EP-DT
Detector Technologies

Towards environmentally friendly gases: a difficult path

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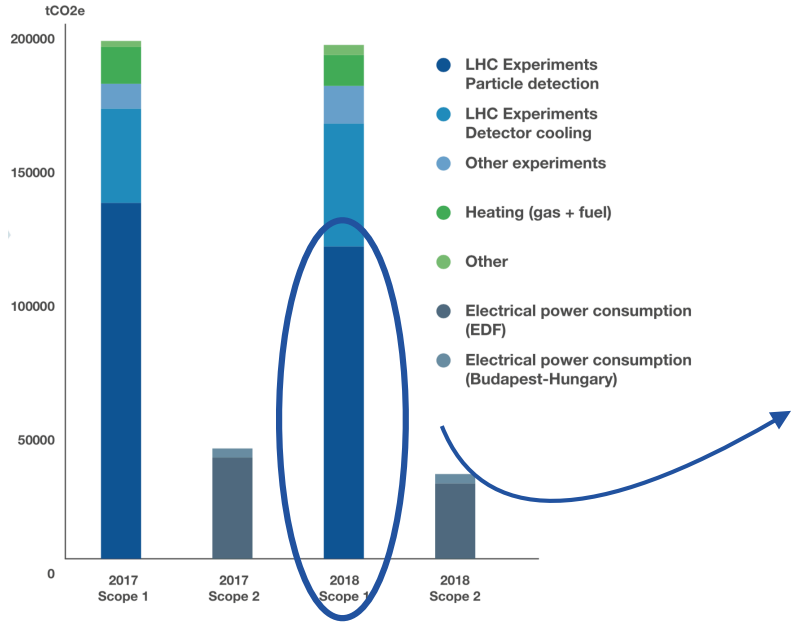
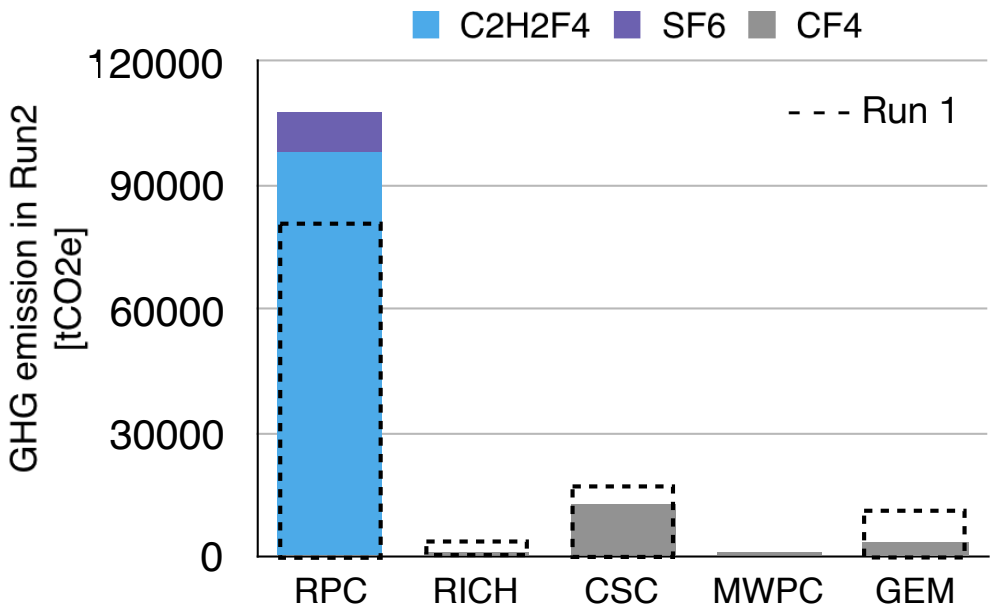
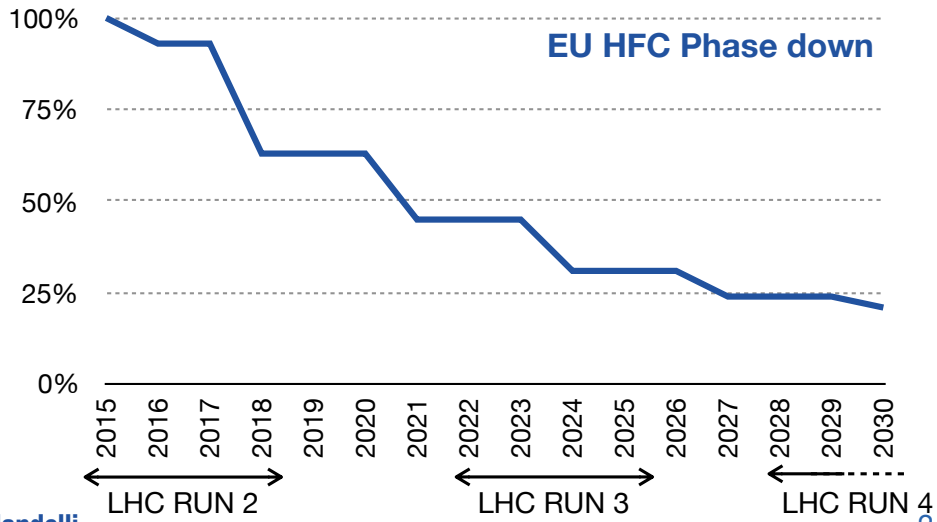
CERN GHG emissions and strategies to reduce

GHGs are used in CERN experiments
due to their properties necessary for good detector operation



https://e-publishing.cern.ch/index.php/CERN_Environment_Report/index



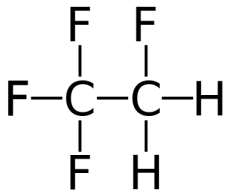


CERN Strategies to reduce GHG emissions in particle detection

- Optimisation of current technologies
- Gas Recuperation
- **Alternative gases**

Possible alternatives to $C_2H_2F_4$ and SF_6

New eco-friendly liquids/gases have been developed for industry as refrigerants and HV insulating medium… not straightforward for detector operation



R134a

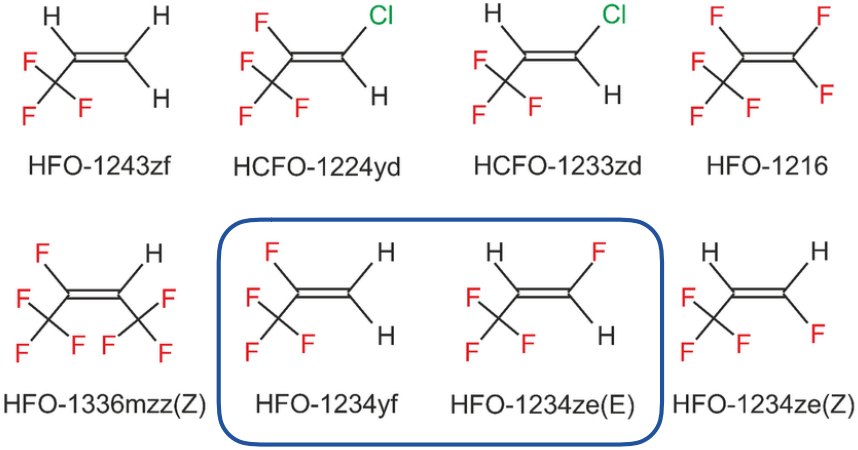
($C_2H_2F_4$)

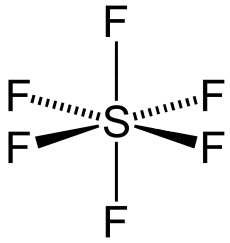
GWP 1430

Hydro-Fluoro-Olefin (HFO)

- C=C double bond
- fluorine-containing
- hydrogen-containing

GWP <10





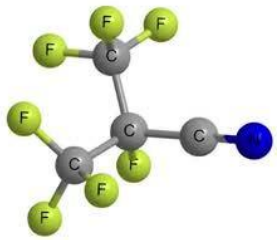
SF_6

GWP 23900

3M™ Novec™ 5110

($CF_3C(O)CF(CF_3)_2$)

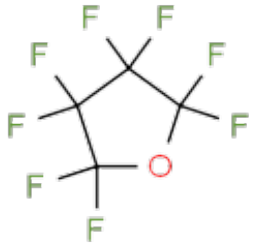
GWP <1



3M™ Novec™ 4710

($(CF_3)_2CFCN$)

GWP 2100



C_4F_8O

GWP 8700

CF_3I

GWP <1

The goal is to find a <u>eco-friendly gas mixtures</u> that are compatible with the <u>current LHC detector systems</u> (i.e. no change in HV cables, FEB electronics, etc.)

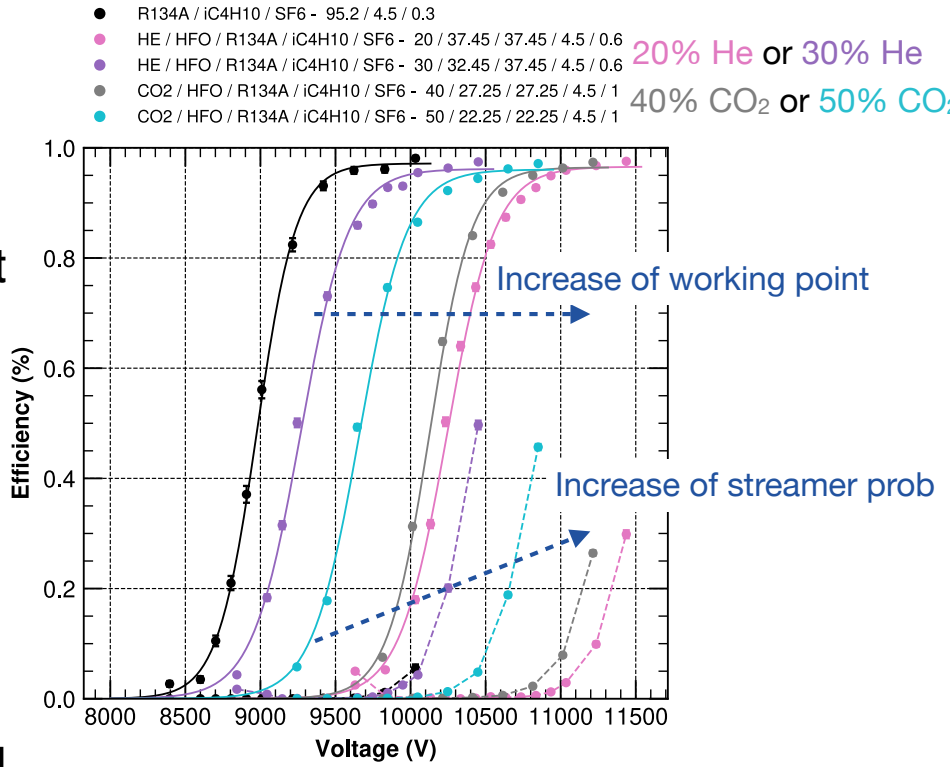
Characterisation in laboratory

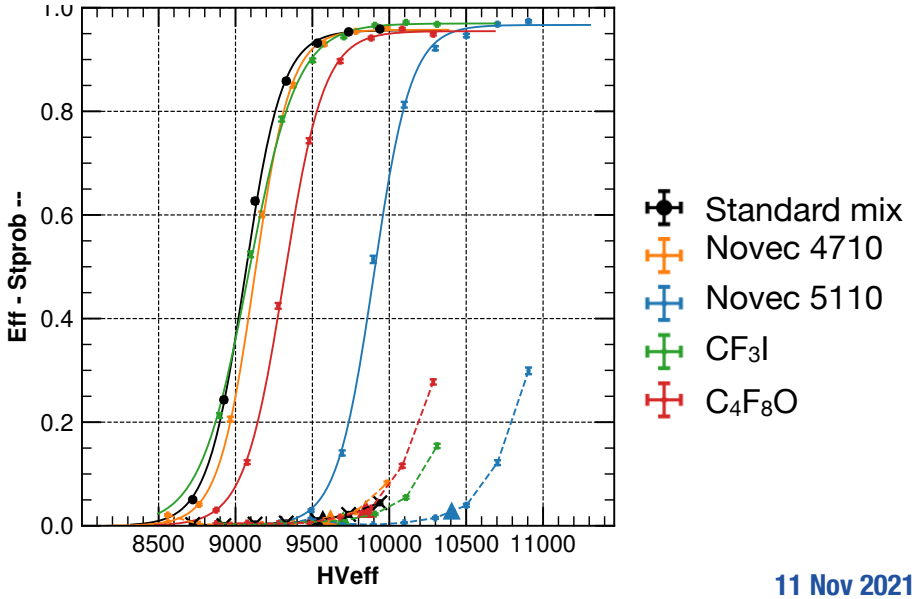
HFO as substitute of $C_2H_2F_4$

- HFO cannot directly replace $C_2H_2F_4$
  - very high applied voltage
  - more streamers
- Addition of He or CO_2 to lower the working point
  - between 20% and 50% but increase of streamers
  - need to increase SF_6 concentration
- Use both HFO and $C_2H_2F_4$ in same mix
  - HFO reduces the GWP
  - $C_2H_2F_4$ reduces the signal charge
- More than 50 eco-friendly gas mixtures tested

Substitutes of SF_6

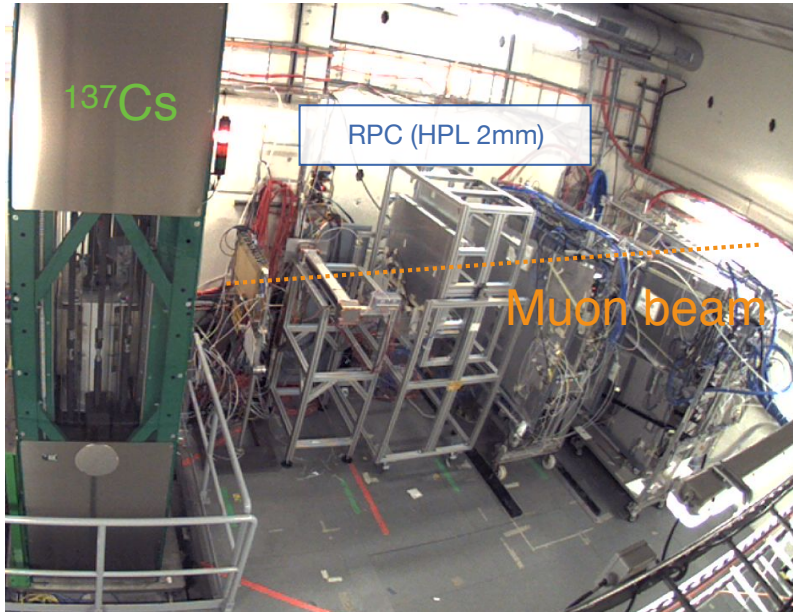
- Novec alternatives to SF_6 for arc quenching and insulation applications
  - Dielectric breakdown strength ~1.4-2 times > SF_6
- Novec 5110
  - Discrete performance but… it breaks with UV light
- Novec 4710
  - Very good performance but… it reacts with H_2O
- CF_3I
  - Very good performance but… toxic and mutagenic
- C_4F_8O
  - Good performance but…not low GWP

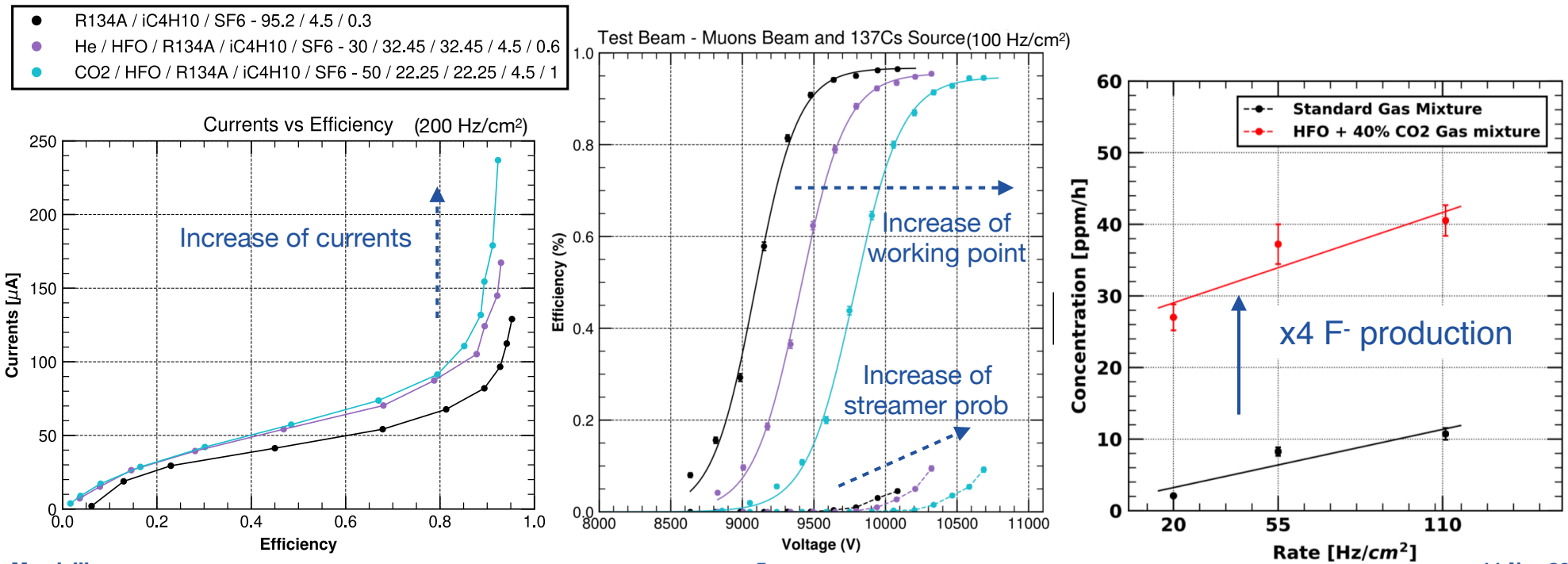




Measurements at GIF++

- Long-term studies (aging-test)
  - Fundamental for the validation of new eco-friendly gas mixtures. Accumulation of high integrated charge
- Studies on detector performance
  - In presence of LHC and HL-LHC like background radiation and muon beam
- Studies on creation of impurities
  - HFO breaks easier than $C_2H_2F_4$ during detector operation
- Studies under gas recirculation





Conclusions

Different strategies to reduce GHG emissions

- Main contributor to GHG emissions from particle detector are RPCs (but only due to leaks)
- Gas recirculation systems are the best way to reduce GHG consumption
- For future, we have to start to look for alternatives eco-friendly gas mixtures

Alternatives to $C_2H_2F_4$

- A lot of work especially in RPC community to search for alternative to $C_2H_2F_4$
- Several gases/liquids available in industry but not straightforward for detector operation
- HFO under study, need to add He/CO_2 but higher streamer probability
- Long-term performance studies on HFO based gas mixtures started

Alternatives to SF_6

- Some alternatives available for HV insulation plants
- Good results but some chemical reactions need to be investigated

Back-up slides

Why it is so difficult to find good GHG alternatives

When looking for alternatives eco-friendly gases, several factors have to be taken into account

Safety

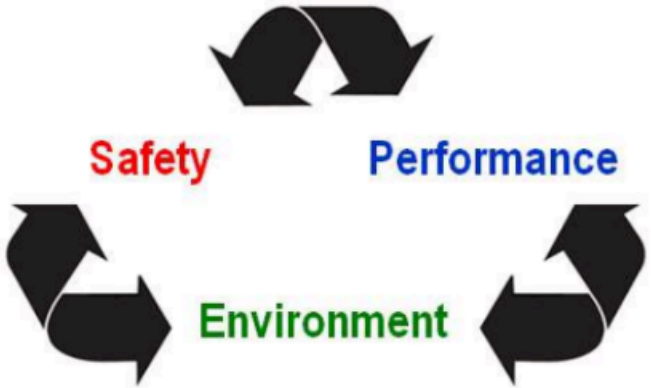
Safety first for detector operations

- Gas mixture not flammable
- Gas components cannot have high toxicity levels

Performance

RPC short and long term performance are affected

- Good quenching gases required
- Radiation-hard gas required
- Gases cannot heavily react with H_2O or UV radiation



Tradeoff between flammability and GWP

- Replacing F with Cl or H: it shortens atmospheric lifetime BUT increase flammability limit
- Adding C=C bound: it increases reaction with O_2

GWP is related to IR absorption over time. Low GWP gases have short atmospheric lifetimes

- Water solubility —> rain out
- OH reactivity —> oxidation
- UV absorbance —> photolysis

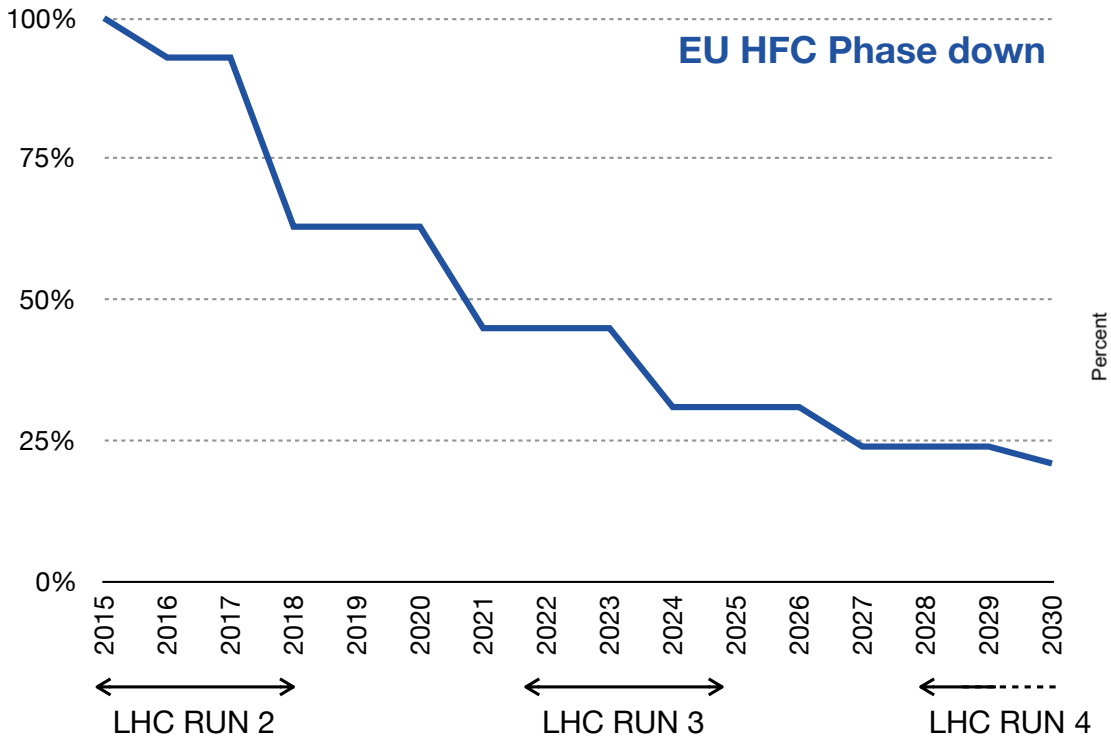
Environment

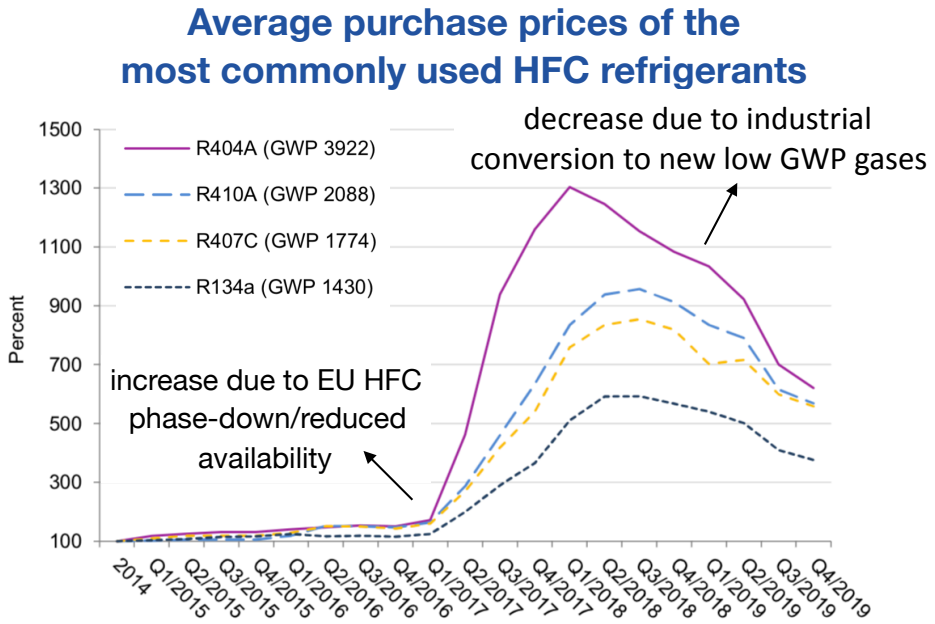
GWP represents the main environment concern

EU HFC phase-down policy

European Union "F-gas regulation":

- **Limiting the total amount** of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030.
- **Banning the use** of F-gases in many new types of equipment where less harmful alternatives are widely available.
- **Preventing emissions** of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.





European Environment Agency, Fluorinated greenhouse gases 2019 report
Öko Recherche report, March 2020 J. Kleinschmidt et al.

Prices could increase in EU and availability in the future is not known.
Reduction of the use of F-gases is fundamental for future particle detector applications