

HONEYWELL UOP EFFORTS ON SUSTAINABLE AND LOW CARBON SOLUTIONS



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Honeywell
UOP

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HONEYWELL UOP AT A GLANCE

100+ Years of Global Expertise and Leading Technology Development



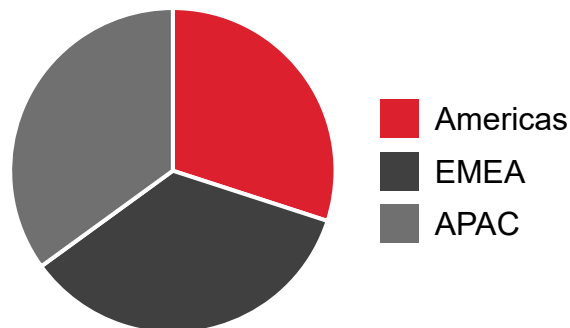
UOP TECHNOLOGY POWERS

- 90% of biodegradable detergents
- 70% of the world's polyester
- 60% of the world's gasoline
- 60% of the world's on-purpose propylene
- 60% of the world's paraxylene
- 50% of the world's renewable fuels
- 40% of LNG processed
- >30 Mtons of captured CO₂



GLOBAL REACH

Diversified regional presence that can effectively react to changes in demand



NEW TECHNOLOGIES

Honeywell UOP creates new technologies that convert oil, natural gas, and renewable feeds into transportation fuels, energy, and petrochemicals



EXPERTISE

Broadest range of downstream refining and petrochemical technologies; leading process technology licensor



2,000

Engineers and scientists



4,900

Active patents and applications



LARGEST
process licensing
organization
in the world

31 out of **36**
refining technologies in use
today were developed by
UOP

OUR PORTFOLIO SOLUTIONS FOR THE ENERGY TRANSITION



UOP Process Technologies

Process technologies, engineering, and equipment for the refining, petrochemicals, and gas processing industries

- Chemical feedstocks
- Transportation fuels
- Hydrogen recovery and purification
- Burners and flares
- Natural gas purification



Sustainable Technology Solutions

Ready-now technologies for renewable low-GHG fuels, targeted solutions for a majority of the world's GHG emitters, H₂, and plastic waste recycling

- Renewable fuels, Ecofining™, SAF
- Blue and Green hydrogen
- Carbon capture
- Plastics recycling – UpCycle technology
- Energy storage – Flow battery



Lifecycle Solutions and Technologies

Serving customers in the operational phase with catalysts, adsorbents, aftermarket equipment, and services

- Catalysts for refineries and petrochemical plants
- Adsorbents for separations and purification
- Field services
- Equipment aftermarket
- Software-enabled services to advance project execution and improve plant operations

ENERGY INDUSTRY PROFITABILITY AND TRANSITION

What our customers are telling us

Need to maximize profitability of existing assets:

- Continue need to produce fuels (esp diesel) with high yields...
- ...and with more challenging feeds

Shift to low carbon fuels is accelerating – SAF demand is very high

- Co-processing – to increasing levels *and* to produce SAF
- Increase SAF yields through Ecofining
- FOGS are limited – need to utilize alternate feeds

Shift to petchem is an opportunity:

- What solutions exist for refiners?
- On-purpose olefin production – increase profitability and reduce GHG

Pressure to reduce GHG emissions:

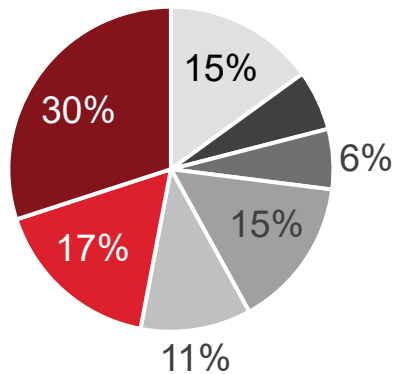
- Scope 1 solutions are needed – carbon capture
- Blue H₂ is an opportunity
- Scope 3 through product slate changes, feedstock changes

Technology focus on new opportunities for profitability while achieving decarbonization goals

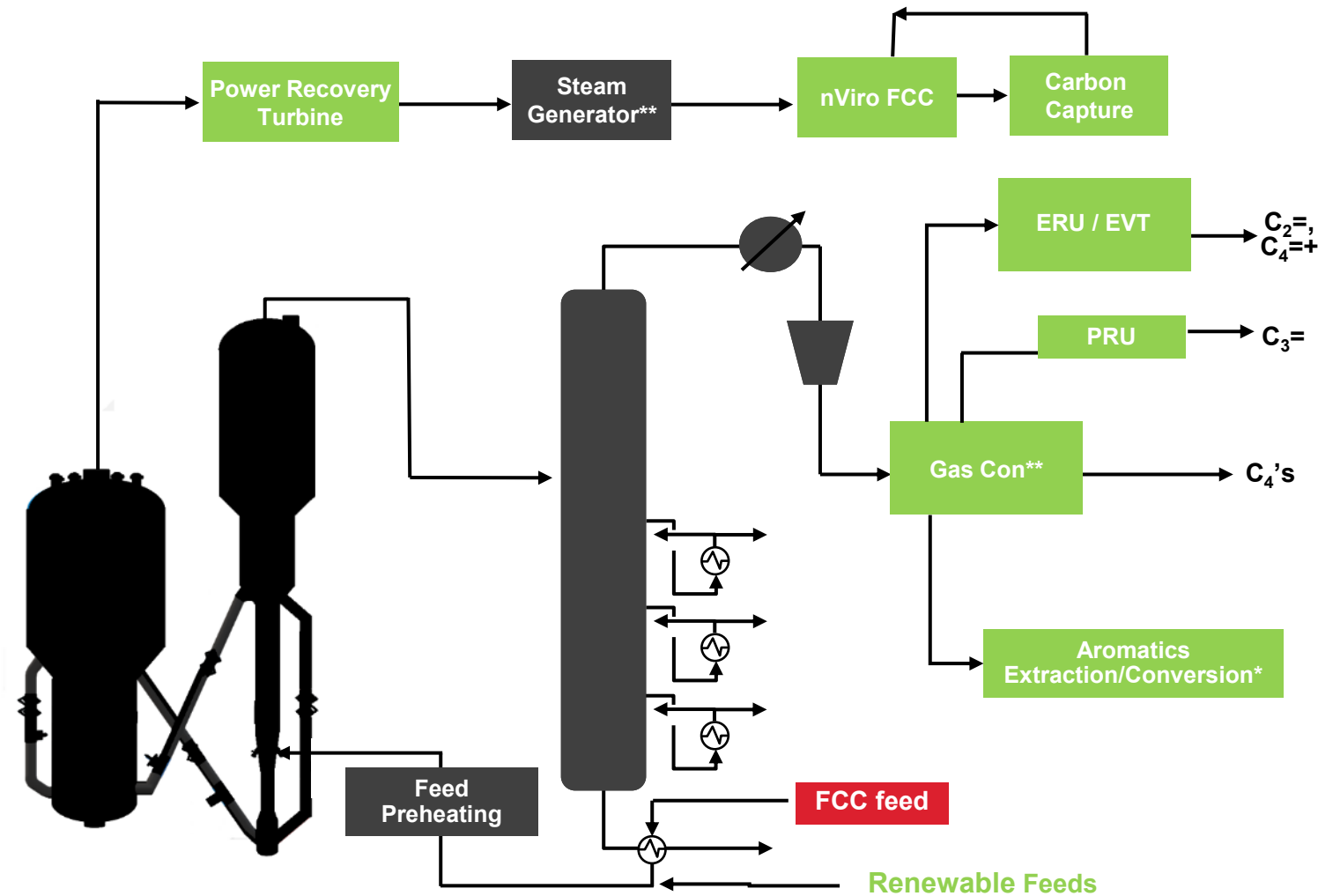
EXAMPLE: FCC SCOPE 1, 2 & 3 EMISSIONS REDUCTION

FCC UNITS:

- Generally used for gasoline production
- Significant point source of GHG
- Present in most refineries



■ Others ■ Chemicals ■ CCR ■ CDU/VDU
 ■ HYT ■ Hydrogen ■ Upgrading



Holistic approach to emissions reduction

EXAMPLE: FCC SCOPE 1, 2 & 3 EMISSIONS REDUCTION

SCOPE 1

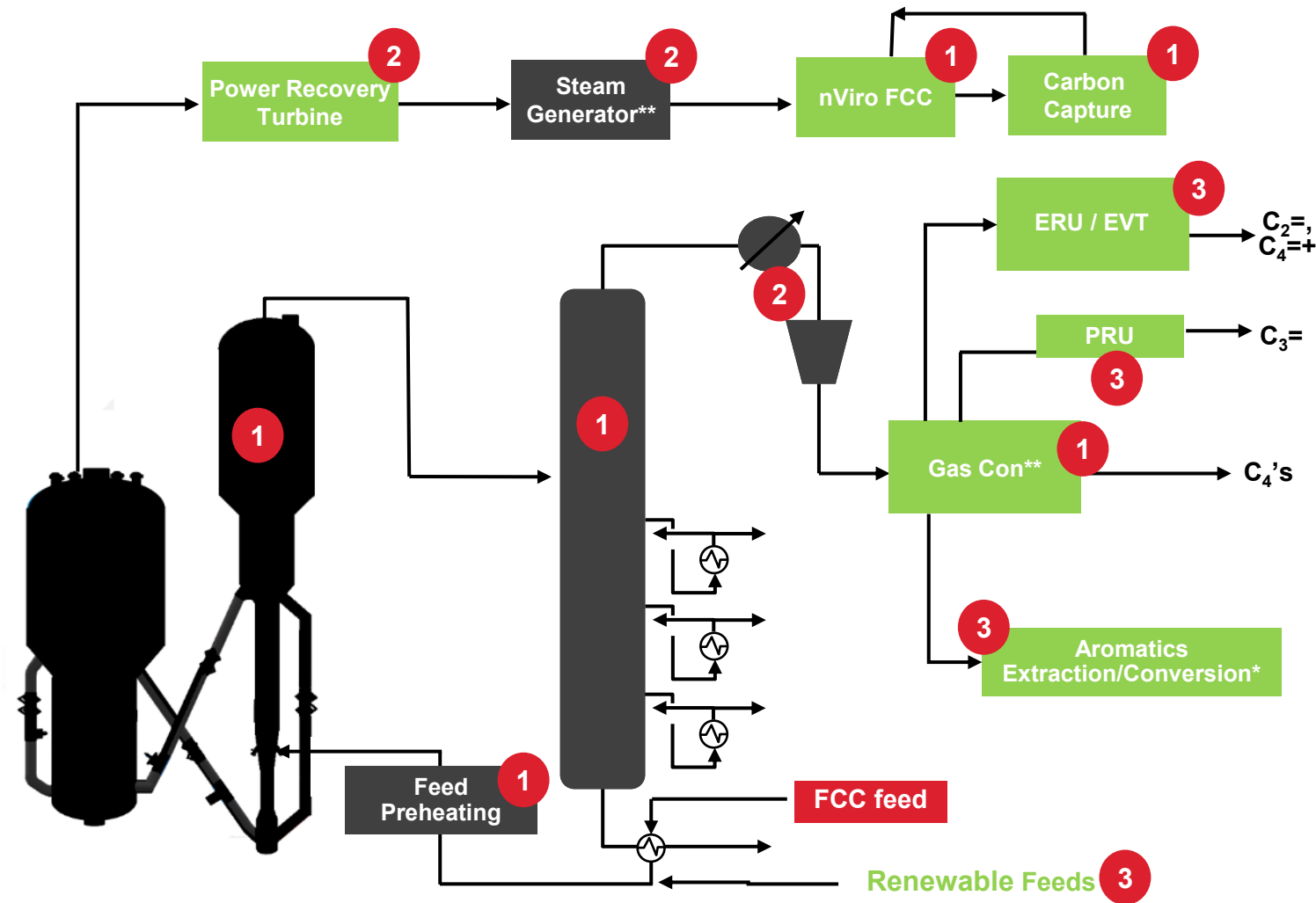
- Flue gas carbon capture
- nViro™ FCC
- Other efficiency Solutions

SCOPE 2

- Power Recovery Turbine
- Flue gas Steam Generation
- Thermal energy harvesting MC OVHD

SCOPE 3

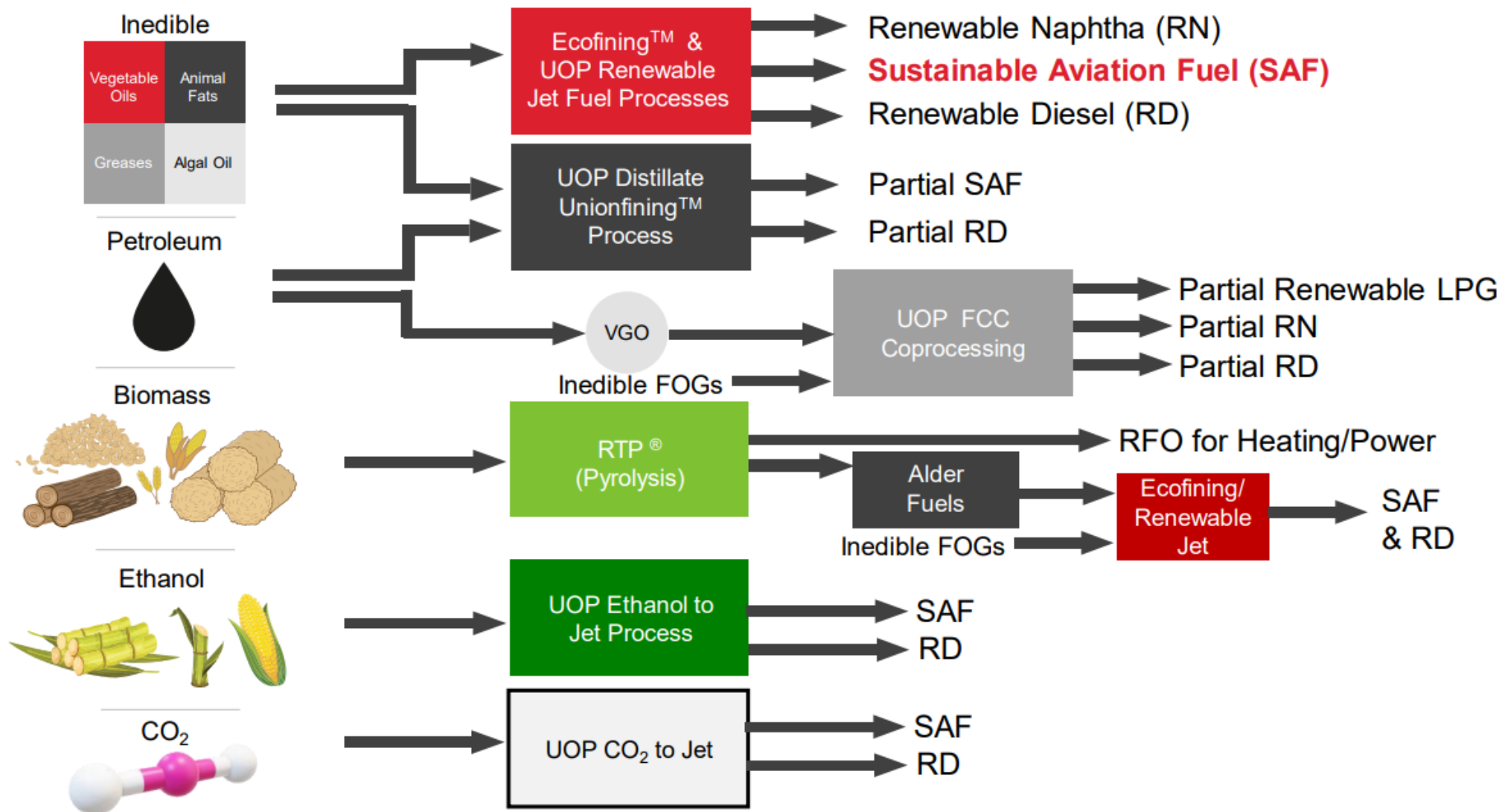
- Renewable Feed Integration
- Increased petchem production ($C_3=$, P.
- Ethylene utilization



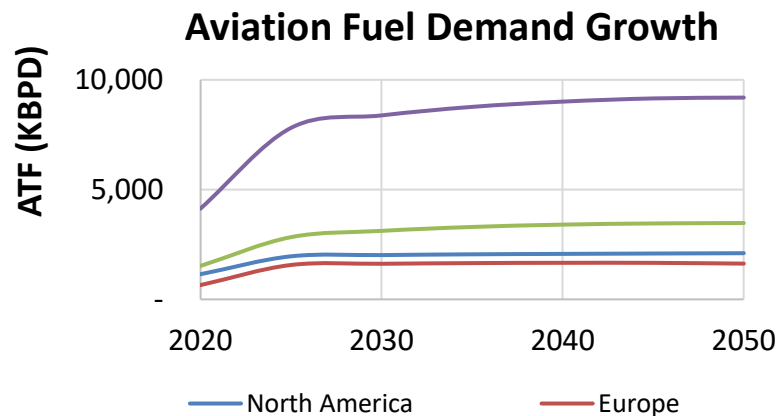
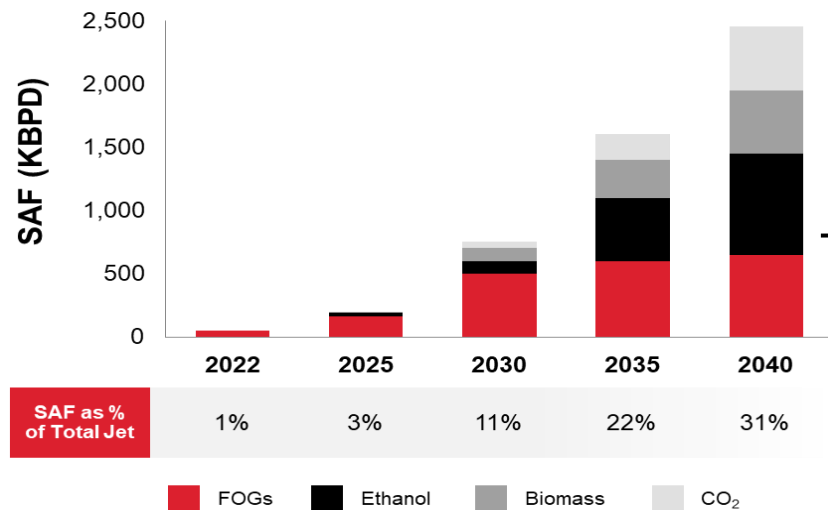
Holistic approach to emissions reduction

UOP RENEWABLE TECHNOLOGY SOLUTIONS

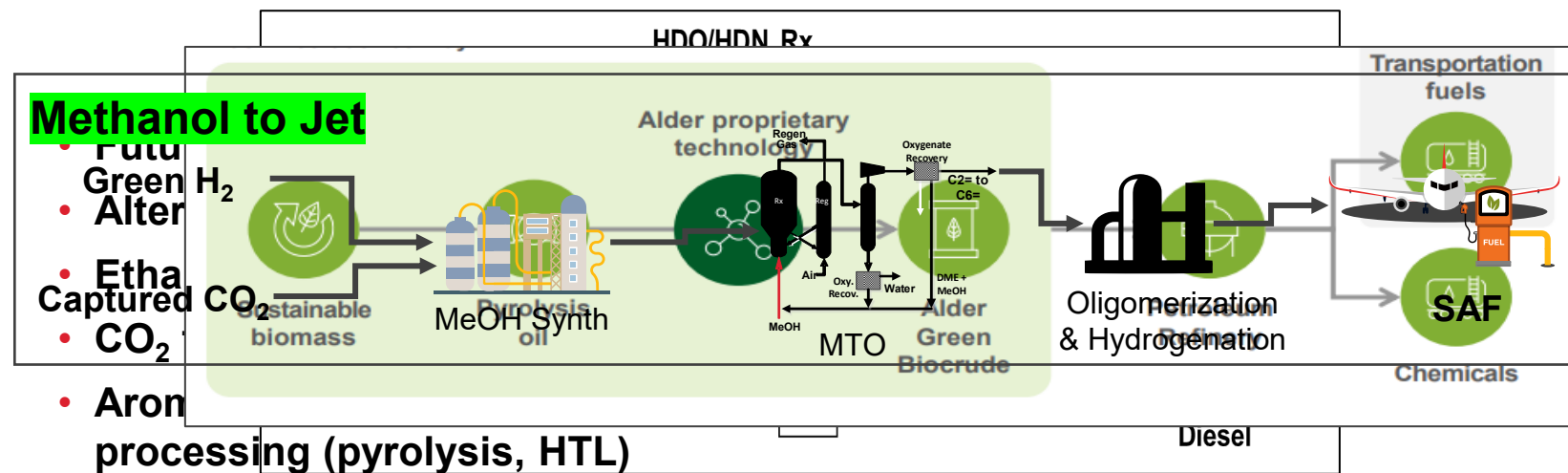
PROVEN TECHNOLOGIES FOR FEEDSTOCK FLEXIBLE DROP-IN FUELS



RENEWABLE FUELS THE ROAD TO 100% SAF



Feed	Route	Max Global SAF production	NCOP	Horizon (production)
FOGS	Hydrotreating	650 kbpd	Med	now
Starches	Alcohol to Jet	885 kbpd	Low	2025
biomass	Alcohol to Jet	up to 7500 kbpd	High	< 5 yrs
biomass	Pyrolysis → upgrade	up to 7500 kbpd	Low	2025
CO ₂	MeOH to Jet	Unlimited	High	2025



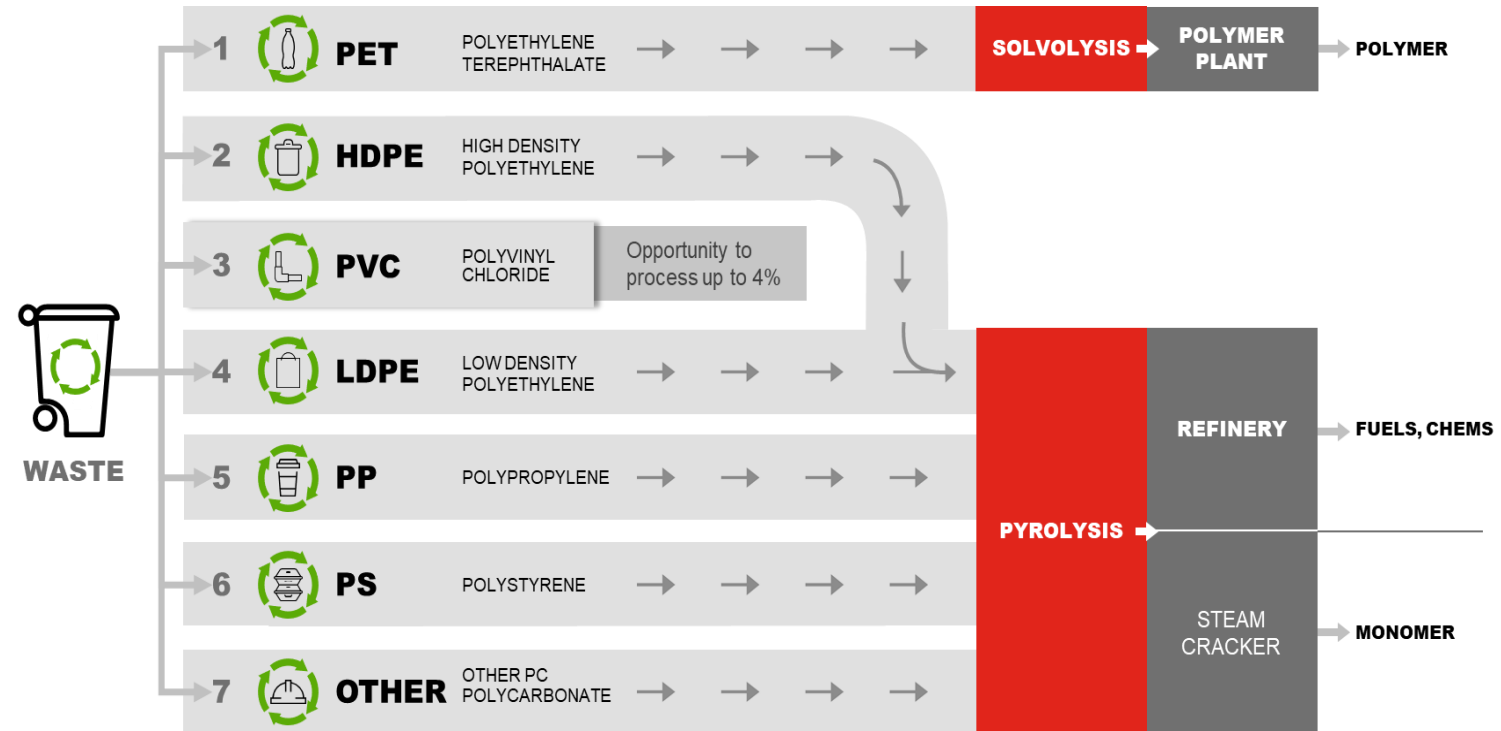
Multiple routes to meet SAF demand growth

HONEYWELL UOP PLASTIC CIRCULARITY

- Honeywell's **UpCycle Process** Technology expands the types of plastics that can be recycled
- Targeting a “**drop-in**” intermediate **recycled polymer oil (RPO)** feedstock viable for Steam Crackers and downstream petrochemical producers
- Honeywell Advanced Recycling aspires to increase **waste plastic circularity from 9% to 90%**

Recycled Polymer Feedstock Properties

Specific Gravity	0.77-0.83
Naphtha (wt%)	20-35%
Distillate (wt%)	45-60%
Gas Oil (wt%)	2-10%
Sulfur (ppmw)	<500 ppm
Nitrogen (ppmw)	<2000 ppm
Chloride (ppmw)	<15 ppm
Olefins (wt%)	25-50%



HONEYWELL UOP CO₂ SOLUTIONS

Chemical Solvents

- **Amine Guard™ & Amine Guard FS Process**
UOP is largest licensor of high concentration MEA-based systems; formulated solvents have lower Opex vs. MEA (> 600 units)
- **Benfield™**
Totally inorganic solvent for pressurized flue gas & industrial processes (> 650 units)
- **Advanced Solvent for Carbon Capture**
Direct CO₂ capture from flue gas for refining, power, steel, cement, and natural gas industries (seeking first commercial scale application)

Physical Solvents

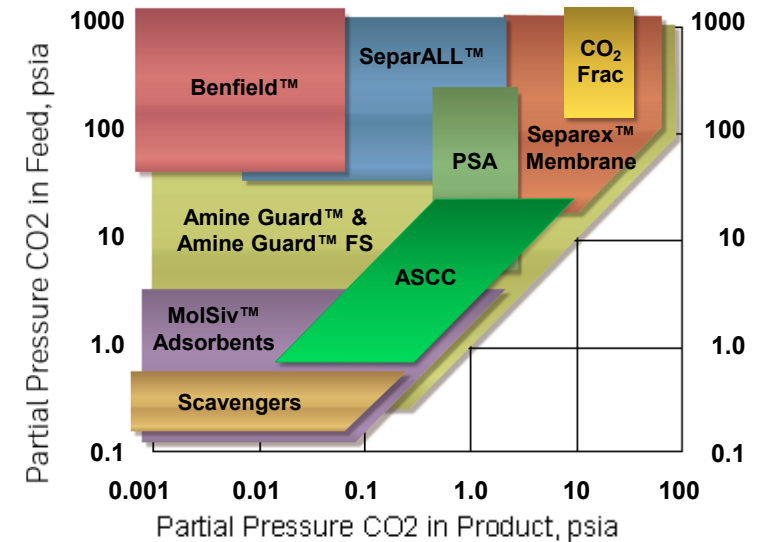
- **SeparALL™ Process**
H₂S/CO₂ selectivity using Selexol solvent for sources containing sulfur or in oxidative conditions (>50 units)

Note: Solvent processes can be used in hybrid cycles with other technologies like PSA, membranes, and cryogenics to optimize CO₂ capture

Adsorbents

- **Polybed™ Pressure Swing Adsorption (PSA) System**
Optimized adsorbents and cycles for CO₂ rejection (>1,150 units, 3 operating in CO₂ application)

Regions of Use for CO₂ Removal Technologies



Cryogenics & Membranes

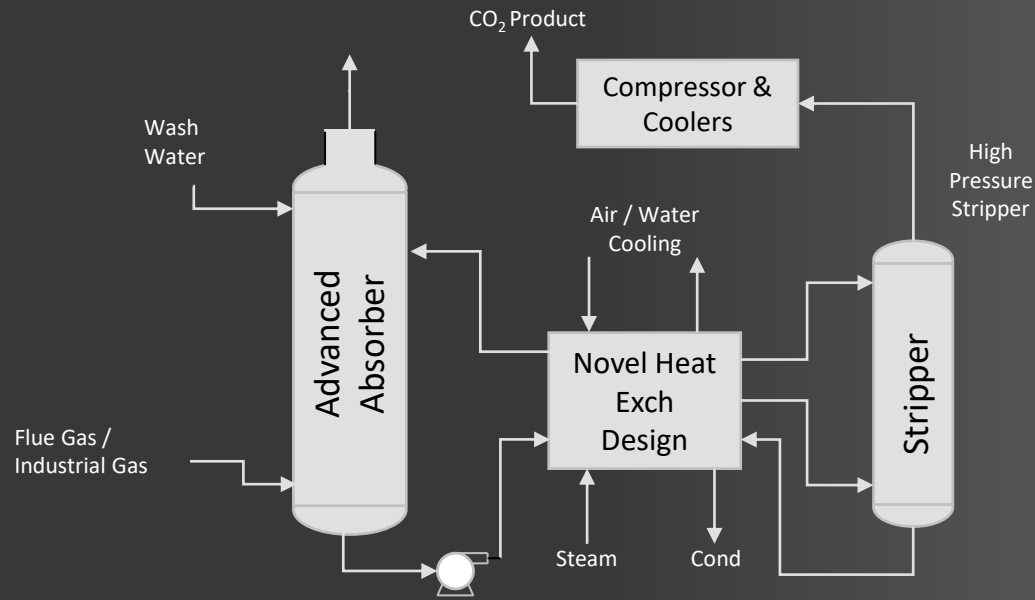
For capture of CO₂ at higher partial pressure

- **Separex™ Membrane Systems**
Significant experience in offshore capturing & sequestering CO₂ (>300 units)
- **Ortloff CO₂ Fractionation**
Not only captures but also provides CO₂ as a high purity liquid product (2 operating units)

UOP is leveraging existing technologies and expertise to deliver differentiation in new applications

Proven Technologies can be used for CO₂ Capture

UOP NEW Technology - Advanced Solvent for Carbon Capture



**Applications Include: Refining, Hydrogen Plants,
Power, Steel, Cement, Natural Gas**

Patented Solvent with Optimal Properties

- High mass transfer rate – smaller absorber
- Low heat of regeneration
- High stability
 - Enables higher pressure stripper & lower solvent makeup rates

Process & Equipment Design

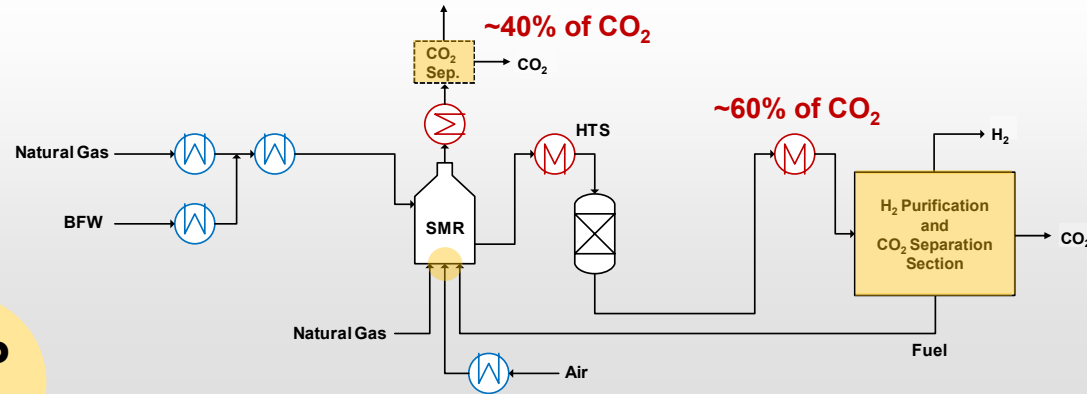
- Advanced absorber with proprietary internals
- Novel heat exchange tailored to solvent
- Reduced solvent regeneration heat duty and lean solvent cooling
- High stripper pressure → reduced CO₂ compression

Development Status

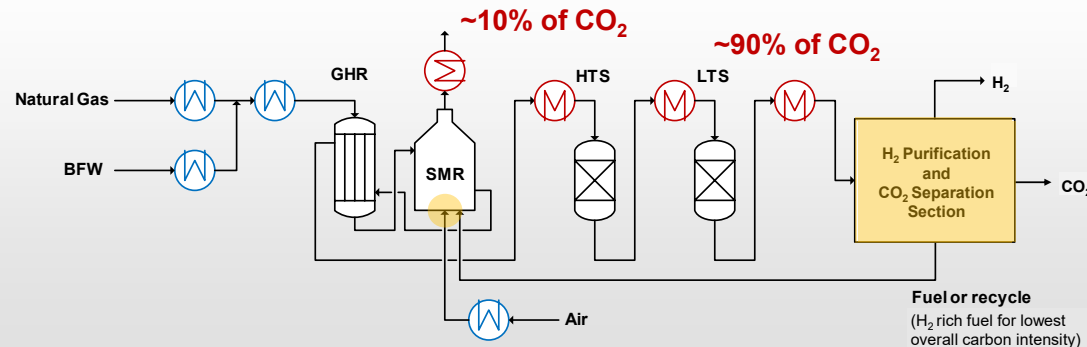
- Technology demonstrated for more than 2000 hours at NCCC with piloting at SRP
- Ready Commercially available technology
- Modular Options up to 150kMTa of CO₂ Captured
- License, Engineering & Solvent Supply for larger capture units

HONEYWELL UOP BLUE H₂ SOLUTIONS

SMR Retrofit with CO₂ Capture



SMR or ATR Optimized for Blue H₂



Tailored syngas section helps provide low-cost CO₂ capture for Blue H₂ solution

- Suitable for any H₂ generation technology or syngas stream including steam methane reforming (SMR), autothermal reforming (ATR), partial oxidation (POX), and gasification
- Optimized configurations using commercially proven UOP process technologies:
- Amine Guard™ FS, Benfield™, SeparALL™, Ortloff CO₂ Fractionation, and Polybed™ PSA
- Customized for H₂ and CO₂ end-use and overall project carbon intensity targets

Blue H₂ solutions customized to help meet sustainability objectives

SUMMARY OF CO₂ CAPTURE TECHNOLOGY OPTIONS

	Pre-Combustion			Post-Combustion
	UOP CO ₂ Fractionation System on Tail Gas	CO ₂ Polybed PSA on Tail Gas	AmineGuard FS on Syngas	Advanced Solvent System on Flue Gas
CO ₂ Recovery from Stream	>99% Liquid product	90-98% Gas phase product	>99% Gas phase product	>95% Gas phase product
Overall CO ₂ Capture	Depends on configuration of H ₂ plant and % of total CO ₂ in pre-combustion stream			95%+
Additional H ₂ Yield	10-20%	NO	NO	NO
Ultra High CO ₂ Purity	YES	NO	NO	NO
Steam Usage	NO	NO	YES	YES
Retrofit	Bolt-on	Bolt-on	May require main PSA retrofit	Bolt-on
Commercial Experience	YES, ref. units in similar applications	YES, ref. units in similar applications	Extensive	Exploring first commercial applications
Cost of CO ₂ Captured*, \$/MT	20–40 (includes H ₂ credit)	35–50	45–60	55-70

*Cost of CO₂ captured includes operating costs, fixed costs, USGC basis annualized capital costs (10%/yr), and product value for additional H₂ production where applicable. Low end of range shown is for \$3/GJ (LHV) and high end of range is for \$6.6/GJ (LHV) natural gas price. CO₂ is provided as high-pressure product at plant battery limits and does not include CO₂ sequestration costs or any tax or credits for CO₂. Cost of CO₂ captured is subject to key variables - stream composition, CO₂ delivery requirement (pressure, purity, phase), utility price set, price of H₂, and geographic location; and is calculated based on internally developed models.

Best option depends on project requirements

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UOP TECHNOLOGY DEVELOPMENT IN R&D

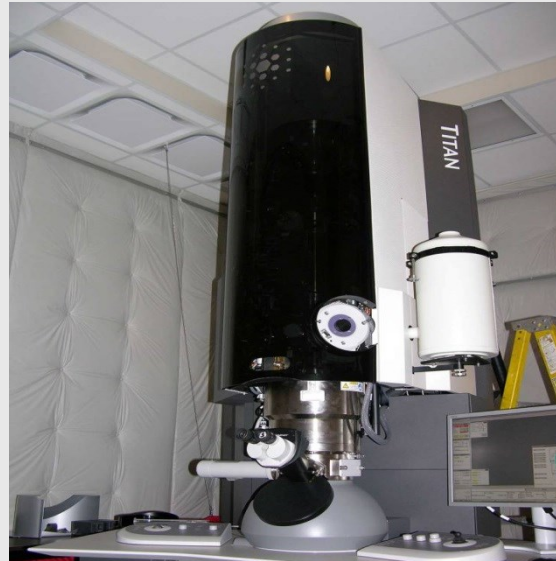
Experienced Team

- 700 scientists and engineers from nearly 40 countries
- More than 400 employees have one patent, 18 have more than 50 patents



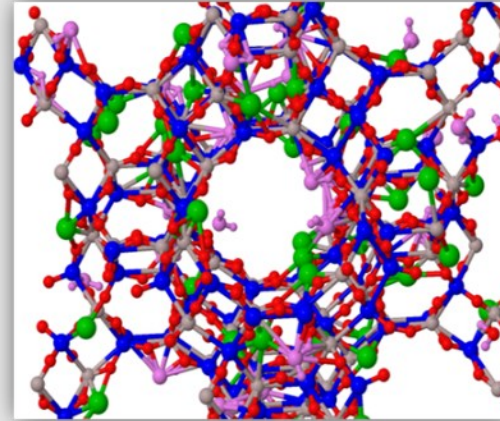
Cutting Edge Tools

- 150 pilot and semi-works plants in 8 sites globally
- Over 3.5 billion data points and 1000 off-line samples per day



- High-throughput screening tools
- Advanced microscopy and materials characterization

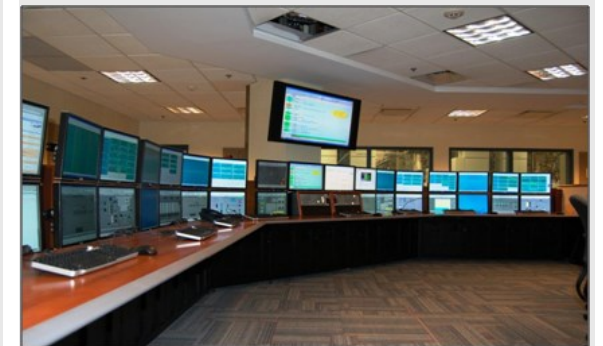
Unique Capability Set



- Materials discovery
- Catalyst invention
- Adsorptive and Membrane separations
- Process optimization and scale-up
- Proprietary equipment designs
- Modular plant delivery

Global Innovation

- Des Plaines, IL
- McCook, IL
- Mobile, AL
- Baton Rouge, LA
- Shreveport, LA
- Gurgaon, India
- Hiratsuka, Japan
- Shanghai, China
- Zhangjiagan, China



UNIQUE TEAM AND CAPABILITIES ENABLE OUR SUCCESS

HONEYWELL

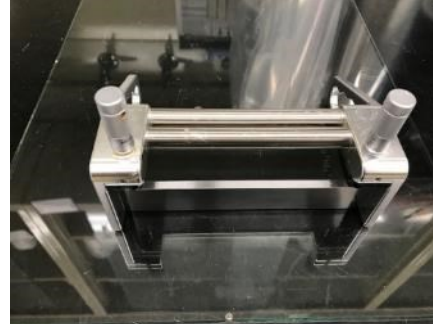
UOP GREEN H₂ R&D CAPABILITIES

- **Polymers/Membranes/CCMs**

- Polymer synthesis
- Membrane fabrication
- Conductivity/stability tests
- Ex-situ H₂ flux measurement
- CCM coating
 - Spray coating
 - Mayer rod coating
 - Slot die coating



Polym./cat. syn.



Manual mem. casting



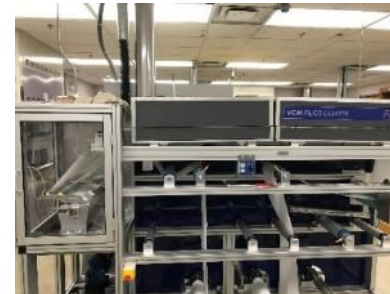
Contin. mem. casting



PEM stability units

- **Catalysts and Electrodes**

- Catalyst synthesis and characterization
- Electron conductivity measurement
- Benchtop electrochemistry



Contin. mem. coating



Spray coater



PEM/AEM Electrolyzers

- **PEM and AEM Electrolyzers**

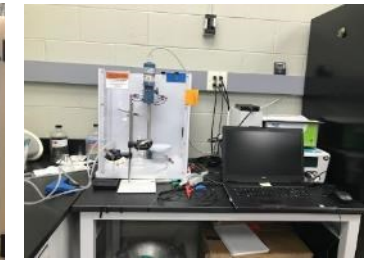
- PEM electrolyzer test units
- AEM electrolyzer test unit
- PEM stability and robustness test units
- AEM stability and robustness test units (in progress)



H⁺/OH⁻ measurement



H₂ permeation



Benchtop E-chem.

TECHNOLOGY FOR THE ENERGY TRANSITION

Decarbonization Challenge will require many solutions

Decarbonization will require a balancing act with profitability

Renewable fuels are here now, but need to greatly expand

Renewable chemicals are an opportunity, but can they compete with fuels?

Clean H₂ and Carbon Capture are important parts of the picture.

Thank you!!