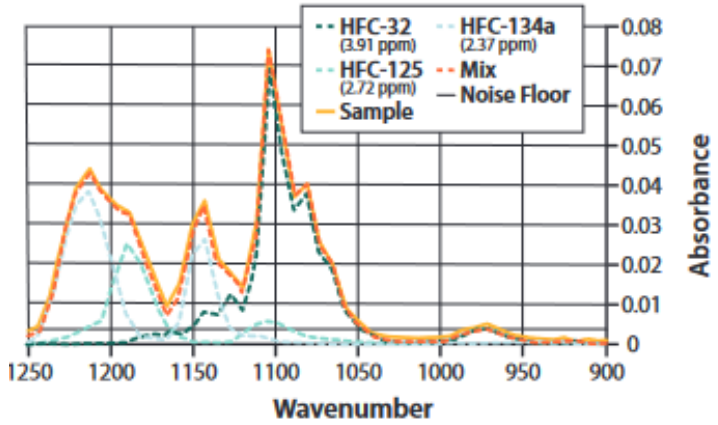
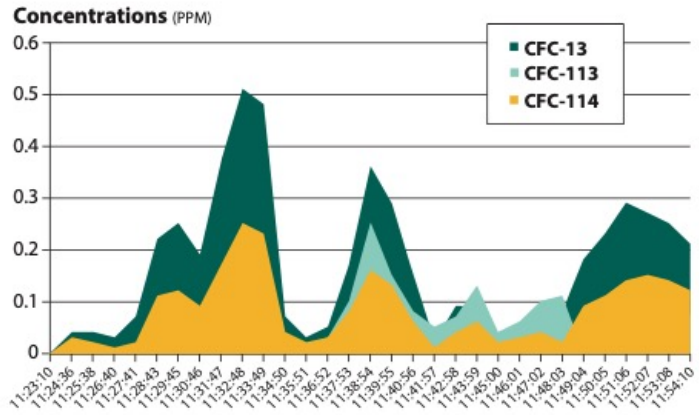
The individual gases, or “reference” lines, add up to the mix line, which can then be matched to the sample line, or what was detected in the field:

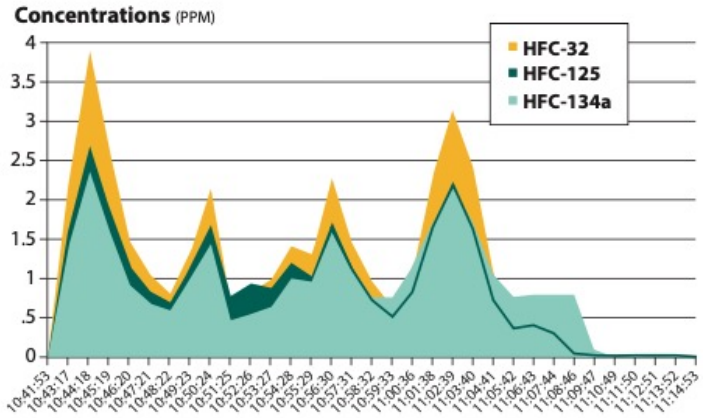




The Gasmet analysis software also tells us the concentration of the gases in the samples over our measurement time.



b. Time Series of CFCs at Honeywell, Baton Rouge



a. Time Series of HFCs at Honeywell, Baton Rouge

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Overview of Gases Detected & Emissions Reporting

Gas Detected	Peak Concentration (ppm)	Lowest Detection Limit (LDL) (ppm)[83]	Location / Facility	Emissions Reported under GHGRP and TRI (2018-2022)*
CFCs				
CFC-113	0.24	0.1547	Honeywell, Baton Rouge	Yes, reported emissions show recent increase
CFC-114	0.16	0.0427	Honeywell, Baton Rouge	Yes, reported emissions show recent increase
CFC-13	0.36	0.0308	Honeywell, Baton Rouge	2018 only, not reported for 2019-2021
HFCs				
HFC-32	3.91	0.0447	Honeywell, Baton Rouge	No
HFC-125	2.72	0.0569	Honeywell, Baton Rouge	No, and not reported for 2022, the year of detection
HFC-134a	2.37	0.0758	Honeywell, Baton Rouge	No
HFC-143a	2.57	0.0316	Honeywell, Baton Rouge	Yes until 2018, not reported for 2019-2021 or 2022, the year of detection
HFC-245fa	0.82	0.0534	Honeywell, Baton Rouge	Yes, 2021-2022 only
HFOs				
HFO-1234yf	1.01	0.0347	Chemours, Corpus Christi	N/A, reporting not required
HFO-1234ze	2.03	0.0175	Honeywell, Baton Rouge	N/A, reporting not required
HFO-1233zd	1.46	0.0614	Honeywell, Baton Rouge	N/A, reporting not required

1. The CFCs detected are rising in the atmosphere, and so are their reported emissions. CFCs are not produced at these facilities.

2. Some gases were not reported in recent years under mandatory programs

3. Detecting emissions up to 3.9 ppms hundreds of feet from the facility means these emissions are likely significant.

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Summary Findings

- Some CFCs detected are linked to recent atmospheric findings on rising global emissions.
- CFCs (ODS, high GWPs) detected at a Honeywell facility in Baton Rouge, Louisiana - banned globally, except to produce other fluorochemicals.
- HFCs (high GWPs) detected at Honeywell - some not reported by the facility in mandatory greenhouse gas reporting.
- HFO-1234yf detected at Chemours facility near Corpus Christi, Texas. HCFO-1233zd and HFO-1234ze were detected at Honeywell; in each case these are end products: not covered by emissions reporting requirements.
- Detection at parts per million concentrations several hundred feet from facilities points to likely significant emissions.

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EIA's Recommendations

- **Scale up investment in atmospheric monitoring**, **particularly consider rapid and targeted emissions detection** and other localized monitoring of concentrated sources F-gases;
- **Reexamine the exemption of feedstock uses** under the Montreal Protocol and consider additional compliance mechanisms to eliminate unnecessary feedstock production and use;
- **Enhance and modernize the MRV&E** framework under the Protocol;
- **Strengthen and expand existing national** and sub-national **emissions monitoring and reporting** mandates, including requiring continuous monitoring and mitigation of all by-product emissions
- **Adopt tighter controls on production emissions**, with mandatory third party verification of implementation and use of mitigation systems;
- **Seek to eliminate all non-essential uses of fluorinated substances** and transition to non-fluorinated (PFAS-free) and ultra-low GWP alternatives for each sector of significant use and emissions, including refrigerants.

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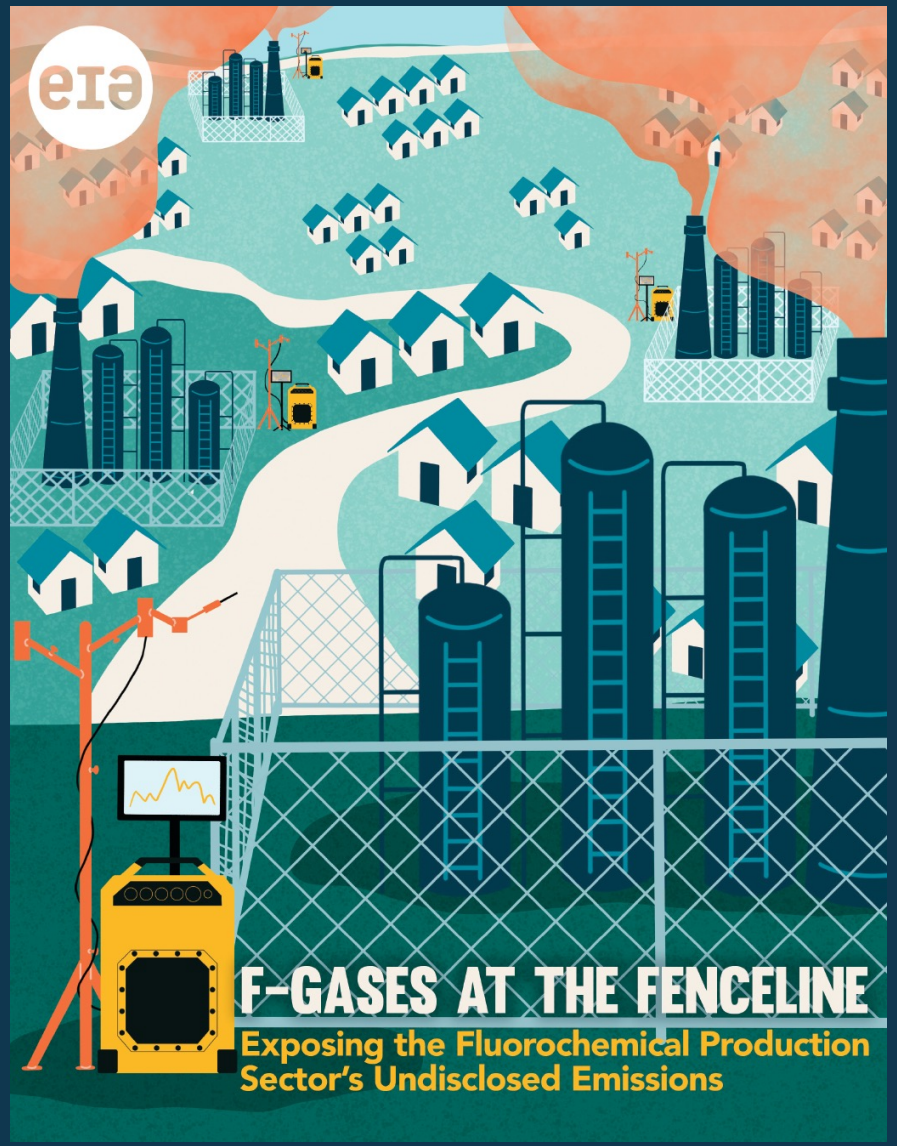

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