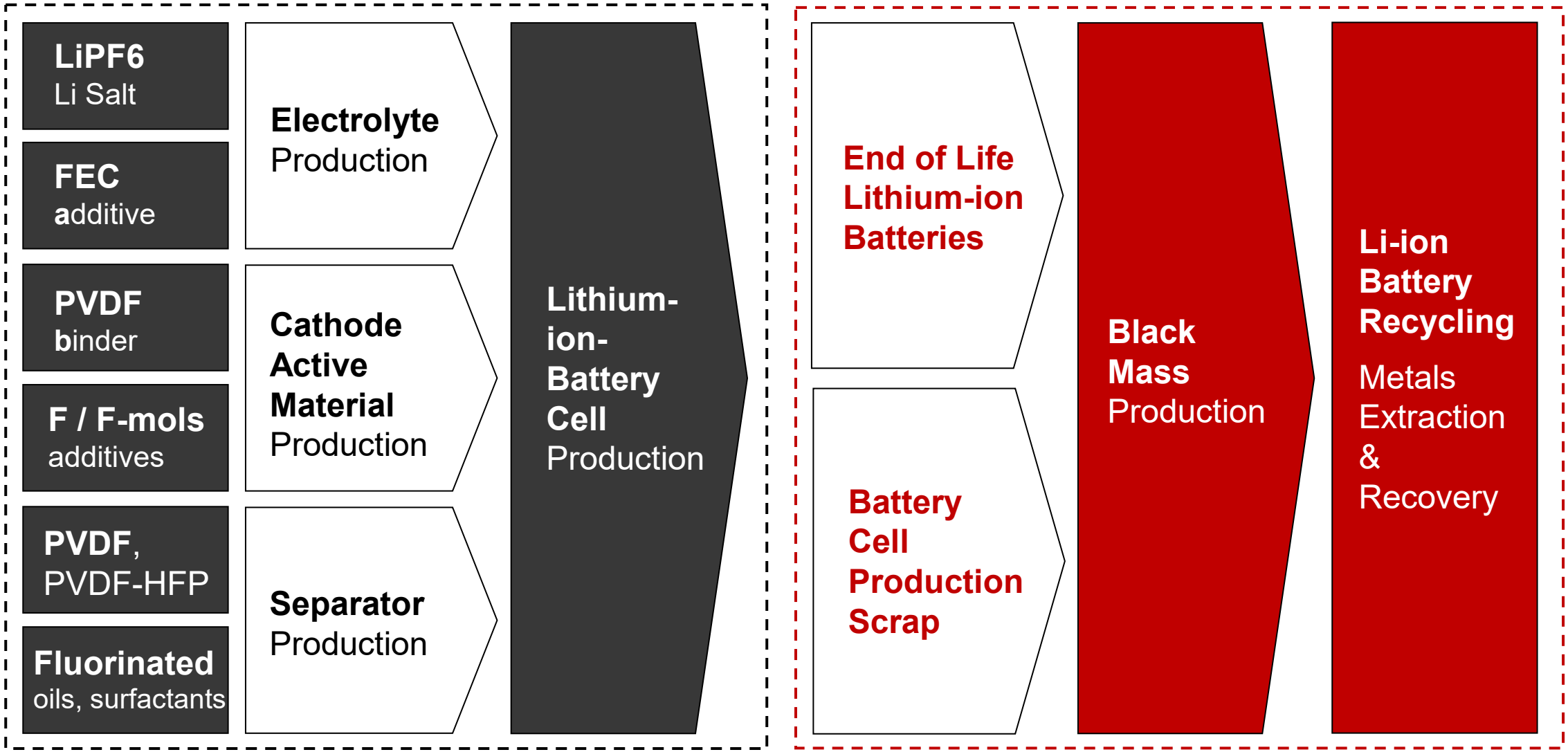
HONEYWELL CFX™
FOR PFAS WASTE DESTRUCTION

Honeywell
UOP

FLUORINATED WASTE / DISCHARGE PERSISTENT THROUGHOUT LIB AND EOL LIB SUPPLY-CHAINS



FLUORINATED MATERIALS TYPICALLY NEEDED FOR ELECTROLYTE PRODUCTION

Electrolyte Salts	Fluorinated Additives	Process Operations
$LiPF_6$ lithium hexafluorophosphate	FEC fluoroethylene carbonate	Non-stick Coatings (PTFE)
$LiBF_4$ lithium tetrafluoroborate	DHFPh 2,2,2-Trifluoroethyl difluorophosphite	Fluorinated Lubricants (PFPE)
LiFSI lithium bis(fluorosulfonyl)imide	TFP tris(2,2,2-trifluoroethyl) phosphate	Fluoropolymer Membranes / Filters
LiTFSI lithium bis(trifluoromethanesulfonyl)imide	LiDFOB lithium difluoro(oxalato)borate	Fluorotelomer Alcohols, PFOS Derivatives
	TPFPB tris(pentafluorophenyl)borane	

Summary of Sources → Types	
Lithium Salt ($LiPF_6$, LiFSI, LiTFSI, $LiBF_4$)	Fluorinated Anions (that can degrade to carbon-fluorine species)
Additives (FEC, Fluorinated Additives)	Fluorinated-Carbon Compounds
Solvent Contamination	Trace PFAS / Fluorotelomers
Manufacturing Residue (Equipment Coatings)	PFOA, PFHxA, HFPO-DA
Filtration Membranes (PVDF, PTFE)	Fluorocarbon Polymers / Extractables
Cleaning Agents / Surfactants	PFOS, Fluorotelomer Sulfonates, FTOHs
Container / Packaging Leachables	Short-Chain Carbon-Fluorine Molecules

FLUORINATED MATERIALS TYPICALLY NEEDED FOR CATHODE ACTIVE MATERIAL PRODUCTION

Binders	Process Operations
PVDF polyvinylidene fluoride PTFE polytetrafluoroethylene	Fluorinated surfactants used in precursor synthesis Cleaning / Dispersing Agents | Heat Transfer Fluids | Equipment Coatings (PTFE liners) Membranes / Filters used in Precursor Purification | Packaging Materials Solvent Contamination | Drying and Air Handling Systems

Summary of Sources → Types	
Fluorinated binders or coatings (PVDF, PTFE)	Polyvinylidene Fluoride, Polytetrafluoroethylene
Fluorinated Surfactants used in Precursor Synthesis	PFOS, PFHxS, Fluorotelomer Sulfonates
Cleaning / Dispersing Agents	Fluorinated Surfactants (Perfluorooctanoic Acid Derivatives)
Heat Transfer Fluids	Perfluoropolyethers (PFPEs)
Equipment Coatings (PTFE liners)	PTFE, PFA
Membranes / Filters used in Precursor Purification	PVDF, PTFE
Packaging Materials	Fluorinated HDPE / Liners
Solvent Contamination	Trace PFAS
Drying and Air Handling Systems	Fluorocarbon-Treated Filters / Gaskets

FLUORINATED MATERIALS TYPICALLY NEEDED FOR SEPARATOR PRODUCTION

Separator Material	Process Operations
PVDF polyvinylidene fluoride PVDF-HFP PVDF-co-hexafluoropropylene	Wetting Agents / Surfactants | Processing Solvents | Mold Release Agents Heat Transfer Fluids | Heat Transfer Fluids | Equipment Linings (PTFE-coated) Separator Coatings | Lubricants and Greases | Packaging Materials

Summary of Sources → Types	
Separator Material: PVDF, PVDF-HFP	Polyvinylidene Fluoride, PVDF-co-hexafluoropropylene
Wetting Agents / Surfactants	Fluorotelomer Alcohols, PFOS, PFHxA
Processing Solvents	NMP, DMF Contaminated with Fluorinated-Carbon Compounds
Mold Release Agents	Fluorinated Oils / Surfactants
Heat Transfer Fluids	Perfluoropolyethers
Equipment Linings (PTFE-coated)	PTFE, PFA
Separator Coatings	PVDF / PVDF-HFP Binders
Lubricants / Greases	PFPE
Packaging Materials	Fluorinated HDPE Liners / Films

GASEOUS FLUORINATED RELEASE LIKELY FROM LITHIUM-ION BATTERY PRODUCTION

SOURCE	TYPE	PROCESS STEP	RELEASE PATHWAY
Thermal Decomposition of PVDF in Cathodes & Separators	Fluorinated Gases: HF, CF_4, PFIB, ultrafine PFAS precursors	Electrode Drying, Calendaring, Slitting	Emitted from Drying Ovens, Kilns, or Calciners
Volatilization of Fluorosurfactants	Carbon-Fluorine Short-Chains: FTOHs, PFHxA	Separator Coating, Electrolyte Mixing	Fume Hoods, Exhaust Stacks
Off-Gassing of PFPE Oils / Fluorinated Lubricants	PFPEs, Perfluoropolyethers	Rollers, Bearings, Mixers (under heat)	Ventilation Ducts, HVAC
Electrolyte Mist / Aerosol during Filling	Volatile Fluorinated Additives	Electrolyte Filling, Vacuum Degassing	Filling Booth Air Discharge, Bag Vents

LIQUID FLUORINATED RELEASE LIKELY FROM LITHIUM-ION BATTERY PRODUCTION

SOURCE	TYPE	PROCESS STEP	RELEASE PATHWAY
Spent Cleaning Solvents Contaminated with Fluorinated-Carbon Compounds	FEC, LiFSI, PFHxA, PFAS Surfactants	Cleaning Mixers, Coaters, Gloveboxes	Waste Drums, Solvent Recycling Tanks
Wastewater from Floor / Area Washdowns	Carbon-Fluorine Short-Chains, Surfactants, Leachates	Entire Facility, especially Electrolyte & Binder Areas	Floor Drains, Containment Basins
Aqueous Precursor Synthesis Waste	PFAS-based Wetting Agents	Cathode Precursor Production (Coprecipitation)	Liquid Waste Tanks, Sumps
Dehumidifier / Air Scrubber Condensate	FTOHs, HFPO-DA	Dry Rooms, Cleanrooms	HVAC Drainage Systems
Electrolyte Waste from Rejected / Faulty Cells	LiTFSI, LiFSI, PFAS-containing Additives	Electrolyte Filling, Cell Formation	Hazardous Liquid Waste Drums

SOLID FLUORINATED RELEASE LIKELY FROM LITHIUM-ION BATTERY PRODUCTION

SOURCE	TYPE	PROCESS STEP	RELEASE PATHWAY
Scraps of Electrodes and/or Separator Coated with PVDF	PVDF, PTFE	Slitting, Cutting, Coating	Solid Scrap Bins, Recycling Drums
Spent Filters, Gaskets, Gloves, and PPE	FEC, PFPE Oils & Additives	Maintenance, Handling	Hazardous Solid Waste, PPE Disposal
Used Activated Carbon / Resin from Air / Water Treatment	Concentrated PFAS (adsorbed)	VOC / PFAS Mitigation Systems	Hazardous Solid Waste Bins
Contaminated Rags, Wipes, Floor Mats	Residual PFAS from Spills / Leaks	Facility-Wide	General Industrial Waste Stream
Fluorinated HDPE Drums	Fluorinated-Carbon Compound Leachates	Storage of Electrolyte & Raw Materials	Recyclable / Hazardous Material Streams

HONEYWELL CFX™ — ADVANCED OXIDATION SYSTEM

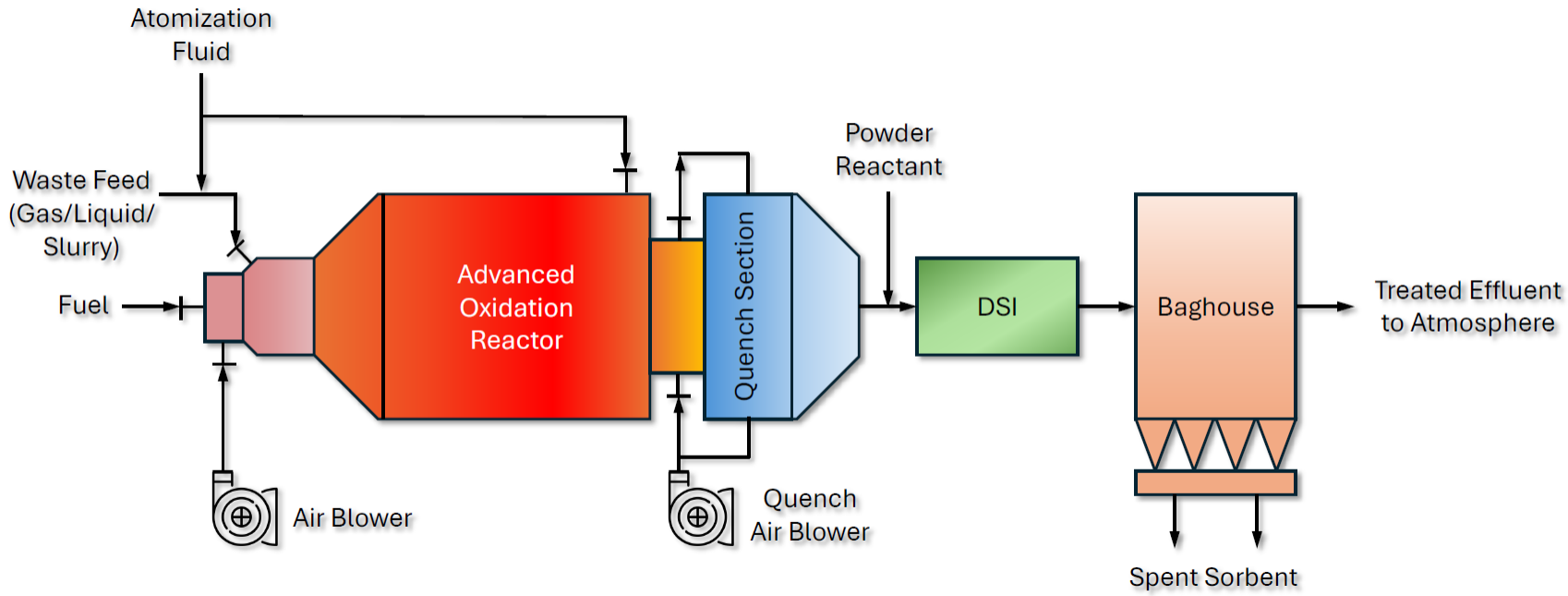
Up to **1400 °C** stable operation

1-1200 GPH capacity

Designed for **CF_4 destruction**

Zero liquid waste discharge

Automated with minimal maintenance



CF_4 DESTRUCTION SIGNIFICANCE

C—F BONDS

C–F is the **strongest** single **bond** in organic chemistry—dissociation energy of **485 kJ/mol**

- Short bond length of 1.35 Å—small atomic radii of C & F
- Large electronegativity difference between C & F makes for strong electrostatic attraction

CF_4 is comprised of **100% C-F bonds**

C–CHAIN LENGTH

Based on number of carbons—the shorter the molecule, the stronger it is

CF_4 has **no C–C** bonds nor functional end groups—no weak sites to initiate attack

MOLECULAR SYMMETRY

Perfectly symmetrical—tetrahedral geometry, minimizing electron-electron repulsion

109.5° bond angles—most stable for 4 electron pairs around central C atom

STABILITY

1,200°C+ uniform temp for decomposition—inert to many reagents, acids, & hydroxides

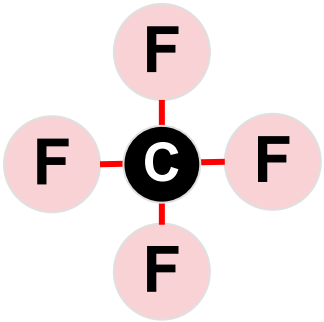
50,000-year atmospheric lifetime—potent GHG—**7,390 times** the **GWP** of CO_2

INCOMPLETE DESTRUCTION BYPRODUCT

Occurrence of fragmentation, generating fluorinated radicals: CF_3•, CF_2•, CF•, F•, with most stable endpoint being CF_4

- Molecular strength of **CF_4** makes it an effective chemical dead-end (with other destruction techs)

CF_4 **destruction** is **benchmark**

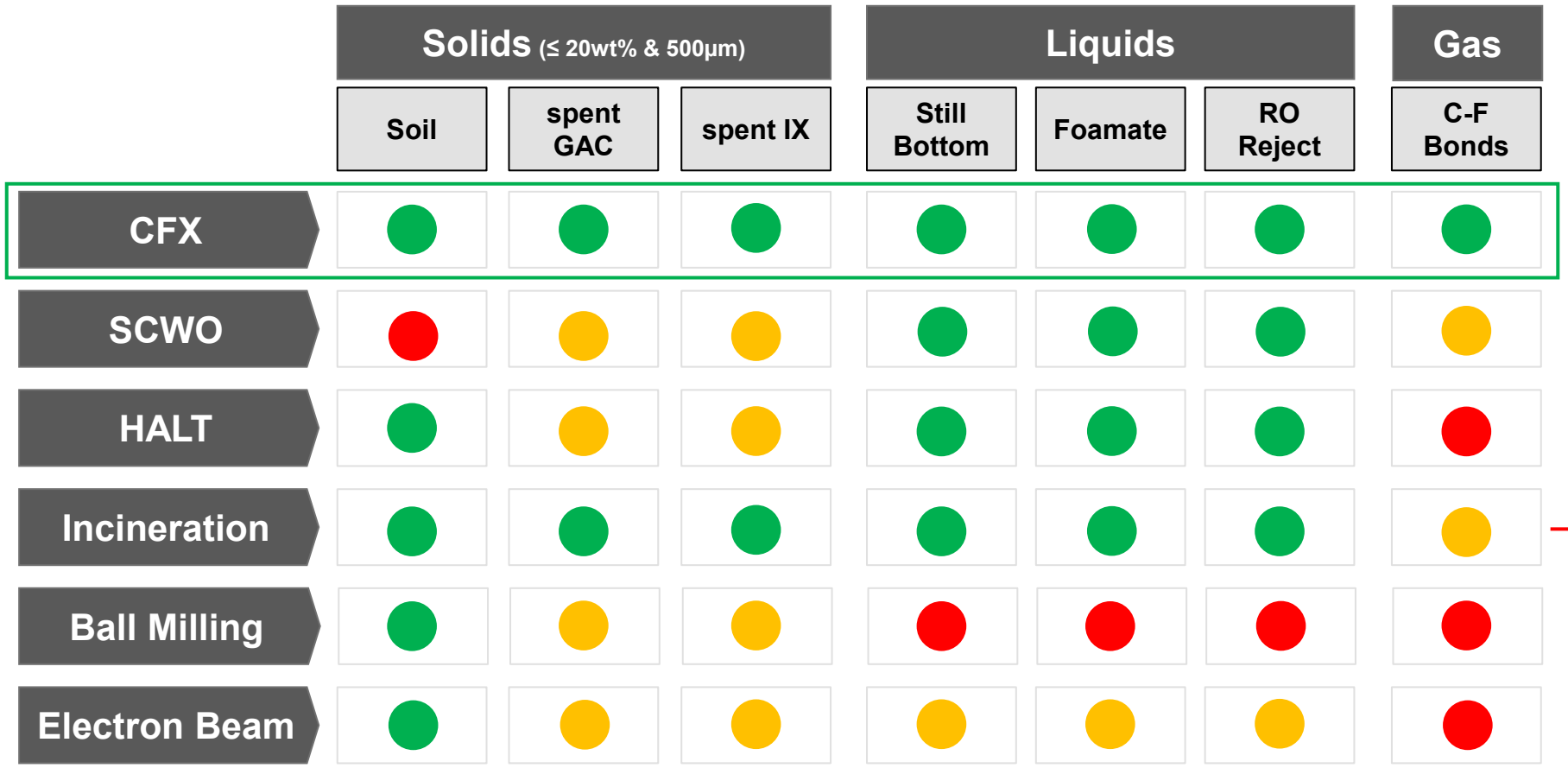


for **measuring** fluorocarbon **destruction** efficiency

HONEYWELL CFX™ — DIFFERENTIATED OFFERING

	Honeywell CFX™	Plasma	Catalytic Reduction	Incineration	SCWO	HALT	ECO
Scalability	15 Systems at Industrial Scale	Point-of-Use	Small Scale / Lab Systems	Commercial	Commercial / Pilot	Pilot	Bench and Pilot
Ultra-Short Chain DRE	99.998%	90 – 99.9%	60 – 95%	60 – 99.99%	TFA's shortest C-F with 99%	>90% for TFA	Unknown
Feed Compatibility	Gas, Liquid / Solvent, & Solid	Primarily Gas	Primarily Gas	Gas, Liquid, & Solid	Primarily Liquid	Primarily Liquid	Primarily Design Liquid
Residence Time	~1.5–2 seconds	<1 second	0.5–2 seconds	2–7 seconds	10–90 seconds	10–60 minutes	1–24 hours
Operational Simplicity	Runs Continuously via HON Automation	Power & Gas Flow Tuning	Reducing Gas Control	Feed Swings Impact Temps	Sensitive to Feed Changes	Batch / Semi-Batch	Limited by Electrode
Energy Efficiency	Steady-State, Heat Recovery	High Electrical Input	Lower Input, Less Effective	High Energy Demand	High Pressure	Chemically Assisted	Low Net Energy
Maintenance Needs	Minimal	Electrode Wear; Fouling	Catalyst Poisoning	Corrosion Checks	High Pressure	Chemical Control	Fouling Cleaning
Reliability / Life	>90% Uptime; >15 Year Life	Frequent Part Replacement	<1 year Catalyst Life	Refractory Lasts 1+ yrs	3–10 yrs, Liner	2–5 yrs, Batch Vessels	1–3 yrs, Electrodes

HONEYWELL CFX™ — ENCOMPASSING SOLUTION



Developing Technologies

Limited applicability & **expensive**

Technically **challenging** & **slow**

Shortcomings of Others

Landfilling is future **liability**

→ **Incineration** can have **incomplete** destruction that releases to atmosphere

GAC reactivation has **limited** applicability

Solving the **problem** of **diverse waste** with a **one-stop** shop for **total destruction**

HONEYWELL CFX™ — READY-NOW AT INDUSTRIAL-SCALE

SUPERIOR — **destroys** strongest waste and highly persistent pollutants like PFOA, PFOS, GenX, biosolids, & industrial byproducts

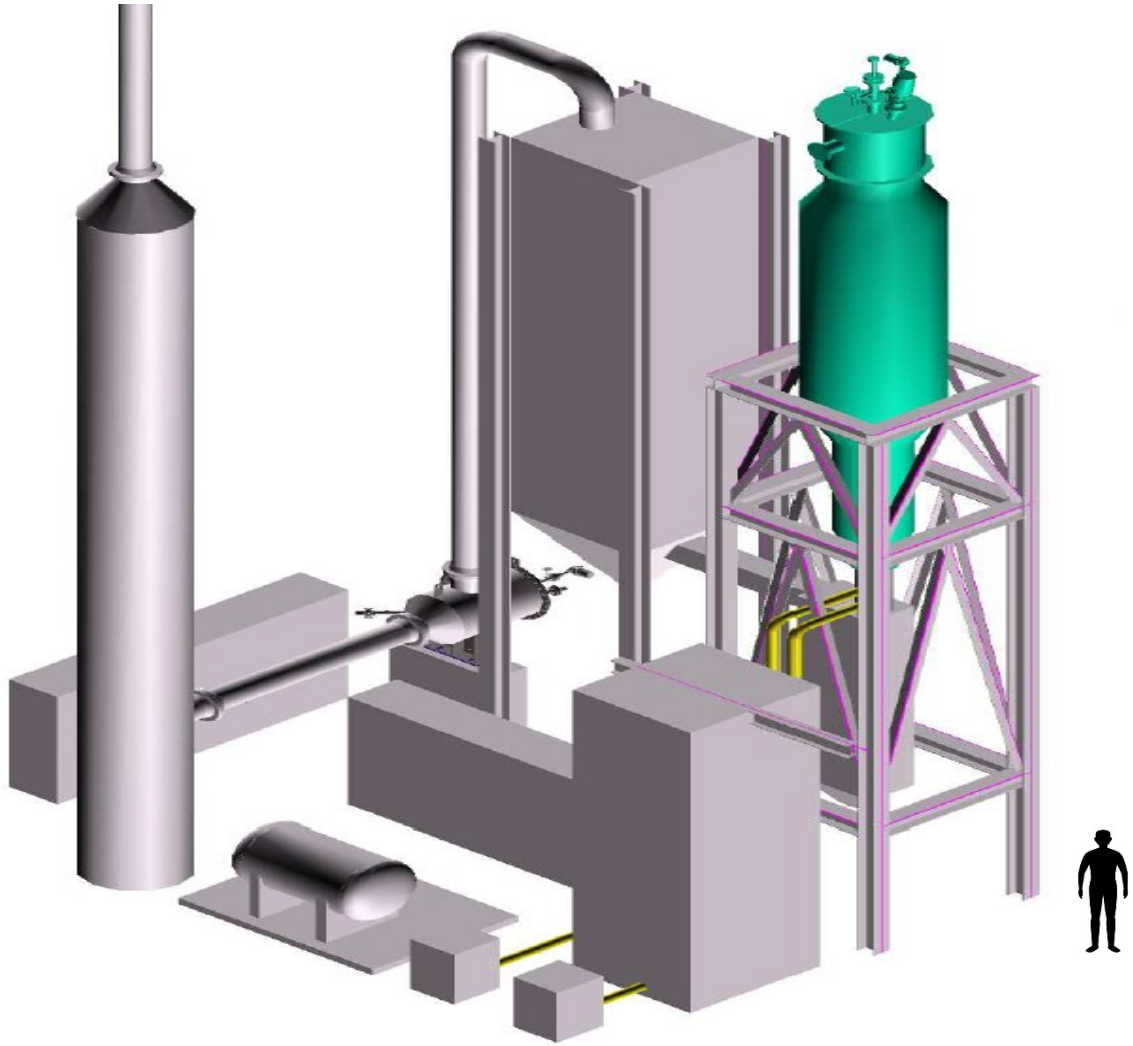
SUSTAINABLE — **avoids** gaseous release of CF_4, C_2F_6, & C_3F_8, which are 7,390 – 12,200 times the GWP of CO_2

ADVANCED — **runs** on **Honeywell automation** – avoids dedicated personnel

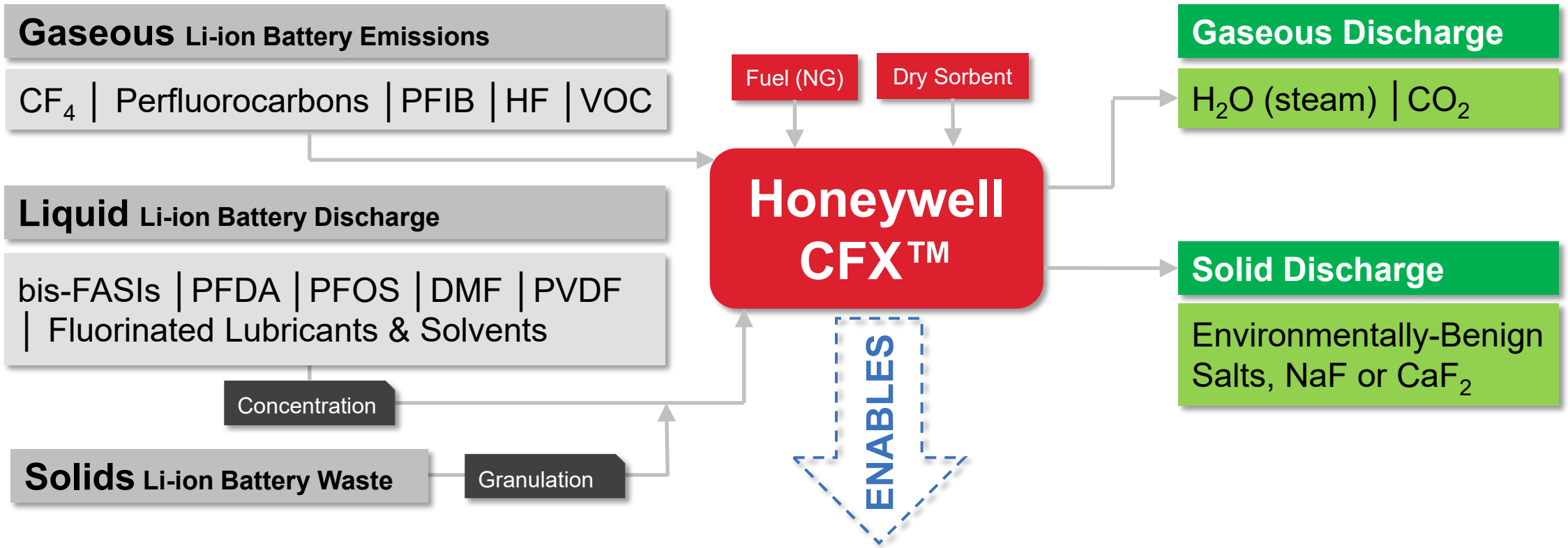
PRACTICAL — mature & ready-now with 30 years proven performance

RISK AVERSE — **>99.99% destruction** of all waste (ex-nuclear), **eliminating** landfilling & long-term **contamination** & **liability** risks

ECONOMICAL — **high** throughput and corrosion resistant for **MAX** system **life**



LIB PFAS WASTE DESTRUCTION VIA CFX



COMPLIANCE
with current & future environmental regulations by minimizing releases

AVOIDANCE
of LIABILITY common with disposals to landfills / wastewater

SUSTAINABILITY
that is technologically advancing the Li-ion battery industry to achieve corporate ESG values & low GWP

SAVINGS
by avoiding costly external disposal & long-term remediation expenses and benefiting from clean-tech incentives

SUSTAINABILITY SOLUTION

The **Honeywell CFX™** technology is a **proven** solution for managing challenging and diverse wastes effectively to avoid environmental threats & associated liabilities.

KEY FEATURES of Honeywell CFX™

High Success Rate

Eradicates over 99.99% of hazardous/toxic wastes.

Landfill Avoidance

No risk of landfill contamination to groundwater and soil.

Cost-Effectiveness

Eliminates disposal, logistics, insurance costs and liabilities with onsite solution.

Environmental Safety

No toxic emissions/byproducts – cleaner water and air for safer communities.