



carbon clean

TECHNOLOGY TO ACHIEVE 'NET ZERO'

The Key to Efficient Carbon Capture:

High-Performance Solvents

carbonclean.com

What Is Amine-Based Carbon Capture?

Solvents — specially formulated liquids that extract carbon dioxide from a mixture of other gases — have been used for decades, and are the most proven and mature carbon capture technologies on the market. They have been used in the petrochemical and fertiliser sectors for many years. Conventional solvents for carbon capture are amine-based, with the most common being monoethanolamine (MEA).

MEA is an organic chemical compound that has been used in heavy industry for the past century. Originally used to purify (or “sweeten”) natural gas by removing carbon dioxide (CO₂) and sulphur containing components such as H₂S and mercaptants, it began its career in environmental cleanup for off-gases and flue gas emissions in the 1970s.

Since that time, the conventional solvent used for carbon capture from post-combustion emissions and biogas purification has remained largely unchanged.

How amine-based solvents work

Amine-based solvents are inherently reactive towards CO₂ under the right conditions and their carbon capture processes can be distilled into three steps:

- Bring the target gas (flue gas emissions, natural gas, etc.) in contact with the amine-based solvent under optimal **absorption** conditions
- Move the CO₂-rich solvent to a **regeneration step** where temperature increase allows the solvent to release the captured CO₂ into a gaseous stream for collection
- Recirculate the regenerated solvent back to the absorption stage for further CO₂ recovery

Improving Solvent Technology

Better Solvents for Higher Performance

Amines, including MEA, have been used as the primary solvent for commercial carbon capture due to their ability to react quickly and selectively with the CO₂ in the gas stream. Amine-based solvents have not evolved their formulation since their original implementation over 100 years ago.

As a workable approach for the petrochemical industry, amine-based solvents were a “good enough” solution despite having significant drawbacks, including:

- High energy costs due to limited carbon capture capacity
- Corrosive and environmentally harmful byproducts as the solvent degrades
- Foaming, a condition where the solvent loses efficiency, increases solvent losses due to contamination and one of the major reasons for plant downtime



Enter APBS Solvents

Carbon Clean has improved upon conventional solvents with our patented formulation of amines and salts — known as Amine-Promoted Buffer Salts (APBS). The result is a unique, fast-acting, high capacity carbon capture solvent that delivers higher performance in any existing solvent-based carbon capture system.

Carbon Clean's Solvents

APBS-CDRMax®

APBS-CDRMax® is formulated for industrial flue gases or off-gases across cement, refineries, steel, energy from waste, and many more industries. It can be used as a drop-in replacement solvent in existing systems for immediate cost savings. When combined with the unique CDRMax™ chemical absorption process, operational costs can be reduced up to 50% over conventional options.

- ✔ Less Corrosion and Degradation
- ✔ Reduced Foaming and Waste
- ✔ Lower Aerosols
- ✔ Longer Solvent Life
- ✔ Drop-in Replacement Capability



APBS-CARBex®

APBS-CARBex® removes CO₂ concentrations of up to 50% volume from biogas and landfill gas streams at low pressure. The APBS-CARBex® solvents have been widely proven and demonstrate a higher efficiency than conventional solvents such as MDEA for the production of pipeline-quality renewable natural gas (RNG), biomethane or compressed natural gas (CNG).

- ✔ Lower Energy Costs
- ✔ Maximised Methane Purity
- ✔ Lower Disposal Costs
- ✔ Longer Solvent Life
- ✔ Drop-in Replacement Capability

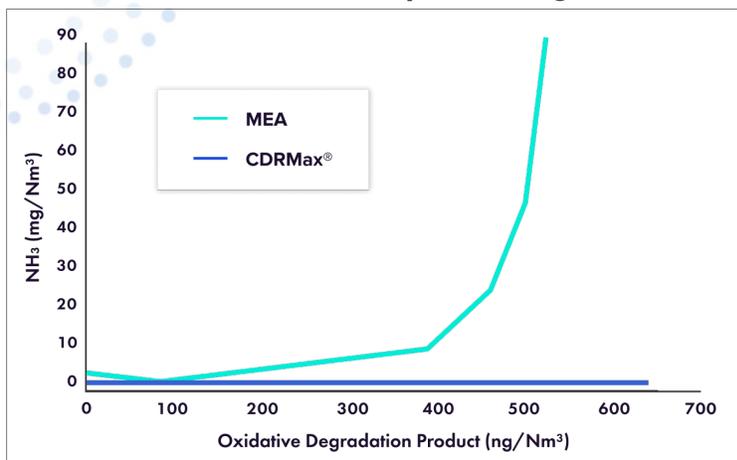


The New Benchmarks

High-Performance Solvent-Based Carbon Capture

Industries around the globe are realising the critical role of the circular carbon economy (CCE) in which CO₂ is captured and utilised. This gives businesses the ability to grow and compete in the environmentally-conscious economy of the 21st century. High-performance solvents like APBS-CDRMax[®] and APBS-CARBex[®] offer well-proven, feasible solutions to the industry facing stricter regulations and monetary costs from CO₂ emissions.

Outperforming Traditional Solvents



- Lower emissions and lower degradation rates mean lower solvent top-up to maintain performance

- APBS-CDRMax[®] is less reactive to oxygen and shows 20x less corrosion and 10x less degradation

Some industries feeling the most pressure to improve carbon capture efficiency include cement, steel, refineries, energy from waste and the biogas sector. Cement alone generates about 8% of global CO₂ emissions, producing more than 4 billion tonnes annually.

These businesses are facing a critical challenge: how to improve their capacity for CO₂ capture without incurring higher operational costs, increasing maintenance demands or adding environmental hazards. And they need a solution quickly.



“ While building a cleaner, sustainable future for our planetary health is the goal, economics remains the primary incentive for industrial businesses in an interconnected global market. High-performance solvents are the crucial bridge between those two forces. ”



Prateek Bumb
CTO and Co-Founder, Carbon Clean

Upgrading & Optimisation

Solvents and Your CCUS System

Industries that adopt APBS solvents realise immediate advantages in cost savings, reduced operational maintenance, and lower byproduct emissions. These improvements are magnified when combined with a purpose-built system that takes full advantage of the unique benefits of Carbon Clean's APBS solvents.

Drop-In Solution Replacement

APBS-CDRMax® and APBS-CARBex® can be utilised as a straight replacement for existing amine-based solutions in any existing carbon capture system without the need for modifications in the equipment. The immediate advantages include*:

- 5-15% higher absorption of CO₂
- 10-25% lower energy demand for the capture and regeneration process
- No downtime or extra maintenance from foaming
- Greater stability improves environmental safety and fewer degradation byproducts
- Considerably decreased corrosion within the carbon capture system

Drop-in solution replacement provides a simple and elegant solution for industries needing an immediate impact without new construction or large additional CAPEX. It can also be used as the first step in a phased approach of installing a CCUS system, leading to an optimised carbon capture solution for maximised efficiency and cost savings.

* When compared to traditional solvents

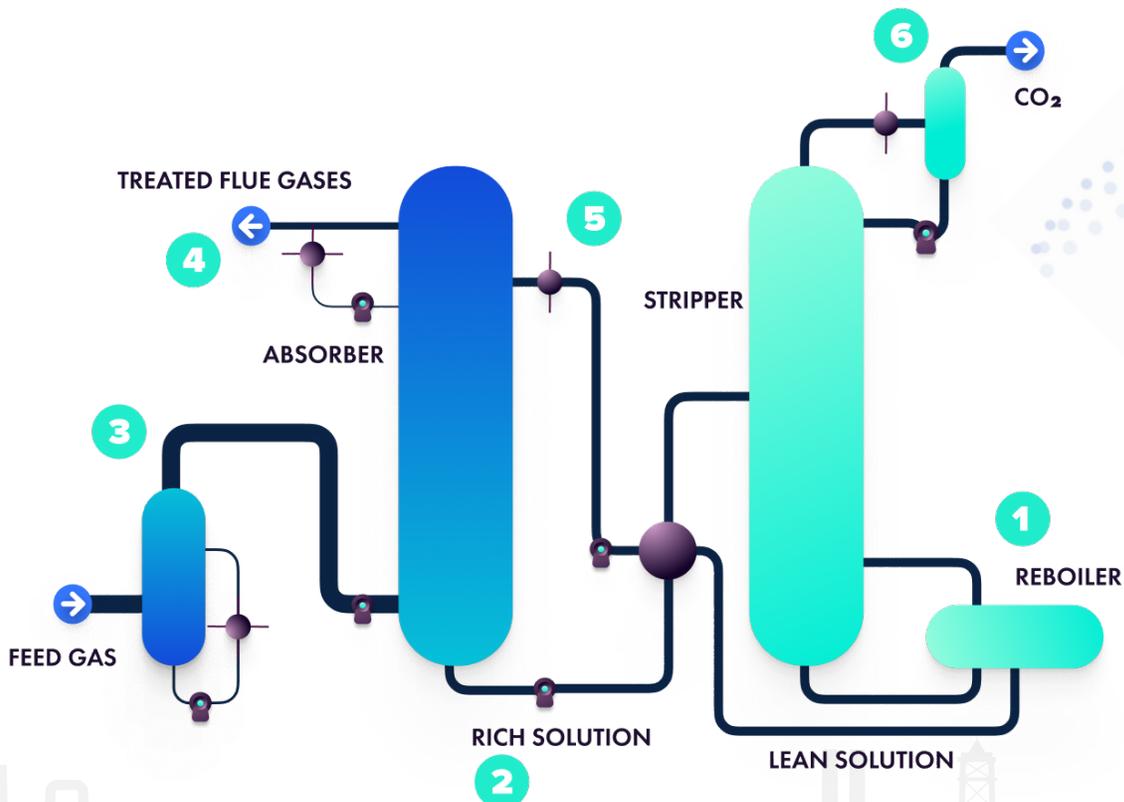
Greenfield System

To realise the full benefit of APBS, Carbon Clean engineered an innovative design of the chemical absorption process for carbon capture that takes full advantage of the high-performance capabilities inherent in the solvents. The CDRMax™ Process utilises efficiencies in the proprietary solvents to maximise operational cost savings of the carbon capture plant.

These systems result in up to 50% reduction in energy demand, the single biggest operating cost associated with carbon capture.

Performance Chemistry – CDRMax™ CO₂ Capture Technology

- 1** 50% reduction in direct thermal energy (up to) *
- 2** 75% reduction in solvent make-up *
- 3** 20-50% cost reduction *
- 4** Parts per billion level solvent emissions in lean gas *
- 5** 75% less solvent disposal *
- 6** 10% reduction in product CO₂ compression power *



* Conventional CO₂ recovery benchmark amine is an MEA based chemical absorption process

Two Case Studies in High-Performance Solutions

Arcanum Energy Cost Savings

The greater efficiency of APBS solvents provides immediate opportunities for cost savings, as Arcanum Energy discovered. Processing 500,000 m³ of biogas daily in multiple locations throughout Germany, Austria and Switzerland, Arcanum was looking for a way to reduce the cost of converting raw biogas into biomethane.

Just by switching to APBS-CARBex[®] from a conventional solvent, Arcanum was able to reduce its energy cost for conversion by 15-25%, providing immediate reduction in thermal energy requirements. What's more, they discovered that they encountered less downtime from foaming and were able to keep APBS-CARBex[®] in production for five times longer than their previous conventional solvent.



Technology Centre Mongstad: Breakthrough Test Results of APBS-CDRMax®

In 2017, Carbon Clean announced breakthrough test results from the Technology Centre Mongstad (TCM) pilot. Corrosion testing confirmed that APBS-CDRMax® makes it possible to construct and operate with a less expensive, lower grade of stainless steel. In conjunction with our CDRMax™ process, costs can be reduced 20–50% compared to conventional options.

In capturing 25,000 tonnes of carbon dioxide, the pilot revealed aerosol emissions were 80 times lower than the permissible HSE limit with APBS-CDRMax®. Meanwhile, solvent degradation was negligible over the test period, demonstrating far superior solvent stability.

The average cost per metric tonne of CO₂ captured is **reduced up to 50%** over the benchmark with the CDRMax™ process when used alongside Carbon Clean's proprietary solvents.



Why Carbon Clean?

Pushing the Envelope of What's Possible with Solvents

The pressure is mounting on industries to optimise their CCUS systems as the carbon economy ramps up. Incentives to reduce carbon emissions are too valuable to pass up, and the penalties for not reducing are too great to ignore.

The European Trading Commission certificates for excess CO₂ are rising in price every month, and are expected to hit €100/tonne by the end of the decade. More and more governmental agencies are moving to further limit or restrict CO₂ emissions each year.

In the midst of these powerful economic forces, reliance on legacy carbon capture systems becomes a competitive disadvantage. When high performance APBS solvents deliver an immediate impact with greater efficiency, lower costs and waste, as well as more reliable operations, the question becomes simple:

Can you afford to remain conventional?

Our mission is to deliver exceptionally cost-effective technology solutions to industrial carbon emitters, enabling capturing over 1 billion tonnes of CO₂.

By upgrading your business's solvents it allows for massive potential improvements in the carbon capture systems that will allow your business to take part in the global circular carbon economy. You'll reduce your emissions, help the world stay on track to meet climate initiatives, and increase your bottom line. The time to invest in carbon capture is now. Let's get started.

For industry, there has never been a better time to prioritise the reduction of carbon emissions.

Advanced CCUS technology provides a scalable and increasingly cost-effective means to do so. By optimising the new opportunities this technology presents, hard to abate industries can begin to rapidly move towards net zero, transforming their businesses to successive levels of sustainability for the future.

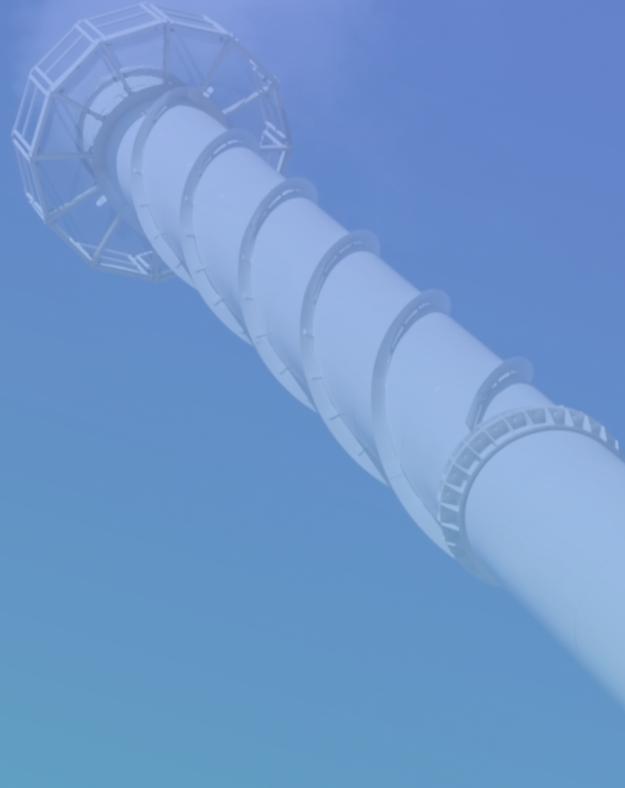


Learn more about working with Carbon Clean to achieve net zero goals.

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