Overview of End of Life (EOL) ODS/HFC Waste Management

UNDP/GIZ SIDE EVENT AT THE 31st MOP– Rome, Italy

4 November 2019

Richard Cooke

Man-West Environmental Group

ODS/HFC Banks versus EOL ODS/HFC as waste

- The global ODS/HFC bank is what is still in productive use and has potential for atmospheric release ("consumption not yet emitted").
- EOL ODS/HFC is no longer in productive use and without the prospect thereof and now subject to atmospheric release.
- EOL ODS/HFC waste is material whose default management option results in global environmental damage but also has a realistic prospect of being captured.
- Essentially a "hazardous waste" requiring environmentally sound management (ESM) but generally without a local environmental/health risk.

EOL ODS/HFC as a manageable waste in practice

- EOL ODS/HFC waste to a waste manager must have characteristics of being practically accessible and for which there is the means to pay for its ESM.
- For purposes of this presentation, confined to consideration of ODS/HFC refrigerant and blowing agents – what might be accessible from the RAC and foam sectors now and in future
- Essentially from stationary domestic/commercial refrigeration and AC equipment
- Note that to a waste manager, it is measured to absolute metric tons not ODP or CO2 Eq.

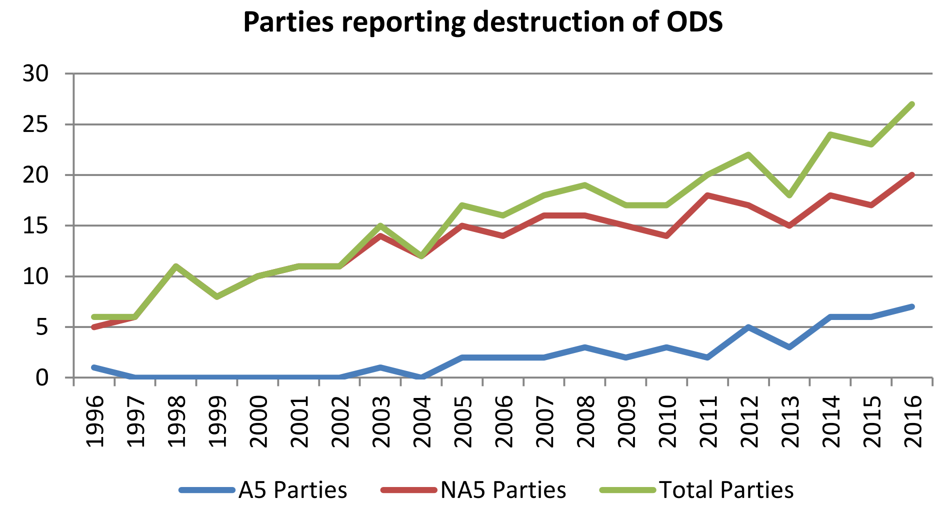
Potential EOL ODS/HFC waste stream characterization

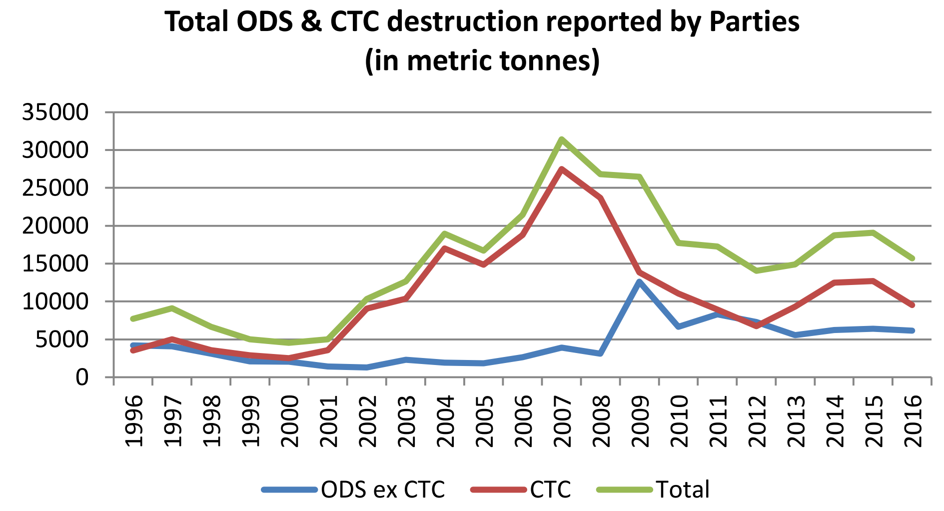
- GIZ studies of banked/potentially available EOL ODS/HFC waste indicate:
  - CFC-12 while the highest impact in terms of ODP and CO2Eq is now only available in small amounts and disappears by 2025.
  - Largest banks are and will continue to be in developed countries largely in foam for ODS (mainly CFC-11) and refrigerant for HFCs
  - Developing countries have less than half of developed country banks but this will be dominated by HCFC/HFC refrigerant and CFC/HCFC blowing agents into the future.

Current State of EOL ODS/HFC Mgt.

- Recognized as an issue by the MP, but action limited to provision for reporting of destructed amounts for purposes of compliance and “best efforts” encouragement for parties to limit release through capture/destruction.
- MP parties approve technologies based on TEAP assessment for destruction of EOL ODS and now also HFCs
- To date no mandatory requirement under the MP to restrict release of, capture and destroy EOL controlled substances
- Limited national regulatory or financial incentives to support a commercial EOL ODS/HFC waste market.
- Globally, modest but increasing actual destruction of EOL ODS/HFCs other than CTC and HFC23 (2016 – 6,100 t ODS) largely confined to a few developed countries

Reported EOL ODS Destruction.





Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Empowered lives. Resilient nations.

EOL ODS/HFCs Management Process

- EOL ODS ESM involves a sequential three stage process:
  - Capture (preprocessing, packaging/transport/storage)
  - Environmentally sound destruction/transformation
  - Validation of its ESM and elimination as an emission
- Priority source targets for most countries are
  - ODS/HFC refrigerant extracted from RAC equipment or as confiscated/expired stocks (concentrated EOL waste)
  - ODS blowing agent retained in foam (dilute EOL waste)
- Characterized as waste originating in small quantities at large number of geographically separated locations.
- Essentially different operational waste mgt. action required for addressing refrigerant (concentrated) and foam (dilute) waste streams

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Empowered lives. Resilient nations.

EOL ODS/HFCs Capture - Refrigerant

- Operational Steps
  - Removal of actual ODS from equipment or securing stockpiles (obsolete or confiscations).
  - Decision on future productive use (is it a waste?)
  - Consolidation/analysis/secure storage
  - Transportation
  - Ownership/care and custody/regulatory arrangements
  - Tracking documentation
- Base on existing service infrastructure upgraded for secure longer term storage arrangements and regulatory enforcement

EOL ODS/HFCs Capture - Refrigerant

- **Capture of refrigerants is relatively simple/potentially cost effective in terms of GEB measures (ODP or CO2 Equiv.)**
- **Requires regulation, expertise, and infrastructure**
- **Barriers/challenges are:**
  - ➢ **Obtaining access to meaningful EOL ODS quantities**
  - ➢ **Mandatory emission bans required**
  - ➢ **Maintaining secure interim storage**
  - ➢ **Access to cost effective destruction**
  - ➢ **Sustainable financing of the management process**
- ***Overall this is where the most value can be obtained today***

EOL ODS/HFCs Capture/Processing - Foam

- More complicated "dilute" EOL ODS/HFC waste stream:
  - Widely distributed/large volume/low weight/mixed ODS
  - Requires separation from equipment
  - Mixed with general waste streams
  - High emission losses during processing
- Low net actual ODS/HFC recovery volume for waste volume handled
- Requires significant incremental processing/infrastructure
- Overall high cost/low CE in ODP or CO2 Equiv. terms
- Currently, a low priority EOL ODS/HFC waste except in a few developed countries where is integrated with other industrial scale resource recovery/waste mgt. systems

EOL ODS/HFCs Capture/Processing - Foam

- Process Option 1: Removal from equipment
  - ➢ Bulk foam extraction from equipment/waste diversion (Manual process)
  - ➢ Size reduction (significant ODS release)
  - ➢ Package for transport/destruction
  - ➢ Consolidation/secure interim storage
- Process Option 2: Processing in-situ
  - ➢ Integrated material separation systems that involve blowing agent extraction and potential integration with destruction (refrigerator de-manufacturing plants)
  - ➢ Direct destruction with metal white goods

The MP and EOL ODS/HFC Destruction

- MP definition: "Permanent transformation or decomposition of all or a significant portion of the controlled substance".
- MP parties approve technologies based on TEAP assessment:
  - Technical/environmental performance criteria (for ODS and now HFCs)
  - Code of Good Housekeeping
  - Approved technologies list
- Generally track destruction requirements applicable to halogenated HW but in the detail are less stringent and more flexible.

Technology Reference Documents: Performance Criteria /Technology Options

For ODS

2002 TEAP Task Force Report (Volume 3b of 2002 TEAP Report)

http://ozone.unep.org/Assessment_Panels/TEAP/Reports/Other_Task_Force/TEAP02V3b.pdf

Montreal Protocol Handbook On-line Edition

http://ozone.unep.org/en/Treaties/treaties_decisions-hb.php?sec_id=29

2011 TEAP Report (Task Force Report - Pages 65-81)

http://ozone.unep.org/Assessment_Panels/TEAP/Reports/TEAP_Reports/TEAP_Progress_Report_May_2011.pdf

Decision XXX/6 Destruction technologies for controlled substances

https://ozone.unep.org/treaties/montreal-protocol/meetings/thirtieth-meeting-parties/decisions/decision-xxx6-destruction

Report of Halon Technical Options Committee, Technical Note #5 – Halon Destruction 2014

http://ozone.unep.org/en/Assessment_Panels/TEAP/Reports/HTOC/Technical%20Note%205%20-%20Halon%20Destruction%20-%202014.pdf

For HFC

Decision XXIX/4 TEAP Task Force Report on Destruction Technologies for Controlled Substances, April 2018

http://conf.montreal-protocol.org/meeting/oewg/oewg-40/presession/Background-Documents/TEAP-DecXXIX4-TF-Report-April2018.pdf

Decision XXX/6 Destruction Technologies for Controlled substance, MP Handbook, 2019

https://ozone.unep.org/treaties/montreal-protocol/meetings/thirtieth-meeting-parties/decisions/decision-xxx6-destruction

For POPs

Basel Convention POPs Disposal G/L

http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/AdoptedTechnicalGuidelines/tabid/2376/Default.aspx

GEF STAP POPs disposal technology selection G/L (2011)

http://www.thegef.org/publications/selection-persistent-organic-pollutant-disposal-technology-gef

TEAP and POPs Destruction Performance Criteria

Performance Parameter	TEAP Task Force Report Decision XV/9	Basel Convention G/L (POPs)	GEF STAP G/L for POPs
Particulates (mg/Nm^3)	50	NR	NR
HCl (mg/Nm^3)	100	NR	NR
HF (mg/Nm^3)	5	NR	NR
HBr/Br_2 (mg/Nm^3)	5	NR	NR
CO (mg/Nm^3)	100	NR	NR
Dioxin/Furan ($ng\text{-}ITEQ/Nm^3$)	0.2 (Conc.) 0.5 (Dilute)	0.1	0.1
DE (%)	n/a	99.99	99.99
DRE (%)	99.99 (Conc.) 95.0 (Dilute)	99.9999	99.9999

NR: National Regulation

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Decision XXX/6, Annex II: Approved Destruction Technologies (Refrigerant/Foam Applications)

Technology	Applicability						
	Concentrated Sources					Dilute Sources	
	Annex A	Annex B	Annex C	Annex F		Annex A,B,C	Annex F
	Group 1	Group 1	Group 1	Group 1	Group 2		Group 1
	Primary CFCs	Other CFCs	HCFCs	HFCs	HFC-23	ODS	HFCs
DRE*	99.99%	99.99%	99.99%	99.99%	99.99%	95%	95%
Cement Kilns	Approved	Approved	Approved	Approved	Not determined		
Gaseous/Fume Oxidation	Approved	Approved	Approved	Approved	Approved		
Liquid Injection Incineration	Approved	Approved	Approved	Approved	Approved		
Municipal Solid Waste Incineration						Approved	Approved
Porous Thermal Reactor	Approved	Approved	Approved	Approved	Not determined		
Reactor Cracking	Approved	Approved	Approved	Approved	Approved		
Rotary Kiln Incineration	Approved	Approved	Approved	Approved	Approved	Approved	Approved
Argon Plasma Arc	Approved	Approved	Approved	Approved	Approved		
Inductively coupled radio frequency plasma	Approved	Approved	Approved	Not Determined	Not Determined		
Microwave Plasma	Approved	Approved	Approved	Not Determined	Not Determined		
Nitrogen Plasma Arc	Approved	Approved	Approved	Approved	Approved		
Portable Plasma Arc	Approved	Approved	Approved	Approved	Not Determined		
Chemical Reaction with H2 and CO2	Approved	Approved	Approved	Approved	Approved		
Gas Phase Catalytic De-halogenation	Approved	Approved	Approved	Approved	Not determined		
Superheated steam reactor	Approved	Approved	Approved	Approved	Approved		
Thermal Reaction with Methane	Approved	Approved	Approved	Not Determined	Not Determined		
Thermal Decay of Methyl Bromide	Not Determined	Not Determined	Not Determined	Not Determined	Not Determined		

Empowered lives. Resilient nations.

Commercial High Tempurature Incineration (HTI)

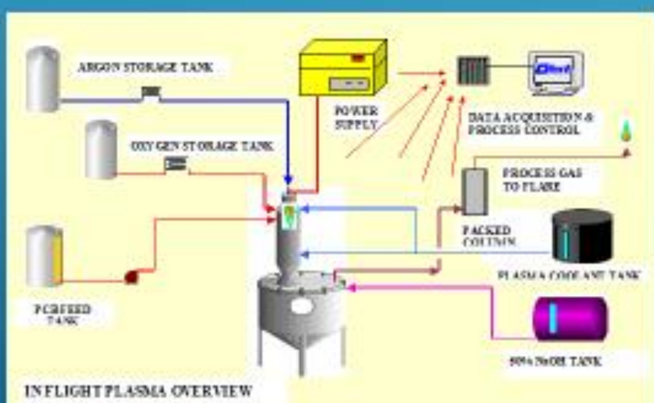
- High DE/DRE >99.99 DE/99.9999 DRE
- Readily available prequalified service providers in developed countries – Caution: Performance variation across facilities.
- Generally well monitored/regulated in developed countries
- Good tracking and validation
- Unit Cost Range US$1.5 – 15.0/kg depending on volumes
- Predominant technology of choice
- Export/import barriers in some regions/countries
- Public acceptance/ENGO opposition issues

Commercial High Tempurature Incineration (HTI)

Commercial Scale Plasma Arc

- Designed for specialty HW destruction including EOL ODS/HFC - Several suppliers, main one is PLASCON
- Modular/transportable (single shipping container)
- Commercial facilities in Australia, Mexico, Japan and US
- High DE/DRE >>99.99/99.9999 and low emissions
- Capacities range -40-80 kg/hr. (250-500 MT/year) for ODS/HFC
- Capital Costs - US$2.5-3.0 million w/o infrastructure
- Unit costs quoted in the range of US$5-20/kg. depending on overall plant throughput/market – US$9/kg quoted in Mexico
- Relatively high operating cost/power consumption
- Typically needs another stable waste market to be viable

Commercial Scale Plasma Arc



Cement Kilns

- High DE/DRE in theory but difficult to verify
- Limited direct systematic qualification data available
- Operator interest limited due to small volumes/revenue and product quality issues
- Option is limited to relatively new/current process facilities achieving BAT/BEP air quality standards
- Costs for an established/qualified facility should be similar to HTI but often higher – US$7/kg quoted in Mexico for CFC-12
- Potentially a good option in absence of HTI access and potentially for foam if sufficient quantities can be regularly supplied

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Cement Kilns

Empowered lives. Resilient nations.

Small Scale Portable Plasma Arc

- Small footprint transportable unit, marketed by ASADA, variant reported developed in China
- Reported installations in Japan and China as well as Argentina/Ecuador (neither operational)
- DE/DRE >99.99 and emission compliance reported
- Capacities range from 1-2 kg/hr. (3.6-7.2 MT/year)
- Capital Costs - approximately US$150,000 w/o infrastructure cost which are high (electrical, pad etc.)
- High operating costs (US$30-50,000/year) for labor, utilities, service/maintenance and imported consumables
- Unit costs estimated to be > US$25/kg. dependent on refrigerant and throughput
- Potential viability in small but stable markets

Small Scale Portable Plasma Arc

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Empowered lives. Resilient nations.

ODS Destruction Demonstration Experience

- MLF Program - 12 national and 2 regional demonstration projects approved – US$11.3 million
- 392 t ODS destroyed, 100 t pending (Colombia)
- ExCom SYNTHESIS REPORT ON THE PILOT ODS DISPOSAL PROJECTS -DECISION 79/18(e) Dec. 2018 http://www.multilateralfund.org/82/English/1/8221.pdf
- Ecuador, Costa Rica, Trinidad doing projects outside this program
- 8 projects - export to commercial HTI facilities, 3 projects qualifying national commercial HTI or plasma arc facilities, 6 qualifying cement kilns
- Only 3 projects directly qualified technologies against TEAP criteria (China, Colombia, Mexico)
- General issue of ability to collect sufficient of originally targeted EOL ODS for projects

Country	Substance	GWP*	ODS destroyed (mt)	Greenhouse gas emission reduction (CO_2-eq.tonnes)
China	CFC-11	4,750	183.005	732,020
	CFC-12	10,900	11.788	100,198
		Subtotal	194.793	997,763
Colombia	CFC-11	4,750	8	38,000
	CFC-12	10,900	6	65,400
	CFC-foam	n/a	n/a	n/a
		Subtotal	14	103,400
Georgia	CFC-12	10,900	1.467	15,990
		Subtotal	1.467	15,990
Ghana	CFC-12	10,900	2.272	24,765
	Methyl Bromide	5	5.2	26
		Subtotal	7.4	24,791
Mexico	CFC-11	4,750	24.7	117,325
	CFC-12	10,900	25.3	275,770
	CFC-114	10,000	0.5	5,000
	HCFC-22	1,810	40.1	72,581
	HCFC-141b	725	0.2	145
	HFC-134a	1,430	21.5	30,745
	R-407	2,107	0.9	1,896
		Subtotal	113.2	503,462
Nepal	CFC-12	10,900	9.03	98,427
		Subtotal	9.03	98,427
Nigeria	CFC-12	10,900	1.66	18,094
		Subtotal	1.66	18,094
Region: ECA**	CFC-12	10,900	32.79	357,411
	HCFC/HFCs	***	8.58	***
		Subtotal	41.37	357,411
Turkey	CFC-12	10,900	9.162	99,866
		Subtotal	9.162	99,866
		Total	392.154	2,229,777

Columbia HTI Test Burn Program - Conclusions

- At modest feed rates and Cl/Fl content meets MP/TEAP.
- Possibility of exceeding National Regulations in some cases likely related to B/L rather than ODS.
- TECNIAMSA facility is qualified for ODS destruction with a limit on feed rates.
- Improved B/L waste QA/QC and consideration of further APC upgrades for PCDD/F reduction recommended (both being implemented).
- Main issue may be low productivity for ODS destruction associated with long term destruction program of large quantities.
- Estimated capacity in the range of 25 – 50 t/year of EOL ODS chemical in a single unit (up to three units could be available).

Columbia Test Burn Program - Conclusions

- MP compliant, technically qualified capability available to the developing national EPR system for EOL ODS Mgt.
- Productivity limitations can be addressed by qualification of multiple units and technology upgrades to increase Cl and Fl content limitations.
- Indicative commercial costs competitive within alternatives for ODS chemicals (range of US$6-6.5/kg) with future application to HFC Mgt
- Economic/GEB cost effectiveness for dilute ODS waste (foam) may require further analysis.
- Qualification process may be most rigorous undertaken globally at least for this technology and potentially has replication value.

Barriers to EOL ODS/HFC Elimination

- **Barriers to effective EOL ODS/HFC waste management**
  - **Effective regulation and its enforcement both national and international level**
  - **Limited integration with broader integration of waste management/source segregation and diversion**
  - **Awareness and commitment to address issue by waste generators, public, industrial beneficiaries**
  - **Access to appropriately scaled infrastructure and technology**
  - **Sustaining Financial instruments to expand and sustain it at level that captures meaningful amounts and required economies of scale**

Financing of EOL ODS/HFC Elimination

- **Principal barrier to achieving anything but a symbolic level of EOL ODS/HFC elimination is have a financing mechanism that pays for it in a competitive market setting.**
- **Direct public sector funding at national or international level can be useful supporting initial infrastructure and programs but not sustainable or sufficient**
- **Financial mechanism that transfer cost to the originators of the chemicals/products/generated waste, and to mechanisms that create a value to the waste linked to its global impact most promising.**

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Empowered lives. Resilient nations.

Financing of EOL ODS/HFC Elimination

- Potential financing operating in combination may be pursued
  - Dedicated public sector funding to support EOL ODS/HFC waste management – awareness, capture infrastructure so viable market size is created
    - Developed countries – nationally in PPP's
    - Developing countries – existing financial instruments (MLF/GEF) and/or assembly of a dedicated funding instrument
  - Surcharges on products that replace ODS/HFC containing products
  - Extended Producer Responsibility (EPR) that requires the waste originator to assume financial responsibility for waste
  - Direct monetization of EOL ODS/HFC release prevented through its ESM

Concluding Remarks

- Practically EOL ODS/HFC can only be comprehensively addressed if it is accessible and there is the means to pay for its ESM - only a small portion of it is actually captured and destroyed
- The EOL ODS offering the greatest GEB was CFC-12 but largely missed the window available to address it. Lets not make that mistake again.
- Importance in terms of ODP impacts declining - limited accessibility to foam/low ODP HCFC
- The priority going forward GHG impacts from HFCs mainly refrigerant (HFC blends in the medium term, HFC-134a in the longer term) – Will be increasingly attractive for carbon finance
- ESM management not technology limited although available commercial technologies will evolve – prospects for economically viable smaller scale technologies, particularly based on breaking down ODS/HFC chemicals

Thank You

Rick Cooke
E-Mail: rickcooke1@compuserve.com
SKYPE: manwestrjc