Honeywell
UOP



EXPERT HELP ON YOUR ROAD TO NET ZERO

Tailored Carbon Capture Solutions from Honeywell UOP



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INTRODUCTION

CARBON CAPTURE SOLUTIONS ARE CRITICAL IN THE PATH TOWARD NET ZERO

Action must be taken to address the climate crisis, and carbon capture is key to lowering emissions and driving business outcomes.

Transforming the global economy to achieve net-zero greenhouse gas emissions by mid-century is essential to avoid dangerous effects of climate change. CCUS is an important lever in limiting the global rise in temperature to less than 1.5 degrees Celsius. Without it, in fact, it will be practically impossible to reach shared climate goals while achieving business outcomes.

Carbon capture is a broad, complex, and evolving field, and it is urgent that industries implement and scale their climate solutions. CCUS usage needs to grow by 120 times by 2050 for nations to achieve their net zero commitments, with 70 to 100 new projects per year required to get there. In order for successful carbon capture projects to go forward we need ready now technologies, a price on carbon, and infrastructure and permitting to move and permanently sequester CO_2. Many companies and governments have set bold carbon-neutral pledges for as early as 2030—a deadline that is rapidly approaching.

To reach these goals, CCUS is a viable option to consider, with proven technologies are available today to significantly reduce emissions and growing policy support to encourage deployment.

CARBON CAPTURE CAPACITY MUST INCREASE MORE THAN 20 TIMES TO ENABLE CAPTURE OF 840 MILLION METRIC TONS PER YEAR OF CO_2 BY 2030 TO MEET GLOBAL EMISSION GOALS

– International Energy Agency[1]

CUSTOM SOLUTIONS FOR A UNIVERSAL PROBLEM

As urgent as it is, there are significant challenges in CCUS. National and corporate net-zero policy ambitions are not always clearly defined, with many legal, regulatory, and financial frameworks still being established. It is difficult to rapidly create a full ecosystem that embodies all elements of carbon capture amid so much uncertainty.

The transition is especially important for carbon-intensive markets such as power, steel, cement, refining, petrochemicals, hydrogen and natural gas processing. Reducing environmental impact has been difficult and technology is continuously evolving and improving.

Honeywell UOP can be your trusted advisor in finding your best solutions. We have a full suite of pre- and post-combustion technologies that can be custom engineered to your needs. Let us help you execute your road map towards net zero.

Our support spans the project life cycle from conceptual and feasibility studies, though Front End Engineering Design (FEED), commissioning startup and services during the operational life. Honeywell can deliver technologies through basic engineering packages as well as modular solutions to meet your needs.

CCUS IS A KEY LEVER IN REDUCING GLOBAL EMISSIONS, ACCOUNTING FOR 15% OVERALL EMISSIONS REDUCTIONS IN THE IEA SUSTAINABLE DEVELOPMENT SCENARIO

Source: IEA Energy Technology Perspectives



THE HONEYWELL UOP COMMITMENT TO INNOVATION

Honeywell UOP has a track record of innovation, a broad portfolio of carbon capture technologies and decades of experience helping industry leaders move towards a lower carbon footprint.

To help reach your climate goals, Honeywell UOP can deliver a variety of industry-leading CCUS solutions, tailored for individual customers from a variety of industries. Our experts can work with you to determine the best solution to meeting your particular CO_2 emission goals.

Our solutions include physical and chemical solvents, adsorbents, membranes, and cryogenics. Additionally, Honeywell offers a range of effective emissions monitoring and controls quicker action.

For more than a century, Honeywell's commitment to innovation has helped businesses overcome the most difficult problems of their era – and today, we're helping organizations like yours realize the social and economic benefits of operating more sustainably. We offer expert guidance and solutions to help you chart out a viable carbon reduction plan that works for your business.



5.700 SUSTAINABILITY PROJECTS COMPLETED SINCE 2004,

WITH MORE THAN **$100M IN ANNUALIZED SAVINGS**





APPROXIMATELY **60% OF R&D SPEND** IS DIRECTED

TOWARD ESG-ORIENTED OUTCOMES

WE ARE COMMITTED TO ACHIEVING CARBON NEUTRALITY

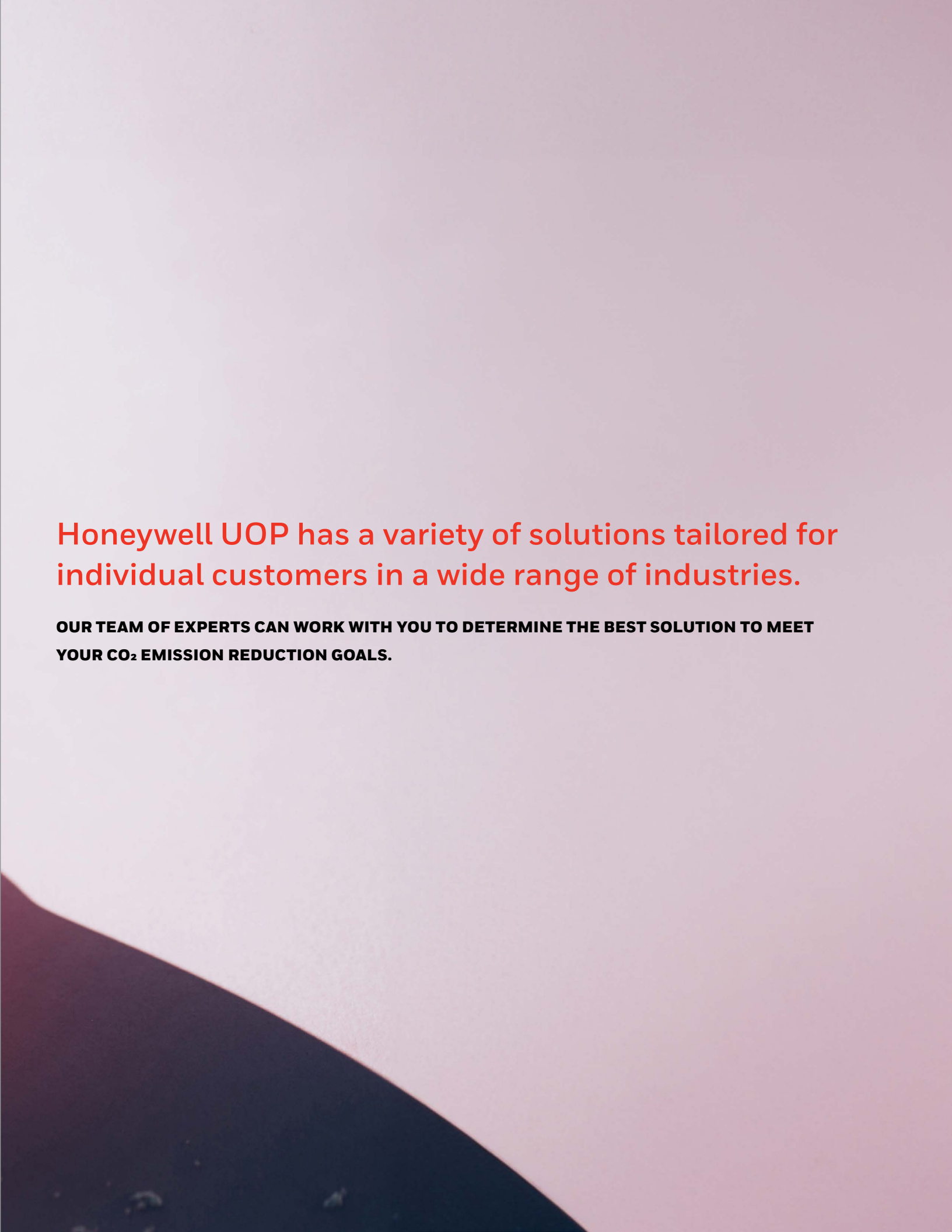
IN OUR FACILITIES AND OPERATIONS **BY 2035**





SOLUTIONS

SOLUTIONS THAT CAN MAKE A DIFFERENCE: CHEMICAL AND PHYSICAL SOLVENTS, ADSORBENTS, AND CRYOGENICS AND MEMBRANES



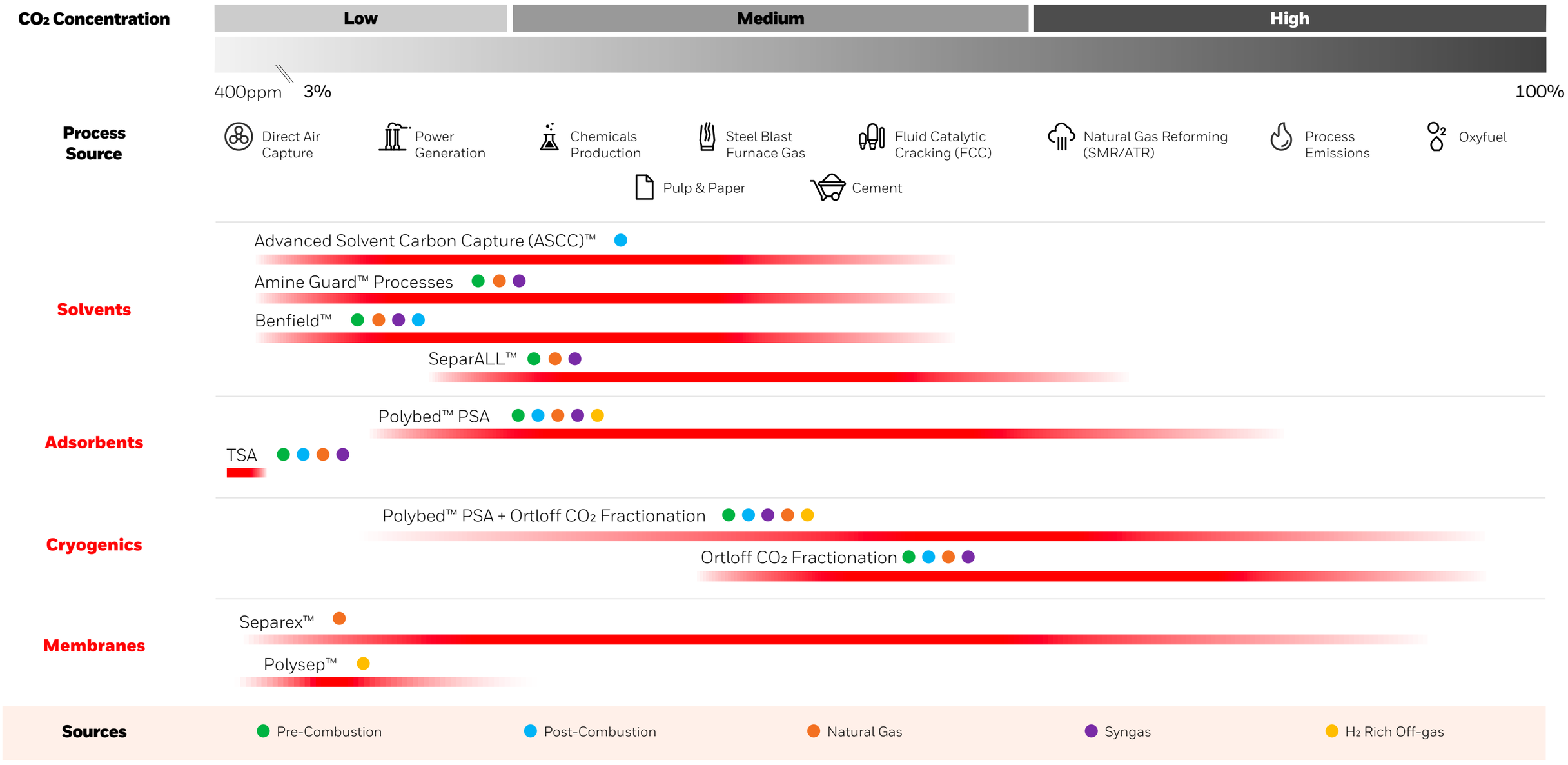
Honeywell UOP has a variety of solutions tailored for individual customers in a wide range of industries.

OUR TEAM OF EXPERTS CAN WORK WITH YOU TO DETERMINE THE BEST SOLUTION TO MEET YOUR CO_2 EMISSION REDUCTION GOALS.

SOLUTIONS

Honeywell UOP offers a wide range of CCUS solutions for pre-combustion, post-combustion, and emissions tracking applications.

Industries emit CO_2 in a wide range of concentrations due to the variety of fuels and processes used in their operations. Honeywell UOP's portfolio of carbon capture solutions can be tailored for project needs such as plot space requirements, utilities consumption, removal efficiency rates, and CO_2 product specs.



CHEMICAL SOLVENTS

ADVANCED SOLVENT FOR CARBON CAPTURE (ASCC)

The new Advanced Solvent Carbon Capture (ASCC) technology captures CO_2 from flue gas, so it can be utilized or stored instead of entering the environment.

- **Application**: Designed for applications of low concentration high volume gases such as power generation, cement, steel, industrial (boilers & fired heaters), pulp and paper, fluid catalytic crackers & more.
- **Description**: Flue gases are scrubbed out in an absorber column using a proprietary solvent (AZ-108). The rich solvent flows through a patented series of heat exchange process and is stripped out in a high pressure stripper, where the lean solvent is recirculated to the absorber for additional CO_2 absorption.
- **Technology Maturity**: ASCC is widely considered TRL 7, and has been in development and scale up for over 20+ years. Multiple feasibility studies & FEED studies are on going at this time.
- **Advantages**: ASCC can enable 30% lower capital expenditures on absorber(s), low energy of regeneration requirements (2.1 Gj/MT of CO_2), stripping at high pressure (6-8 barg) eliminates compression requirements, saving capital and operation expenditures.

AMINE GUARD™ PROCESSES

Honeywell UOP's Amine Guard processes use amine solvent for high-concentration, MEA-based systems. Their high-efficiency designs capture CO_2 with high removal rates.

- **Application**: Designed for applications of high volume gases where removal of CO_2 and H2S are present such as natural gas, syngas, gasification, blast furnace gases, & more removing and purifying gases to meet specifications as appropriate.
- **Description**: Acid or flue gases are scrubbed out in an absorber column using UCARSOL solvent for the application. The now rich solvent flows from the bottom of the absorber through heat exchange process and is stripped out in a stripping tower, where the lean solvent is then recirculated to absorber for additional CO_2 absorption. Waste heat can commonly be utilized to provide the stripping steam.
- **Technology Maturity**: Amine Guard and Amine Guard FS is considered TRL 9, and has been in commercial operation since the 1990s with over 400 units worldwide.
- **Advantages**: Selecting the optimum UCARSOL solvent for the situation can optimize regeneration energy requirements. Low energy two stage configurations can also be implemented where appropriate.

CHEMICAL SOLVENTS

BENFIELD ACT-1

Benfield ACT-1 is an inorganic solvent for highly oxidative streams. It uses proprietary technology developed by Honeywell UOP for removal of CO_2 from flue gases, suitable for power plants and other industrial facilities (i.e., natural gas, sygnas, ethylene oxide, and DRI plants).

- **Application**: Designed for applications of high volume gases where CO_2 and H_2S are present, such as natural gas, ammonia syngas, hydrogen sygnas, gasification, flue gases, partial oxidation, & more removing and purifying gases to meet specifications as appropriate.

- **Description**: Flue or acid gases are pressurized and scrubbed out in an absorber column using potassium carbonate solution (with Benfield additives to improve performance and prevent corrosion) solvent. The now rich solvent is regenerated by reducing its pressure and stripping in a tower. The lean solvent is then recirculated to absorber for additional CO_2 absorption. Waste heat can commonly be utilized to provide the stripping steam.

- **Technology Maturity**: Benfield is considered TRL 9, and has been in commercial operation since the 1960s with over 700 units worldwide.

- **Advantages**: LoHeat and HiPure versions are available to reduce energy requirements or reduce flue and acid gases to very low levels. Selecting the optimum additives for the potassium carbonate for the situation can optimize regeneration energy requirements.



CONTACT A HONEYWELL UOP REPRESENTATIVE FOR MORE INFORMATION.



SOLUTIONS

PHYSICAL SOLVENTS

SEPARALL™ PROCESS

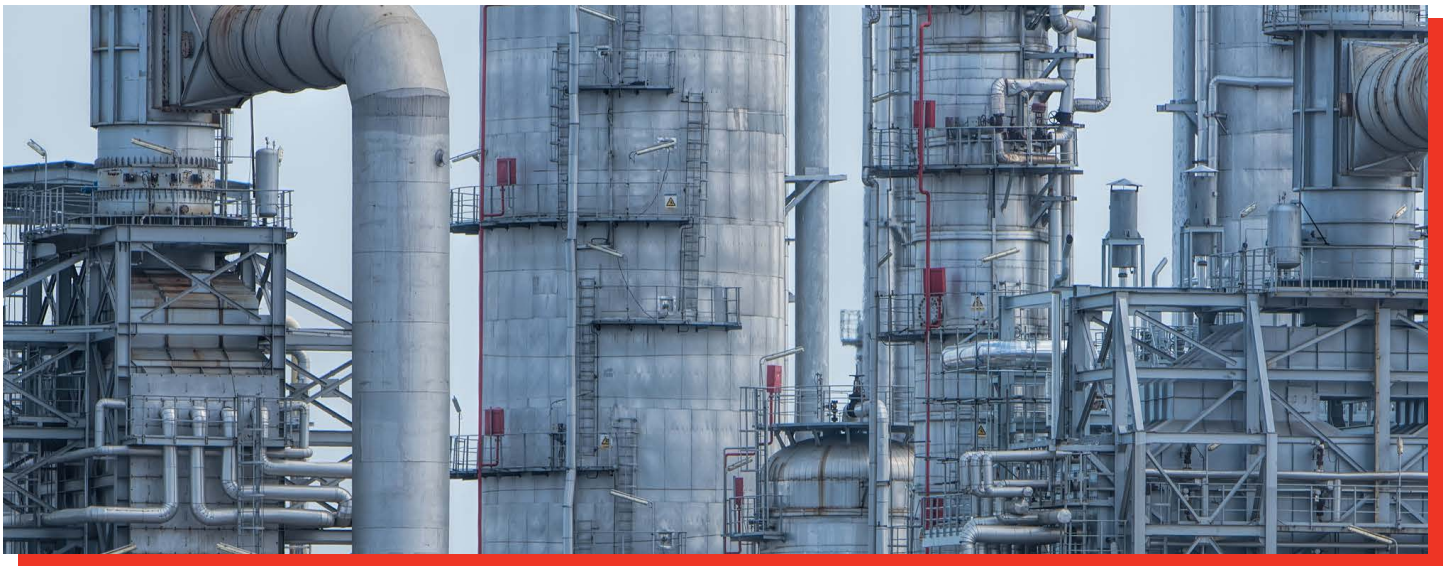
A key technology in enabling chemicals and fuels, SeparALL™ is a process that uses the Selexol™ physical solvent to selectively remove carbon dioxide (CO_2) from high-pressure gas streams. It is a proven, versatile, efficient and reliable technology used for carbon capture for many years. Efficiency of the SeparALL™ process for carbon capture is typically very high, with removal efficiencies of up to 99%.

- **Application**: Designed for applications on high pressure gas streams to selectively remove CO_2, H_2S, and carbonyl sulphide. Applicable processes include coal or biomass gasification, natural gas, ammonia syngas, hydrogen sygnas, hydroprocessing upgraders, synthetic natural gas, chemicals, fertilizer and molecular sieve regeneration in CNG, LNG, and GTL front end treating removing and purifying gases to meet specifications as appropriate.

- **Description**: The SeparALL Process utilizes Selexol physical solvent comprised of dimethyl ether of polyethlene glycol, where partial pressure is the key driving force. Feed gas is at an elevated pressure, where in the H_2S and CO_2 is removed in an absorption column, rich solvent is run through heat exchange and regenerated. Lean solvent is recirculated for more absorption.

- **Technology Maturity**: SeparALL is considered TRL 9, and has been in commercial operation since the 1960's with over 110 units world wide.

- **Advantages**: Selexol solvent is chemically inert and not subject to degradation.



CONTACT A HONEYWELL UOP REPRESENTATIVE FOR MORE INFORMATION.

ADSORBENTS

POLYBED™ PRESSURE SWING ADSORPTION (PSA) SYSTEM

The Polybed™ Pressure Swing Adsorption (PSA) System is optimized for H_2 purification and CO_2 rejection. It uses a series of pressurization and depressurization cycles with a bed of adsorbents to selectively provide high-pressure and high-purity hydrogen from a wide variety of gas streams. PSAs can also be selective for CO_2 purification.

- **Application**: Pressure Swing Adsorption (PSA) systems have mainly been designed for applications for production of high purity hydrogen from syngas. PSAs can also be designed to purify CO_2 in post combustion capture service as well as CH_4, He, N_2, and Cl purification.

- **Description**: PSA purification is based on advanced pressure swing technology. Units contain between 4 to 16+ absorber vessels, where one or more vessels is on adsorption step whiles others are in various stages of regeneration. All systems use advanced proprietary adsorbents and patented void-gas recovery techniques to provide maximum product recovery.

- **Technology Maturity**: PSA is considered TRL 9, and has been in commercial operation since 1966 with over 1150 units worldwide.

- **Advantages**: Operation is automatic, with push button startup and shutdown, and on-stream factors in excess of 99.8%. Units are compact requiring small plot space, and units are skid mounted and modularized to mitigate cost and installation time. All impurities for H_2 production are removed in a single step.



CONTACT A HONEYWELL UOP REPRESENTATIVE FOR MORE INFORMATION.

CRYOGENICS & MEMBRANES

ORTLOFF CO_2 FRACTIONATION

Ortloff CO_2 fractionation is an all-electric solvent-free option that captures CO_2 as a high-purity liquid product.

- **Application**: designed for applications of recovery of natural gas liquids (NGL), liquified petroleum gas (LPG), liquified natural gas production (LNG), refinery off gas and carbon capture to meet pipeline specifications.
- **Description**: Cryogenic fractionation technology uses temperature and pressure controls to separate materials of varying boiling points and isolate specific chemicals from a given industrial process stream. When applied to CCUS, CO_2 is condensed out while the rest of the process stream remains in a gaseous state. The Ortloff CO_2 Fractionation system uses a proprietary blend of refrigerants to manage the temperature of the system, minimizing the amount of equipment required and optimizing the required power for the process.
- **Technology Maturity**: Cryogenic fractionation is considered TRL 9, and has been in commercial operation since 1976 with over 400 units in operation.
- **Advantages**: Cryogenic fractionation is an all electrically driven technology, produces a high purity product, and has lower equipment counts relative to amine solutions which reduce plot area.



CONTACT A HONEYWELL UOP REPRESENTATIVE FOR MORE INFORMATION.

CRYOGENICS & MEMBRANES

SEPAREX™ MEMBRANE SYSTEMS

Separex™ membrane systems are designed for high, partial-pressure CO_2 capture in industrial applications. They are compact and lightweight, making them easy to install and operate, and can be used for a wide variety of gas streams.

- **Application**: designed for applications for removing CO_2, H_2S, and water vapor from natural gas to meet pipeline specification for onshore and offshore locations. Hydrogen and Helium purification and upgrading of low-GHV gas for fuel. De-bottlenecking existing solvent scrubbing systems or providing bulk removal upstream of new or existing installations. Hydrocarbon recovery from enhanced oil recovery floods for CO_2 reinjection and landfill and biogas purification.

- **Description**: Separex membrane systems are dry systems requiring minimal moving parts. Feed gas is conditioned (MemGuard™ is utilized when feed streams are heavy or require dewpoint control) and can treated in one or two stage systems. Gases are pressurized and pass over polymeric membrane rapidly separating CO_2, H_2S, and water vapor permeate and are collected at low pressure. High value methane, ethane and other hydrocarbons and nitrogen are collected for sale. In a two stage system the permeate from the first stage is compressed for further treatment and recovery.

- **Technology Maturity**: Separex is considered TRL 9, and has been in commercial operation since 1981 with over 150 units worldwide.

- **Advantages**: Separex is designed for operational simplicity, requiring minimal rotating equipment, no chemical reagent or replacement, and minimal services. Technology is delivered on prefabricated skids to minimize cost and plot space.



CONTACT A HONEYWELL UOP REPRESENTATIVE FOR MORE INFORMATION.

CRYOGENICS & MEMBRANES

POLYSEP™

Polysep™ is designed for efficient hydrogen recovery and purification; it features a pressure-driven process that minimizes moving parts and operator involvement, making it an innovative solution with applications in various industries.

- **Application**: Hydrogen recovery and purification or rejection from various refining, petrochemical and chemical process streams. Feed streams include catalytic reformer off gas, hydrotreater and hydrocracker purge gases, and fluid catalytic cracker off-gas. Chemical and Petrochemical feed streams include ethylene off-gases, ammonia plant purges, methanol plant off-gases, synthesis gas streams from steam reforming, partial oxidation and other gasification technologies. Additional uses include synthesis gas ratio adjustment and carbon monoxide recovery.

- **Description**: The Polysep system is based on state of the art, composite hollow fiber polymer membrane technology. The hollow fibers are packed in a proprietary counter-current-flow bundle configuration that maximizes the separation driving force and minimizes required membrane area. The process is pressure driven and requires minimum moving parts, utilities or operator intervention. The feed pretreatment equipment typically includes a knockout drum for bulk liquid removal, a coalescing filter for particulate and entrained liquid removal, and a preheater to optimize the membranes performance.

- **Technology Maturity**: Polysep is considered TRL 9, and has been in commercial operation since 1985 with over 85 units in operation. The largest unit processes more than 350MMscfd of synthesis gas.

- **Advantages**: Polysep operation features include automatic startup, capacity control, product purity control, auto depressurization and turn-up / turn-down. Turn-down capacity utilizes a patented control strategy integrated with Honeywell Distributed Control Systems (DCS). Once installed, a membrane system can reach steady-state operation from cold startup in a few hours with on-stream factors over 99.8% relative to unplanned shutdowns. Polysep can be easily scaled from just a few modules to over 100 modules.



CONTACT A HONEYWELL UOP REPRESENTATIVE FOR MORE INFORMATION.



INDUSTRIES

HONEYWELL UOP'S CO_2 SOLUTIONS CAN HELP MAKE AN IMPACT WITHIN A WIDE RANGE OF INDUSTRIES WHERE DECARBONATIZATION HAS BEEN A CHALLENGE.

CEMENT

Honeywell UOP's carbon capture portfolio offers the cement industry options for a wide range of CO_2 concentrations, utility sourcing, and plot space constraints to help meet emission reduction targets.

We offer solvent, PSA, PSA + cryogenic, and cryogenic CO_2 capture options, which can be tailored to your needs based on:

- Varying CO_2 concentrations (normal operation >oxygen enrichment)
- Utility sourcing (all-electric or natural gas)
- Plot space constraints
- Level of automation

Our PSA and cryogenic solutions are all-electric, highly automated, and can produce a high-purity liquid product ready for transport. Synergies between the PSA and cryogenics can lead to cost savings.

Advanced Solvent Carbon Capture enables more efficient capture of lower CO_2 concentration cement kiln flue gas and can be made fully electric to meet utility availability.



FOR MORE ON THE SOLUTIONS FOR THE CEMENT INDUSTRY, CONTACT A HONEYWELL UOP REPRESENTATIVE

POWER

Power generation accounts for roughly 40% of global CO_2 emissions and Honeywell UOP's novel Advanced Solvent Carbon Capture (ASCC) provides an effective path to reduce the environmental impact of generators.

Power and utilities generate large volumes of low concentration flue gas for which ASCC enables a lower cost of capture. ASCC reduces parasitic energy loads, with a patented heat exchange design that leads to lower energy consumption for solvent regeneration.

ASCC is backed by:

- 20+ years of ongoing development and testing
- 8,500 hours of testing at the National Carbon Capture Center on flue gas range 2-15%
- Honeywell provides extensive warranty and performance guarantees
- Honeywell has designed 1,200+ solvent-based units



FOR MORE ON THE SOLUTIONS FOR THE POWER INDUSTRY, CONTACT A HONEYWELL UOP REPRESENTATIVE

REFINING, PETROCHEMICAL, & GAS PROCESSING

A full portfolio of carbon capture technologies from Honeywell UOP serve the refining, petrochemical and gas processing industries. We can support decarbonization efforts through new builds or retrofits with a unique perspective on optimal integrations with your existing process units.

We offer multiple technologies that can easily be integrated into current operations. Our solutions and services provide a range of options for multiple emissions points looking to efficiently and economically lower the carbon intensity of the fuels and products they produce. Honeywell UOP is poised to be your trusted advisor in developing a road map to a lower carbon future.



FOR MORE ON THE SOLUTIONS FOR THE REFINING, PETROCHEMICAL, & GAS PROCESSING INDUSTRY, CONTACT A HONEYWELL UOP REPRESENTATIVE

HYDROGEN & DERIVATIVES

Honeywell UOP's integrated solutions enable a tailored approach to carbon intensity, hydrogen purity, and other project requirements, delivering proven, reliable, and flexible solutions.

As the world's largest supplier of hydrogen PSA solutions to the market, we can optimize to meet your hydrogen purity and recovery targets. Designs are capable of meeting 99.99% H_2 purity for a variety of end use applications.[2] We have sold over 1,150 PSA units in services such as hydrogen purification, ethylene off gas recovery, refinery off gas recovery, ammonia, coke oven gas, gasification, methanol off gas, and syngas purification.

PSA units can also be deployed in carbon capture, ammonia cracking purification, and green hydrogen purification.

- Carbon Capture PSAs are typically utilized on hydrogen PSA tail gases where a low CAPEX solution is needed
- Ammonia Cracking PSAs are used in purifying hydrogen from ammonia that has been cracked when used as an energy carrier
- Green Hydrogen PSAs can purify hydrogen to fuel cell requirements after production from an electrolyzer



FOR MORE ON THE SOLUTIONS FOR THE HYDROGEN & DERIVATIVES INDUSTRY, CONTACT A HONEYWELL UOP REPRESENTATIVE

PULP & PAPER

Honeywell UOP's novel Advanced Solvent Carbon Capture (ASCC) technology is a superior and efficient option for the pulp and paper industry.

Pulp and Paper is a unique opportunity for generation of Carbon Dioxide Removal (CDRs) credits as most feedstock originates from biomass or renewable sources. This supports additional revenue streams to make commercially viable projects. Challenges can arise from contaminants in the flue gases of black liquor boilers, but with appropriate pretreatment ASCC is viable technology option.

ASCC is backed by:

- 20+ years of ongoing development and testing
- 8,500 hours of testing at the National Carbon Capture Center on flue gas range 2-15%
- Honeywell provides extensive warranty and performance guarantees
- Honeywell has designed 1,200+ solvent-based units



FOR MORE ON THE SOLUTIONS FOR THE PULP & PAPER INDUSTRY, CONTACT A HONEYWELL UOP REPRESENTATIVE

INDUSTRIAL & MANUFACTURING

Industrial operations need to address large and predictable amounts of low-concentration carbon emissions in a cost-efficient manner.

Many industrial and chemical processes burn fossil or bio based fuels to generate the necessary heat for process reactions. Carbon capture and oxy-fuel on fired heaters and boilers are part of multi component strategy for mitigating difficult to abate emissions, providing a pathway for lower carbon products we use everyday.

ASCC is backed by:

- 20+ years of ongoing development and testing
- 8,500 hours of testing at the National Carbon Capture Center on flue gas range 2-15%
- Honeywell provides extensive warranty and performance guarantees
- Honeywell has designed 1,200+ solvent-based units



FOR MORE ON THE SOLUTIONS FOR THE INDUSTRIAL & MANUFACTURING INDUSTRY, CONTACT A HONEYWELL UOP REPRESENTATIVE

STEEL

Honeywell UOP is a single point of contact for carbon capture and hydrogen recovery solutions for the steel industry, which accounts for about 7% of global CO_2 emissions.

Steel production represents 7% of global CO_2 emissions, and as more infrastructure is built, steel consumption will continue to grow.[3] Carbon capture provides opportunities for integrated steel making to significantly reduce blast furnace gas emissions while making future plans to transition to electric arc furnace (EAF) or hydrogen based direct reduced iron (DRI).

In some cases when treating steel production flue gases, hydrogen can be recovered and sold as a valuable co product driving improved economics in project development. We are uniquely positioned with these technologies in our portfolio for an overall integrated flow scheme of carbon capture and hydrogen recovery.

Multiple technologies are viable for carbon capture such as ASCC, PSA + Ortloff Cryogenic Fractionation, and standalone Ortloff Fractionation, each with tradeoffs.

In addition, Honeywell has a portfolio of solutions that offers flexibility and the ability to capture further value by recovering H_2 as a fuel.



FOR MORE ON THE SOLUTIONS FOR THE STEEL INDUSTRY, CONTACT A HONEYWELL UOP REPRESENTATIVE

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LEARN MORE ABOUT HOW TO GET STARTED AT
UOP.HONEYWELL.COM

youtube.com/Honeywell

linkedin.com/Company/Honeywell-ESS

[1] IEA Report Extract: CCUS in the transition to net-zero emissions: https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-in-the-transition-to-net-zero-emissions

[2] Based on Honeywell UOP PSASIM tool results for hydrogen purity level.

[3] IEA (2020), Iron and Steel Technology Roadmap, IEA, Paris https://www.iea.org/reports/iron-and-steel-technology-roadmap, Licence: CC BY 4.0

[4] Based on the EPA's GHG equivalency calculator comparing nearly 7 million tons of CO_2 per year with gasoline-powered passenger vehicles on the road.

[5] CO_2 equivalent emissions is a calculated value based on the combined carbon compounds emitted from the Hydrogen production and Carbon Capture equipment plus the combined carbon compounds in the H_2 product.

[6] Based on press release issued Feb 15, 2023, announcing HON H_2 tech in Exxon Baytown facility. https://www.honeywell.com/us/en/press/2023/02/exxonmobil-to-deploy-honeywell-carbon-capture-technology

[7] Pilot plant testing at NCCC confirms greater than 98% CO_2 capture is achievable.