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Industrial Scale Carbon Capture Technology Testing at CO_2 Technology Centre Mongstad: Results using CESAR 1

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Abstract

Global CO_2 emission trends show an increase in the total CO_2 emissions, i.e. 36.8 Billion tons in 2022 [1], 37.4 Billion tons in 2023 [2] and in 2024 CO_2 emissions are expected to be above 40 Billion tons [3]. As per IEA analysis, existing energy system infrastructure could emit ~650 Gt CO_2 by 2050—30% above the 1.5°C limit—requiring urgent retrofitting (e.g., carbon capture and storage) to meet climate goals[4] .Though clean energy deployment is increasing, it's not yet at the capacity to reverse the trend of global CO_2 emissions. Energy consumption indicates that energy demand will continue to grow in the coming years. Net-Zero pledges by companies, countries are still far away from achieving the required reduction in emissions.

CO_2 capture using proven amine-based technologies is at the forefront of available solutions, playing a critical role in achieving net-zero ambitions.

Developing large-scale CO_2 capture processes for Carbon Capture and Storage (CCS) applications—especially in energy, chemicals, materials production—requires a stepwise scale-up, validation, and verification to prevent costly technical failures. Rigorous testing at each stage is essential to ensure reliability and performance before full-scale implementation. In EU funded AURORA project, testing is planned to perform with SINTEF Tiller facility at 1 TPD, SLB capture (formerly Aker Carbon Capture) MTU at 2-5 TPD and TCM facility 100 -200 TPD scale covering small pilot to industrial/engineering scale demonstration.

TCM's demonstration-scale test facility shown in **Figure 1**, known as the "amine plant," has already helped several commercial vendors by performing test campaigns on various CO_2 capture solvents since its inauguration in 2012. The active collaboration among public, industrial, research, and academic stakeholders has enriched these campaigns, ensuring that the insights gained benefit a wide audience. The primary objective of these initiatives is to generate knowledge that reduces technical, environmental, financial, and overall cost risks for the commercial-scale deployment of post-combustion CO_2 capture (PCC). At the CO_2 Technology Centre Mongstad (TCM), we systematically quantify CO_2 capture systems to manage risks and lower barriers to commercialization. This approach accelerates technology transfer and supports the global deployment of effective CO_2 capture solutions.

Keywords: CO_2 Technology Centre Mongstad; Post combustion carbon capture; amine based CO_2 absorption; CESAR 1 solvent; Industrial scale demonstration facility, Advanced process configurations, high capture rates

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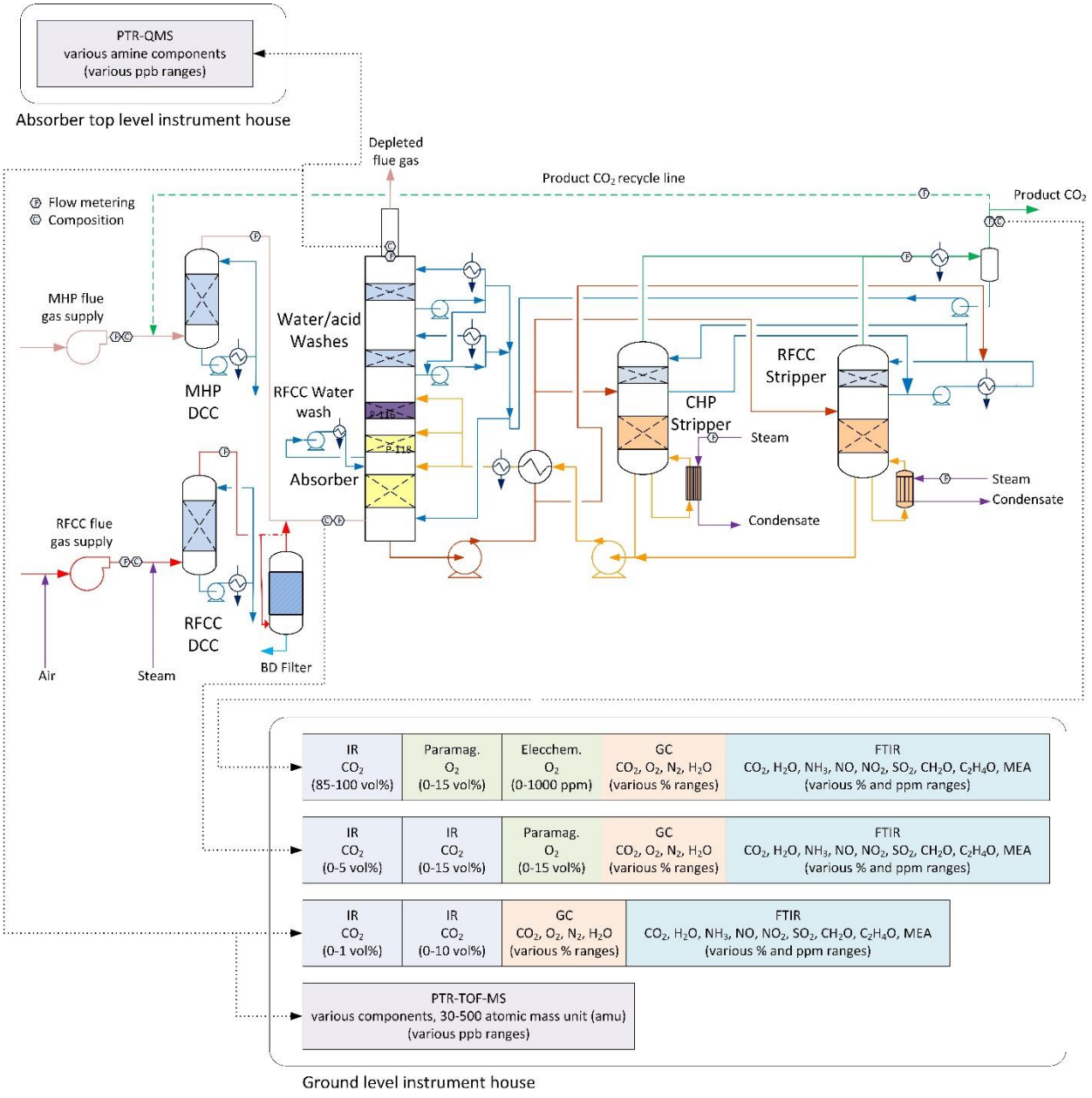

Figure 1 TCM facility for CO2 capture technology demonstration at TRL 7

In AURORA project, amine blend solvent technology with non-proprietary CESAR1 (AMP/PZ) will be optimized and qualified for commercial deployment.

Test plan for demonstrations at TCM facility:

Piloting campaigns in previous EU projects like ALIGN-CCUS [5–7], SCOPE [8,9] have shown that the technology is robust and there is little doubt that it can be deployed industrially. Some of the fundamental gaps related CESAR 1 are listed and discussed by Morlando et al. [10].

Extensive planning has been made by TCM to carry out tests that close the remaining knowledge gaps related to CESAR 1 solvent

industrial deployment.

Non-proprietary CESAR1 technology will be demonstrated at TCM facility at TRL7 by mimicking various relevant flue gases (CO_2 concentrations) relevant for industries like Aluminum smelters, NGCC, refining, Steel and Iron, cement, and materials recycling.

The test activities at TCM will be performed covering numerous objectives as outlined in the **Table 1** below.

Table 1 TCM testing activities for CESAR 1 in AURORA project

Advanced Process configurations	Solvent Regeneration	Emission control	Flue gas industrial cases	Emission monitoring	Online solvent hygiene	Foaming impact and control	Capture rates	Solvent formulation optimization
Conventional	Standard pressure	Double water wash	Smelter flue gas	PTR-tof-MS	Liquid analyzer	Foaming identification	90	CESAR 1 (3 M AMP + 1.5 M PZ)
Absorber intercooling	High pressure	BDU +TCM water wash and acid configurations	NGCC	FTIR	LC-MS	Impact of foaming on KPIs	95	CESAR Mix-2
Absorber intercooling + Cold-rich bypass			Waste to energy	IMR-MS	IC, ICP-OES	Antifoam Injection Optimization	98	CESAR Mix-3
			Coal power plants	isokinetic extractive sampling	Karl-Fischer		99+ (Deep capture)	
			Refinery		pH			
			Iron & steel, Cement		Alkalinity			

Testing at TCM will enable us to close the gap for commercial deployment, main achievements include:

1. Operation of industrial scale carbon capture plants using CESAR 1 without operational issues like precipitations
    a. TCM is optimizing plant operating conditions and adjusting the CESAR 1 solvent formulation to avoid precipitation while maintaining solvent capture capacity and performance.
2. Validating the performance of CESAR 1 solvent for different industrial flue gas while targeting deep capture
3. Assess different strategies to control different types of emissions from the CO_2 capture plant based on flue gas source (volatile emissions, aerosol-based emissions)
    a. TCM is performing multiple combinations of emission control schemes
4. Employing multiple online instruments for monitoring of the emissions to atmosphere and validating the results with Iso-kinetic samples. Collected data will be of great value in terms of knowledge for developing emission permits for CO_2 capture plants.
5. TCM is performing dedicated tests to develop strategies to identify the start of foaming, its impact on key performance indicators and optimal antifoam injection to mitigate foaming and its impact
6. Advanced process design configurations will be testing and evaluate the benefit for different industrial use cases at various target capture rates.
7. To go beyond the current industrial knowledge of CCUS projects implementation, TCM planned to perform testing at high regeneration pressures to assess the advantages and disadvantages from full-chain CCUS projects perspective.
8. TCM implemented advanced online solvent hygiene monitoring system which is being used to develop strategies to maintain the optimise process performance.
9. Providing a comprehensive insight on solvent degradation, and corrosion

10. Investigating level of impurities in CO_2 product as additional knowledge for CCU and CCS projects or clusters

On overall TCM demonstration scale facility testing will generate essential knowledge for industries to evaluate the potential of CESAR 1 solvent based CO_2 capture technology for full-scale deployments.

Below are some of the key performance indicators (KPIs) that TCM will include in its reported results:

- Energy performance/Specific reboiler duty (SRD)
- Solvent stability and consumption
- Technology Performance at high capture rates (≥95%)
- Emissions
- Corrosion
- Benchmarking against MEA baseline

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