



TECHNICAL REPORT

STATE OF THE ART: CCS TECHNOLOGIES 2024



GLOBAL CCS
INSTITUTE

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FOREWORD

Carbon Capture and Storage (CCS) is a crucial tool in addressing global greenhouse gas emissions and tackling climate change. Urgent technological development, deployment, and scale-up of CCS technologies are necessary to meet our net-zero targets across industries such as cement, steel, chemicals, natural gas, and power generation. The uptake of CCS technologies must continue to accelerate to address emissions from these industries and more, alongside deployment of Carbon Dioxide Removal applications to remove CO₂ already present in the atmosphere.

This year's Technology Compendium continues the work of earlier editions, expanding upon technologies applicable to CCS with deeper insight on their performance and applications. Proven, established technologies used for many decades in various industries are represented, as well as emerging technologies that will drive further improvements in performance, system costs, and energy usage. The submissions to this Compendium cover a range of methods in capture, transport, and storage to enable the development of the full CCS value chain.

The Technology Compendium showcases the breadth and depth of CCS technology available for deployment today, as well as technology in the process of reaching full commercial readiness. This insight into the current CCS technological capabilities and what may lie ahead provides a view of the accelerating deployment of CCS across the globe to tackle climate change.

The Technology Team
Global CCS Institute
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Acknowledgements

We are grateful for the contributions and support of all the Submitters who have contributed to this publication.

We are also grateful for the Members of the Global CCS Institute, whose Membership enables the Institute to develop catalytic thought leadership pieces, publications such as this Technology Compendium, our annual Global Status Report and a variety of other publications that can be found on [our website](#).

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EDITOR'S NOTES

The Global CCS Institute ("The Institute") is an international think tank whose mission is to accelerate the deployment of carbon capture and storage (CCS), a suite of technologies to tackle climate change and deliver climate neutrality.

The Institute produces the "State of the Art" Technology Compendium annually to provide a platform for technology owners and producers to share their products, and allow developers, proponents, and interested parties to discover the field's state-of-the-art offerings. This is in accordance with our mission to accelerate the deployment of CCS globally.

The Technology Compendium is a free-to-enter publication, and technology providers collaborate with the Institute to provide their information to the Technology Compendium for review and publication. The technologies present in the 2024 Technology Compendium represent a non-exhaustive picture of the overall landscape of CCS technologies. Where there has been no submission received for the 2024 Technology Compendium, there is no presence within the Compendium. The Institute is aware of other CCS technologies not mentioned in this Technology Compendium, established and emerging, and we are working for future editions to include these technologies.

If you wish to make a submission for the next edition of the Technology Compendium, please contact us via techcompendium@globalccsinstitute.com.

Disclaimer

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Technology Readiness Level (TRL)

In this publication, the TRL of various technologies has been reported as a part of the submission. The guidance provided to submitters for TRL assessment is provided in Table 1. For inclusion in the 2024 Technology Compendium, a Technology must have a TRL of 5 or above.

Table 1: TRL Guidance Provided for 2024 Technology Compendium Submissions

CATEGORY	TRL	DESCRIPTION
Demonstration	9	Normal Commercial Service
	8	Commercial demonstration, full-scale deployment in final form
	7	Sub-scale demonstration, fully functional prototype
Development	6	Fully integrated pilot tested in a relevant environment
	5	Sub-system validation in a relevant environment
	4	System validation in a laboratory environment
Research	3	Proof-of-concept tests, component level
	2	Formulation of the application
	1	Basic principles, observed, initial concept

Front Cover Image: CapsolGo® at EEW Energy from Waste plant in Hanover, Germany, image courtesy of Capsol Technologies.

Foreword Image: Twence CCU 100,000 TPA plant in Hengelo, The Netherlands, image courtesy of SLB and Aker Carbon Capture JV.

CAPTURE





oase-gastreatment.com

SUMMARY

BASF, the world's largest chemical company, markets sustainable and innovative solutions. BASF introduced the first specialty-amine-based CO₂ capture technology in the 1970s, which later developed into BASF's OASE® technology. With 500+ references, the licensed OASE® technologies are now the technologies of choice for amine-based acid gas removal units (AGRU) in the treatment of natural gas, HyCO/NH₃, selective sulphur removal, biogas, and flue gas. Solutions for the flue gas segment are marketed under the OASE® blue brand.

Each OASE® facility's design and solvent are customised to the specific project requirements. Customers benefit from a cradle-to-grave optimisation of the performance and the security of BASF's own solvent supply backed up by all of BASF's chemistry know-how. OASE® offers customers access to OASE® connect – BASF's proprietary digital customer interaction platform which comprises BASF's proprietary in-house simulation tool, an analytical database, and BASF's online solvent analyzer OASE® digilab. OASE® is marketed non-exclusively and holds regular customer workshops.

BENEFITS

OASE® provides business partners with:

- Know-how derived from over 500 references and BASF's expertise in chemistry
- Non-exclusive access to OASE® technology for customers and engineering companies
- OASE® solvents produced and supplied by BASF
- Exclusive digital tools: OASE® connect & OASE® digilab
- Customised design, operating and analytical manuals

- Wide operating range applicable to most flue gas sources
- Long track record and expertise in large-scale CO₂ capture units' design and operation
- Unique licensing model integrating license and solvent sales

Benefits of the OASE® blue solvent:

- Low regeneration energy
- Accelerated kinetics & mass transfer
- High cyclic capacity
- High oxidative resistance / Low degradation / Low make-up rate
- 10-year continuous testing and 7-year commercial operation in various industries
- In-house solvent production

Benefits of the OASE® blue technology:

- High energy efficiency and reliability
- Up to 99+% CO₂ capture rate
- High-purity product CO₂ stream suitable for utilisation and sequestration
- OASE® aerozone emission reduction technology
- Waste-heat integration

KEY DATA

TRL	9	Capture Rate Range (tpd)	10 – 10,000	Modular (Y/N)	Yes
Source CO ₂ Purity Range	<0.1 - 70%	Energy Consumption (GJ/tCO ₂)	0.6 – 3.0	Capture Efficiency (%)	>99%
Number of Commercial Plants	>500	Number of Pilot Plants	6	Feed Gas O ₂	Up to 16%
Target Industries	Cement/Lime, Waste-to-Energy, Power, OCCS, LNG, Syngas, Blue H ₂ , Oil Refining				

TECHNOLOGY DESCRIPTION

CARBON CAPTURE WITH OASE®

For over 50 years, BASF has marketed and continuously improved its amine-based acid gas removal technology to provide customised solutions to clients. BASF boasts a comprehensive portfolio of OASE® technologies for applications in which acid gases – primarily CO₂ but also other carbon and sulphur containing compounds – are extracted from gas streams.

OASE® is the leading carbon-capture technology installed in references with a combined capacity of over 100 million Nm³/h. Today, 7.6 million tons per year of CO₂ extracted with OASE® are sequestered, while tens of millions of tons per year of CO₂ separated with OASE® are used in downstream applications.

The main applications of the OASE® portfolio include:

OASE purple	Natural Gas, LNG
OASE white	Ammonia, Syngas
OASE yellow	Selective Treatment
OASE green	Biogas
OASE blue	Flue Gas

Each OASE® technology is customised for the specific application and adjusted for the specifics of each project. Factors such as feed-gas composition, treated-gas specifications, purity of acid gas, energy consumption, optimisation of capital expenditures, and other customer requirements characterise the optimised project-specific design provided by the OASE® team.

With their presence in five continents, OASE® technical marketing representatives cover the global demand. These are supported by teams of technical and commercial specialists which ensure modern and proven tools for streamlined execution and highest quality.

FLUE GAS TREATMENT WITH OASE® blue

OASE® blue is a patented technology and proprietary amine solvent blend, customised for greenfield and retrofit flue gas capture applications. BASF uses its own customised in-house simulation tools based on BASF's exhaustive know-how in chemical properties, processing, modelling, and operations. OASE® blue benefits from the experience of designing, operating, and scaling up all applications in the OASE® portfolio of technologies. OASE® blue boasts over 100,000 hours of operation and optimisation and is an integral part of BASF's Net Zero strategy.

OASE® blue proprietary solvent was developed in an R&D phase. Screening of over 200 blends of industrially available amines coupled with BASF's chemistry know-how resulted in the industry's best technology/solvent combination delivering low energy consumption, high oxidative resistance, excellent kinetics & mass-transfer, high cyclic capacity and low make-up rates. The unique OASE® blue solvent composition together with high performance & reliable technology solutions based on BASF's 100+ years

of carbon capture experience & expertise allow to ensure an optimal CAPEX/OPEX balance for the customers' particular flue gas and product gas specifications.

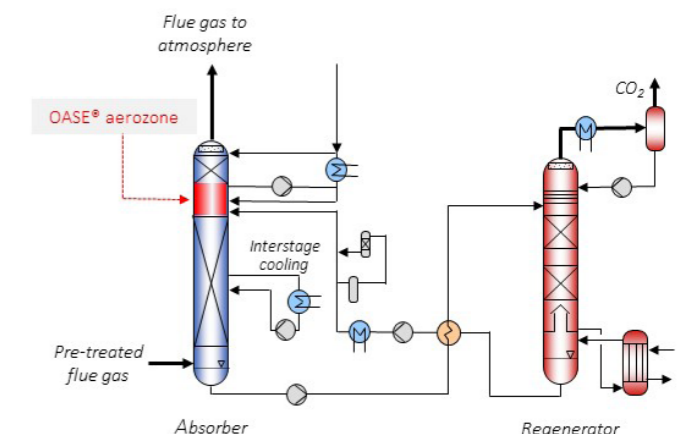
Implementing heat-integration concepts for facilities with available energy is an integral part of the OASE® blue design.

A patented emission control system, OASE® aerozone is integrated into the OASE® blue process to manage aerosols and minimise emissions in the treated gas. Furthermore, a unique degradation-component management system ensures minimisation of these components and minimises emissions.

The OASE® deliverables include a process design package, license, warranties, solvent and services. OASE® is offered in non-exclusive agreements to engineering companies and end users.

As a producer of the OASE® solvent, BASF is the only technology provider that can also ensure solvent supply in the rapidly growing carbon-capture market.

The OASE® licensing model is offered in various versions. In addition to the classical "up-front" model, where a lump sum for the license is paid during the project execution, OASE® can also be licensed with a model which aligns payments with actual CO₂ production and supply of refill solvent. This allows for cash flow for license and refill solvent to be aligned with revenues which are realised only during operation.



The Post Combustion Carbon Capture Process based on OASE® blue Technology

OASE® white, OASE® purple & OASE® yellow

Utilised in the removal of acid gases, these state-of-the-art OASE® technologies have proven their versatility and reliability in synthesis-gas and natural-gas applications – from treating hydrogen (H₂) and/or carbon monoxide (CO) streams, over bulk removal of acid gasses in LNG applications, to selective removal of sulfur components for sales gas, acid-gas enrichment (AGE) and tail-gas treatment (TGT) units. Backed by hundreds of references including BASF's own facilities, these highly efficient and environmentally friendly technologies offer both flexible operability and reduced capital expenditure (CAPEX), while the low energy demand of the processes and their non-corrosive solvent minimise operating and maintenance costs (OPEX). They also provide a high level of gas purity and product gas recovery while keeping solvent losses to a minimum.

GET IN TOUCH

To find out more about the Global CCS Institute including Membership and our Consultancy services, visit globalccsinstitute.com or contact us.

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