HFC scenarios and climate impacts from the Kigali amendment

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Take home message

Kigali (Rwanda), October 2016
- HFCs included in the Montreal Protocol
- Global phasedown of the use of HFCs

Without the Kigali amendment
- HFC emissions could have reached 4.0-5.3 GtCO$_2$-eq/yr by 2050,
- 9-29% of increase in annual CO$_2$ emissions from 2015 to 2050

Kigali amendment reduces surface temperature warming of HFCs from 0.3-0.5 °C to 0.06 °C in 2100
HFC scenarios

Motivation: need for consistent and robust data
- Communicate results in support of decision making process

Starting point:
- Large growth rates in observed concentrations of most HFCs
- Growth in HCFC consumption (demand)
- HCFC phase-out under Montreal Protocol
- National regulation: EU, USA, Japan, etc.
- Montreal Protocol amendment discussions

Products
Scenarios for 1990 to 2050 (and 2100)
- Business-as-usual scenarios
- Effects of national regulations
- Effects of amendment (and proposals)
- \( \text{CO}_2 \)-eq consumption and emissions, radiative forcing, surface temp.

Montzka et al. (2015)
Details of the scenarios

Historical consumption developed countries
- UNFCCC/CRF: Emissions and stocks per country, sector, HFCs, year
  ➔ consumption data and emission factors

Historical consumption developing countries
- E.g., published consumption data for China

Historical HCFC consumption from UNEP

Use shared Socioeconomic Pathways (SSPs)
- Developed countries: HFC demand grows with population
- Developing countries: HFC demand grows with Gross Domestic Product (GDP)

Assume saturation of consumption
- Per capita use in developing countries assumed to not exceed per capita use in USA

Consumption constrained by observed mixing ratios
Building blocks of the HFC scenarios

1990 - 2012
Developed country HFC consumption UNFCCC/CRF
Developing country HFC consumption China, MAC (all)
Developing country HCFC consumption UNEP

Adjusted
Global emissions match emissions inferred from observations

1990 - 2050
Growth proportional to population
Growth proportional to GDP
HCFC Phaseout \(\rightarrow\) HFC + NIK

BAU Scenarios
HFC consumption
Limited to maximum per capita use in developed countries

National regulations: EU, USA, Japan
Montreal Protocol HFC proposals

Model
Banks, Emissions, Mixing ratios, Radiative forcing
For 11 regions, 13 sectors, 10 HFCs
Emissions inferred from observations

Robust information
- Emissions inferred from observed global mean mixing ratios

Bottom-up emission
- Calculated from consumption data and emission factors
- More than 50% from reported UNFCCC data in developed countries
- Confirm significant contributions from developing countries in recent years

Consumption adjusted
- In scenarios the gap is closed by adjusting the consumption
Main contributions from HCFC replacements

- Projections of HFCs emissions in 2050:
  - ~18% from historical HFCs in developed countries
  - ~17% from historical HFCs in developing countries
  - ~65% from replacements of HCFCs in developing countries

Saturation limits emissions past 2025

- Consumption per capita in developing countries limited
- Limits reduce A5 emissions from 4.2-7.9 GtCO₂-eq/yr to 3.2-4.4 GtCO₂-eq/yr in 2050
- Non-A5 emissions are 0.8-1.0 GtCO₂-eq/yr in 2050
- Total emissions 4.0-5.3 GtCO₂-eq/yr in 2050

(CO₂ = 36 GtCO₂-eq/yr in 2013)
Comparison with other scenarios

**Velders et al. (2009)**
- Differences in growth rates IPCC/SRES and SSPs
- Now specific data for 32 regions
- Region specific data yield earlier saturation in consumption for regions

**RCP (2011)/IPCC scenarios**
- Business-as-usual and strong mitigation
- Based on older information

**HFC baseline vs CO₂ RCP6-RCP8.5 scenarios**
- 5-11% of annual CO₂ emissions in 2050
- 9-29% of increase in annual CO₂ emissions from 2015-2050
- 6-9% of CO₂ RF in 2050
- 12-24% of increase in CO₂ RF from 2015-2050
Major 2050 emissions from developing countries

- Historical emissions mainly from USA and EU
- China is projected to be largest emitter in 2020
- Major regions in 2050
  - China (31%)
  - India and other Asian countries (23%)
  - USA (10%), Middle East - N. Africa (11%)
Emissions per region and sector

**CO₂-eq emissions**
- Main non-A5 regions: USA, EU
- Main A5 regions: China, other Asian countries
- Main sectors:
  - ICR: Industrial and commercial refrigeration
  - SAC: Stationary AC
  - MAC: Mobile AC (only for non-A5)

[Diagram showing emissions over time for EU, USA, and China, with notes on vertical scales.]
National/regional regulations

Regulations in force or proposed
- **EU:** Revised F-gas regulation (2014) + MAC directive (2006)
- **USA:** Changes to SNAP list (2015)
- **Japan:** F-gas controls (2015)
- Also in Canada, Australia, etc.

National regulation will drive global technological changes
- Estimate effects of applying national regulations on emissions in developed and developing countries

![Graph showing emissions and radiative forcing over time with different regulations applied.](image-url)
Proposals to MP met in part by regulations

Global effects of technologies

- Proposals by North America, India, EU, Pacific Island States
- Reduce 2050 emissions by 50-90%

Effects on reductions in cumulative consumption (2015-2050) relative to North American proposal →

Reductions meet North American proposal by about 50% for most countries by 2050

- Differences between countries due to differences in HFC use in sectors and regulations

Reductions in cumulative HFC consumption

<table>
<thead>
<tr>
<th>Region</th>
<th>Relative to North America Proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>80%</td>
</tr>
<tr>
<td>USA</td>
<td>70%</td>
</tr>
<tr>
<td>Japan</td>
<td>60%</td>
</tr>
<tr>
<td>Other OECD</td>
<td>50%</td>
</tr>
<tr>
<td>Russia etc.</td>
<td>40%</td>
</tr>
<tr>
<td>China</td>
<td>30%</td>
</tr>
<tr>
<td>India</td>
<td>20%</td>
</tr>
<tr>
<td>Other Asian</td>
<td>10%</td>
</tr>
<tr>
<td>Africa</td>
<td>5%</td>
</tr>
<tr>
<td>Latin America</td>
<td>0%</td>
</tr>
<tr>
<td>M-East N-Afr.</td>
<td>0%</td>
</tr>
<tr>
<td>Global total</td>
<td>0%</td>
</tr>
</tbody>
</table>

Guus Velders
Agreed baselines and phasedown schedules

<table>
<thead>
<tr>
<th></th>
<th>A5 (China etc)</th>
<th>A5 (India, Saudi Arabia, etc)</th>
<th>A2 (USA, EU, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2020-2022</td>
<td>2024-2026</td>
<td>2011-2013</td>
</tr>
<tr>
<td>Formula</td>
<td>Average HFC consumption</td>
<td>Average HFC consumption</td>
<td>Average HFC consumption</td>
</tr>
<tr>
<td>HCFC</td>
<td>65% baseline</td>
<td>65% baseline</td>
<td>15% baseline*</td>
</tr>
<tr>
<td>Freeze</td>
<td>2024</td>
<td>2028</td>
<td>-</td>
</tr>
<tr>
<td>1st step</td>
<td>2029 – 10%</td>
<td>2032 – 10%</td>
<td>2019 – 10%</td>
</tr>
<tr>
<td>2nd step</td>
<td>2035 – 30%</td>
<td>2037 – 20%</td>
<td>2024 – 40%</td>
</tr>
<tr>
<td>3rd step</td>
<td>2040 – 50%</td>
<td>2042 – 30%</td>
<td>2029 – 70%</td>
</tr>
<tr>
<td>4th step</td>
<td>2045 – 80%</td>
<td></td>
<td>2034 – 80%</td>
</tr>
<tr>
<td>Plateau</td>
<td>2047 – 85%</td>
<td></td>
<td>2036 – 85%</td>
</tr>
</tbody>
</table>

* For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan: small difference
Surface temperature projections

Climate effects calculated

- MAGICC6 model

**BAU: range from 0.3 – 0.5 °C in 2100**

**Kigali amendment: reduced to about 0.06 °C**
Information/Research needs related to HFCs

National inventories for all countries
● Production and consumption data per country
● Historical data: 1995-on

Sectoral and species specific information
● Link with UNFCCC data for information per species and sector
● Are there new or missing sectors?
● New (not covered) HFCs: e.g. HFC-161, ...
● Information on alternatives uses: HFOs, ...

Global and regional observations of HFCs and HFOs
● Top-down vs bottom-up emission inventories

Goal: Monitor the HFC phasedown (Kigali amendment) for climate protection
Conclusions

Montreal Protocol amended for climate protection
- HFCs included and phasedown of their global use

Surface temperature contribution of HFCs reduced from 0.3-0.5 °C to about 0.06 °C

Global adoption of technologies required to meet national regulations are sufficient to meet Kigali amendment by about 50% for most countries by 2050
Questions or request?

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Thank you