TECHNOLOGY CENTRE MONGSTAD

Technology Centre Mongstad

DOE-NETL'S 2020
Integrated Project Review Meeting

CONTENT

TECHNOLOGY CENTRE MONGSTAD

The world’s largest open access test centre for carbon capture technologies

Technology Centre Mongstad (TCM) facilitates the advancement of carbon capture technology for mass deployment across industries.

We test, verify and demonstrate different technologies related to cost-efficient and industrial scale CO_2-capture

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Joint venture established in 2009

TCM was established to support development and testing of carbon capture technologies at an early stage. Today, the company is a joint venture between the Norwegian state (managed by Gassnova, 73.9%), Equinor (8.7%), Shell (8.7 %) and Total (8.7 %).

GASSNOVA

«We see an increasing interest for testing at TCM, and we are very pleased that we can continue our important work with testing and research necessary for the deployment of large-scale carbon capture.»

equinor

«TCM has contributed to maturing the carbon capture supplier market and will remain relevant with the increasing number of technology suppliers lining up for testing.»

«TCM plays a key role in further developing and reducing the cost of CCS – a crucial technology to help society and economies thrive through the energy transition.»

TOTAL

«TCM is a cornerstone in Total's strategy to tackle climate change by accelerating the development and adoption of innovative CO_2 capture technologies.»

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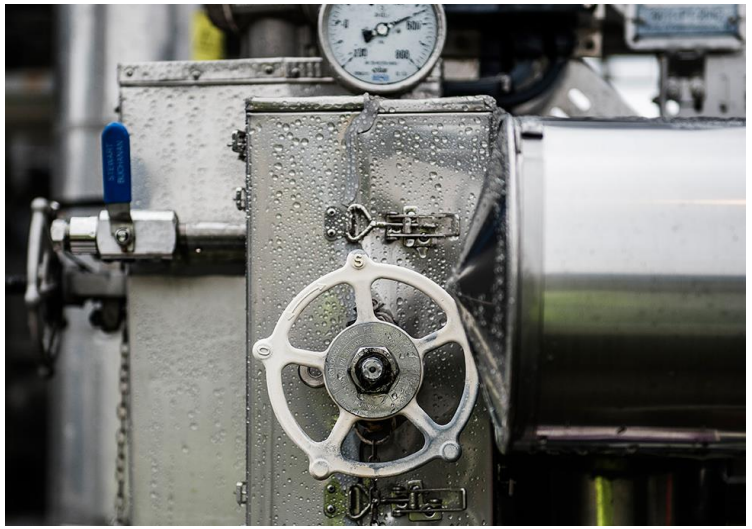

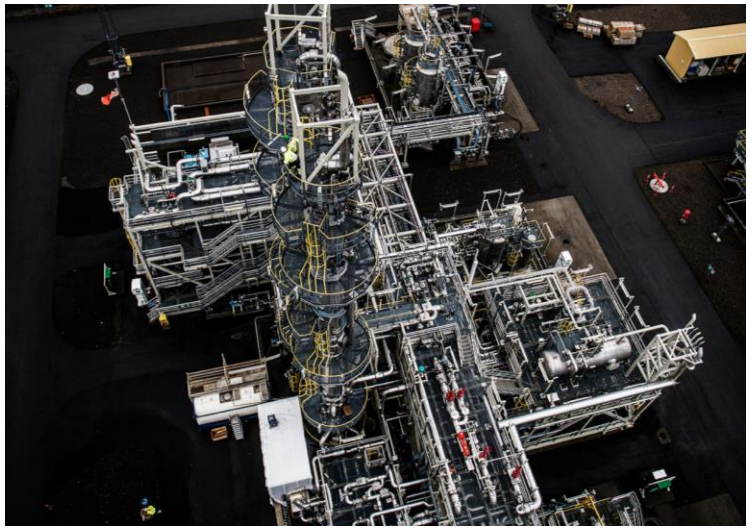

Our unique benefits

- A world class test-centre for CO_2 capture technologies
- Unique scale and flexibility
- Access to world-class competence on carbon capture

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International Test Centre Network

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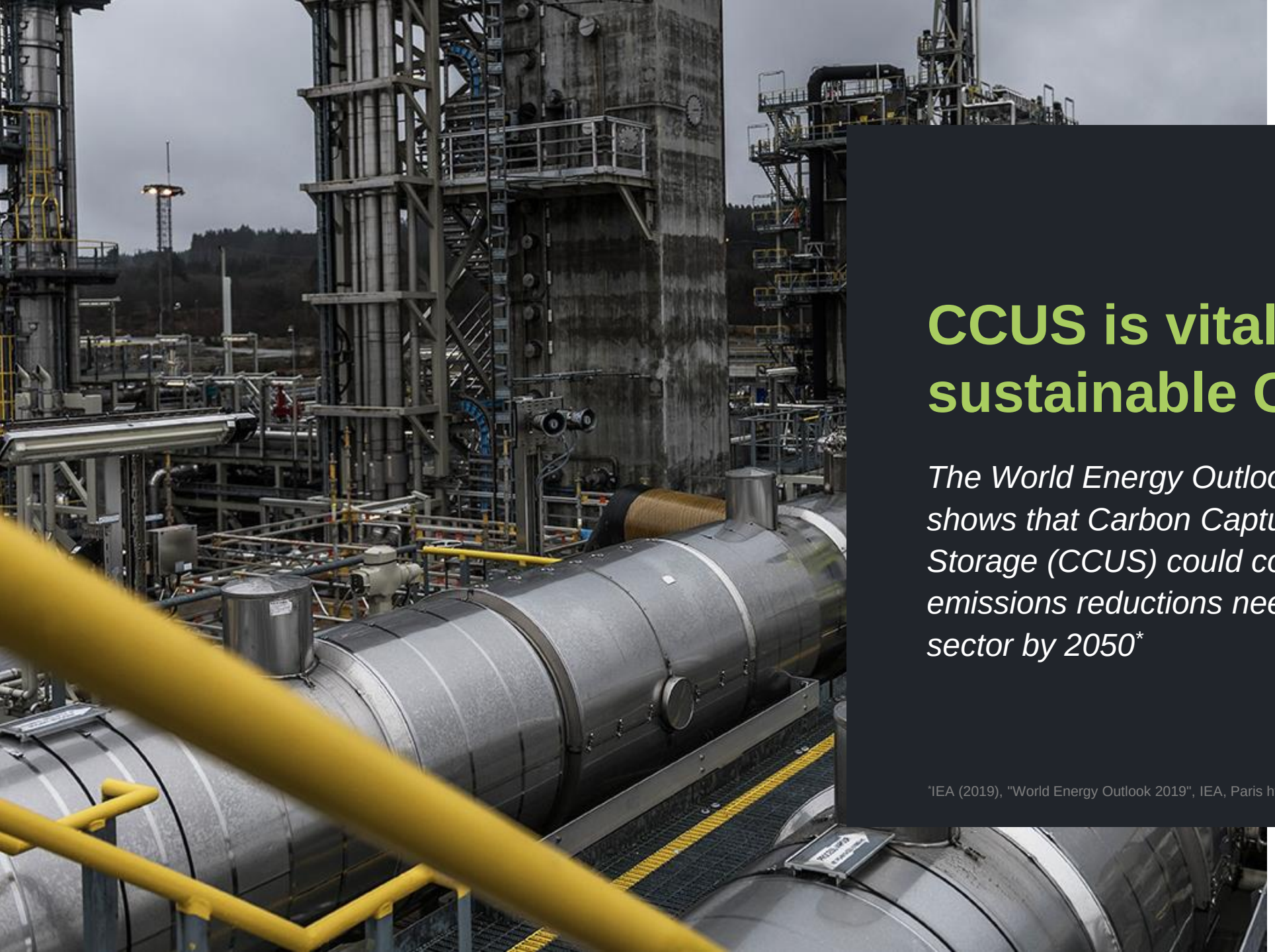

CCUS is vital for sustainable CO_2 reduction

*The World Energy Outlook (WEO) 2019 report shows that Carbon Capture, Utilization and Storage (CCUS) could contribute with 9% of the emissions reductions needed across the energy sector by 2050**

*IEA (2019), "World Energy Outlook 2019", IEA, Paris https://www.iea.org/reports/world-energy-outlook-2019

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Gassnova is coordinating the Norwegian CCS initiative, where TCM is a key component

CLIMIT Research Program

Gassnova grants financial support for development, demonstration and piloting of Carbon Capture and Storage (CCS) technologies.

Technology Centre Mongstad

Gassnova manages the Norwegian state's interest in the Technology Centre Mongstad and will facilitate the sharing and dissemination of these experiences in order to reduce the costs and risks of carbon capture.

Full-scale CCS Project

Gassnova manages and coordinates the work of the Norwegian full-scale project for CCS and has entered contracts with:

Norcem - Heidelberg Cement
Fortum Oslo Heating - Waste to Energy
Equinor, Shell and Total - Northern Lights

History and development of TCM

2006
The Norwegian state and Statoil (now Equinor) agree to build test centre (EUR 600 million investment)

2009
TCM DA established and Gassnova, Equinor and Shell become owners

2010
Sasol becomes owner

2012
TCM officially opened and starts testing operations

2017
Establishment of new ownership period, where Total enters as new owner and Sasol departs

2023
The current ownership period was extended in August 2020 until the end of 2023

2025
TCM has ambitions to deliver more testing, broader advisory services and applied research and development to the CCUS industry

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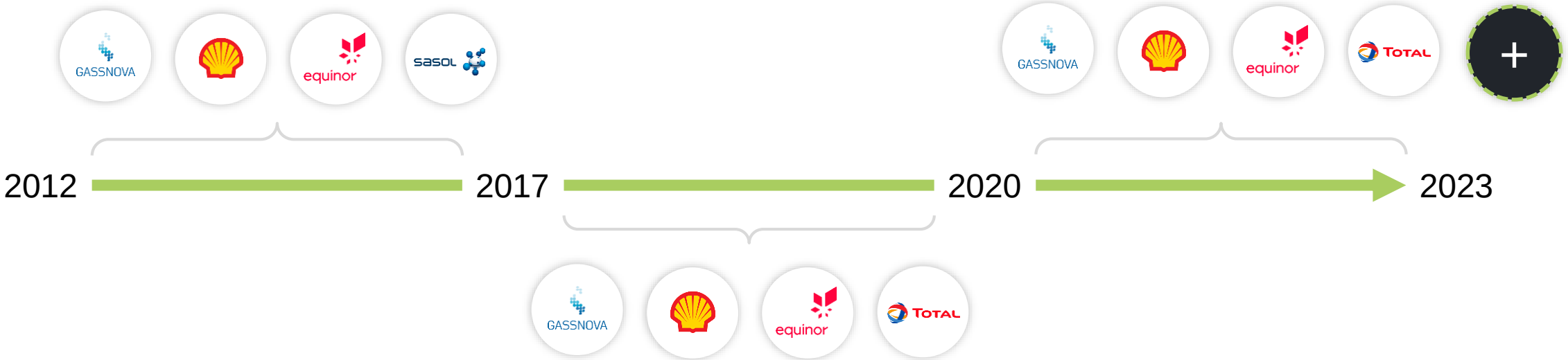
TCM has renowned owners that are willing to make a difference in combating climate change



The Participants' Agreement (PA) and operational owner period is active in a defined time period. The current owner period from August 2020 lasts until end 2023.

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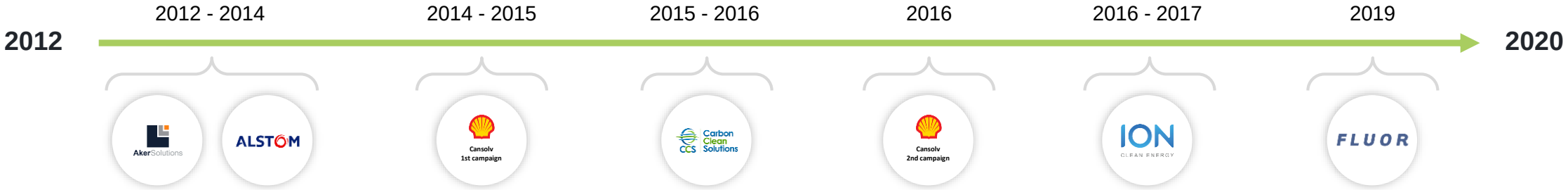
Test campaigns conducted in 8 years of operation

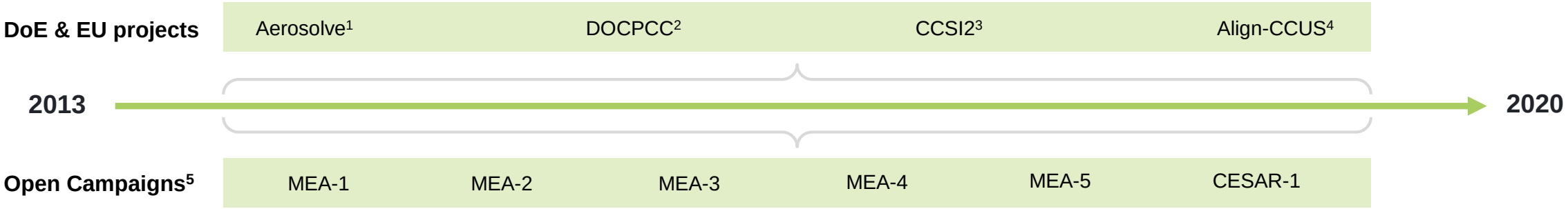
Proprietary test campaigns

Vendors conduct proprietary testing with their own technology.



Non-proprietary test campaigns

Several open scientific campaigns with non-proprietary solvent in collaboration with universities and research organisations, as well as several projects together with the EU.



[1] Project regarding aerosol-related emissions
[2] Demonstration of Optimal Control of Post-Combustion Capture Processes
[3] Carbon Capture Simulation for Industry Impact
[4] Accelerating Low carbon Industrial Growth through CCUS
[5] Long-term testing with monoethanolamine solvents and CESAR-1 (AMP+PZ) solvent

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Key facts

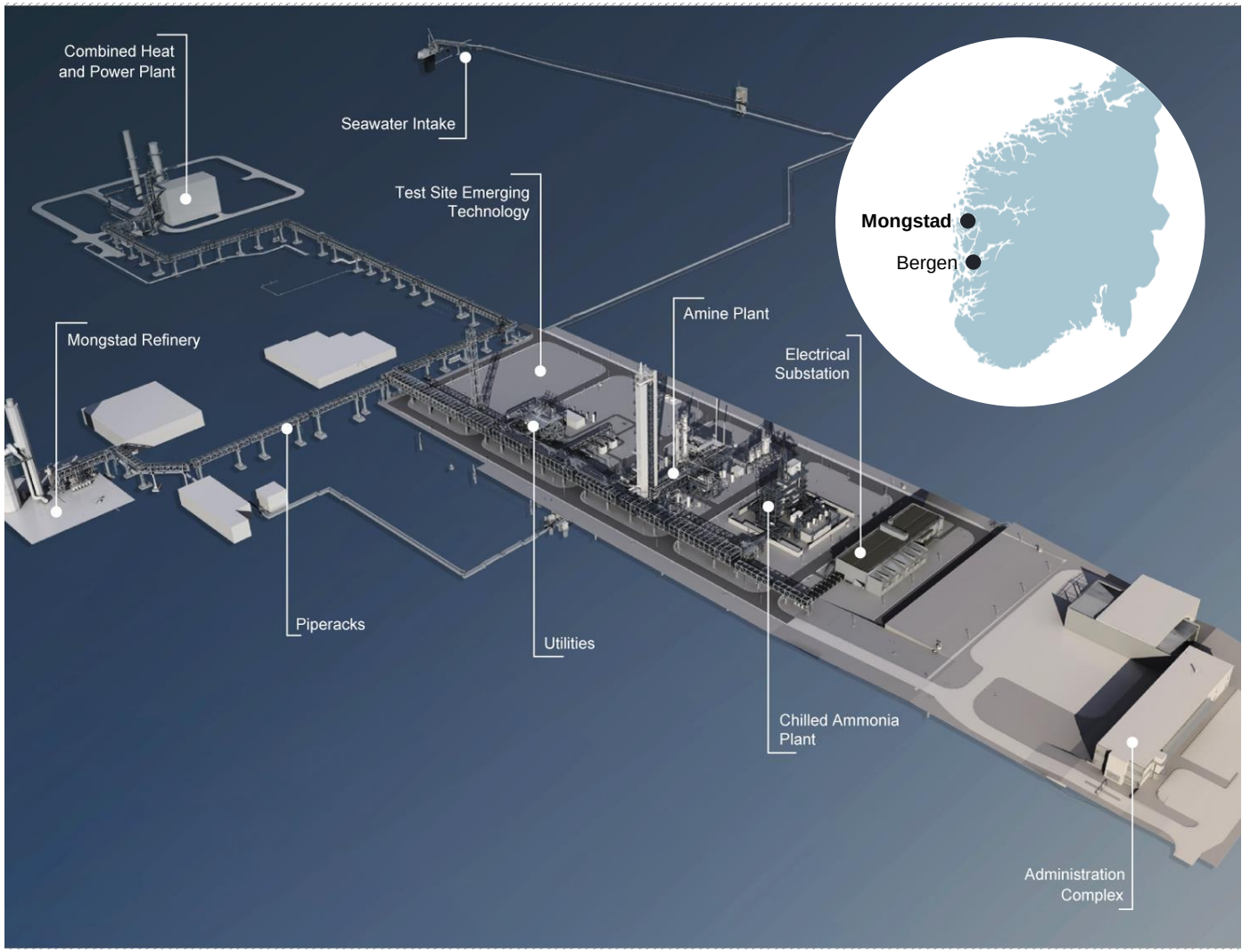
Capture type: Post-combustion.

Source: Two industrial flue gas sources with different levels of CO_2 (3.5-15%).

Technologies: Two existing capture plants designed to test different solvent-based technologies. In addition a new site for emerging technologies designed for modular based testing.

Capacity: Amine and ammonia units have approximately 12 MWe in size each, capturing a total of 100,000 tonnes CO_2 per year combined. Site for emerging technologies has CO_2 capture capacity up to 18,000 tonnes per year using up to 3 MWe modules.

Monitor and control: 4,000 online instruments and 100 manual sampling points, enabling TCM to monitor and find out in detail how processes work.



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New site for emerging technologies

TCM is located adjacent to Equinor Mongstad refinery, allowing for different testing scenarios

TCM provides offices, utilities, control room, laboratory, workshop, warehouse space and meeting rooms to support the testings.

Equinor Mongstad refinery has plans towards 2030 and visions for 2050, ensuring continuity at Mongstad.

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We help industries to successfully adopt technologies that will help them achieve their carbon emission mitigation goals

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Proprietary Testing

>20,000 hrs

Non-Proprietary Testing

>14,000 hrs

Engagement with Environmental Authorities

Advisory Services

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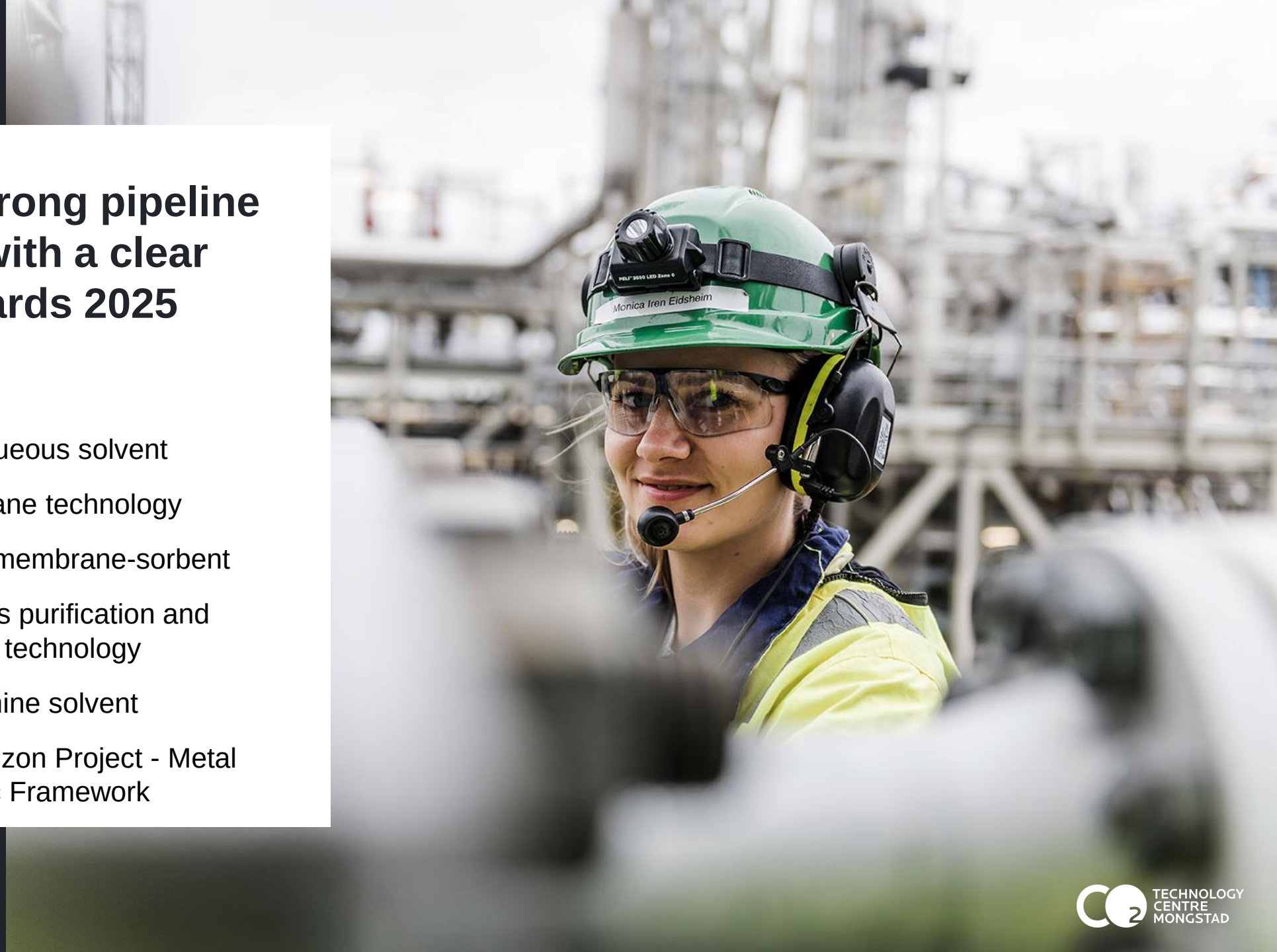
TCM has a strong pipeline of activities with a clear strategy towards 2025

AWARDS

RTI INTERNATIONAL	Non aqueous solvent
MTR Membrane Technology & Research	Membrane technology
TDA	Hybrid membrane-sorbent
InnoSepra	Flue gas purification and sorbent technology
c-capture	Non-amine solvent
M4 MOF4AIR	EU Horizon Project - Metal Organic Framework



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We provide risk intelligence

We help you to reduce HSE, technical and financial risks of technology deployment at scale

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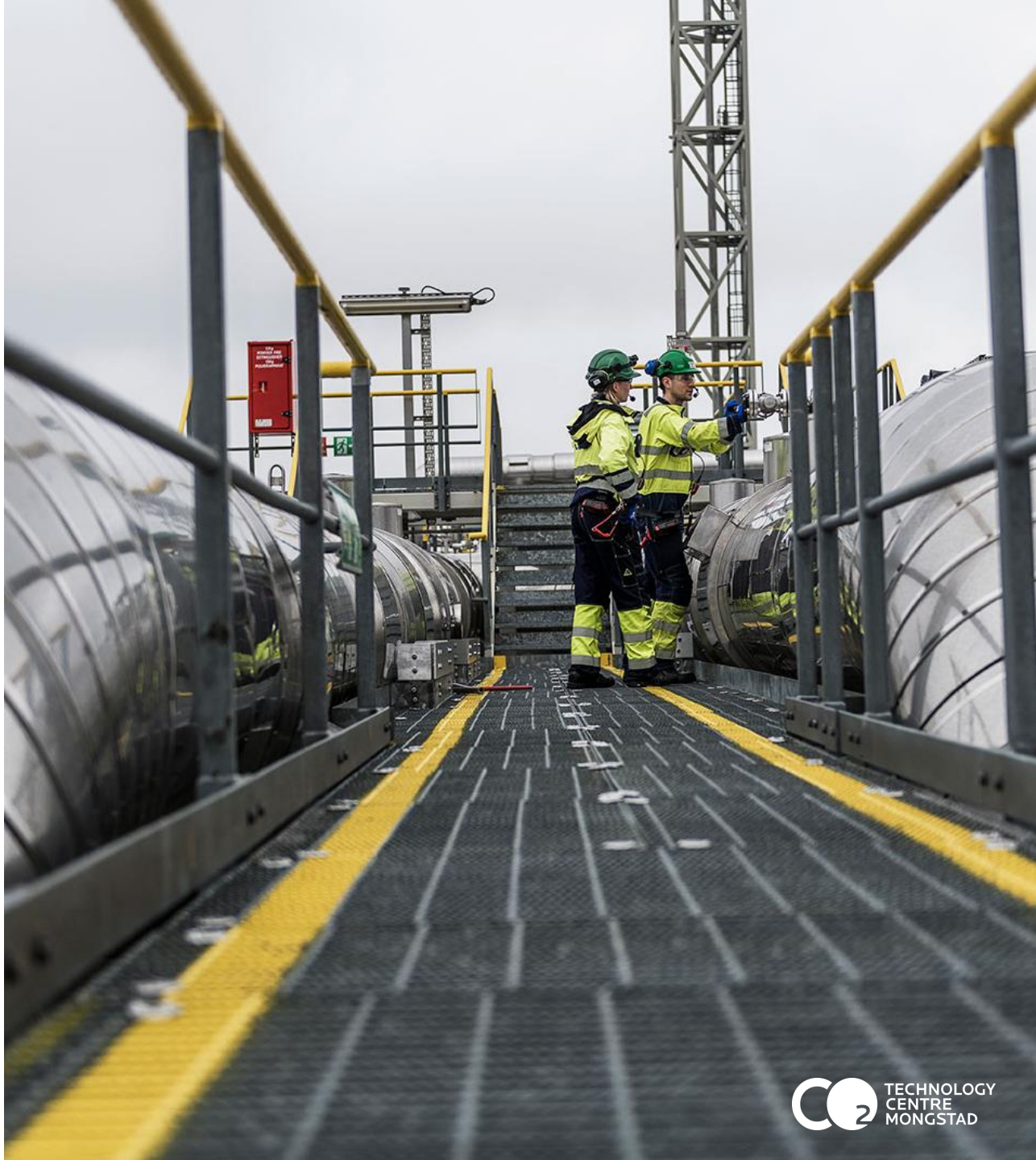
Typical pitfalls observed in CCS projects

- Risks and failure modes not systematically identified
- Chosen technology does not match flue gas specs
- Lack of simulation models and prediction tools
- Actual operating environment often not tested
- Poorly validated analytical models due to lack of operational data
- Probability of failure not determined
- Consequences of risks and failures not determined

Budget overruns, poor reliability, frequent downtime and performance insufficiency



Where can TCM help

- Technical design, planning and construction of a CO_2 capture unit
- Process, control and operations
- Instrumentation and analysis
- HSE and risks including work environment and occupational hazards
- CAPEX and OPEX
- Emissions including measurements, permits and authority dialogue
- Technology assessment methodology
- Flue gas characterization
- Solvent Management

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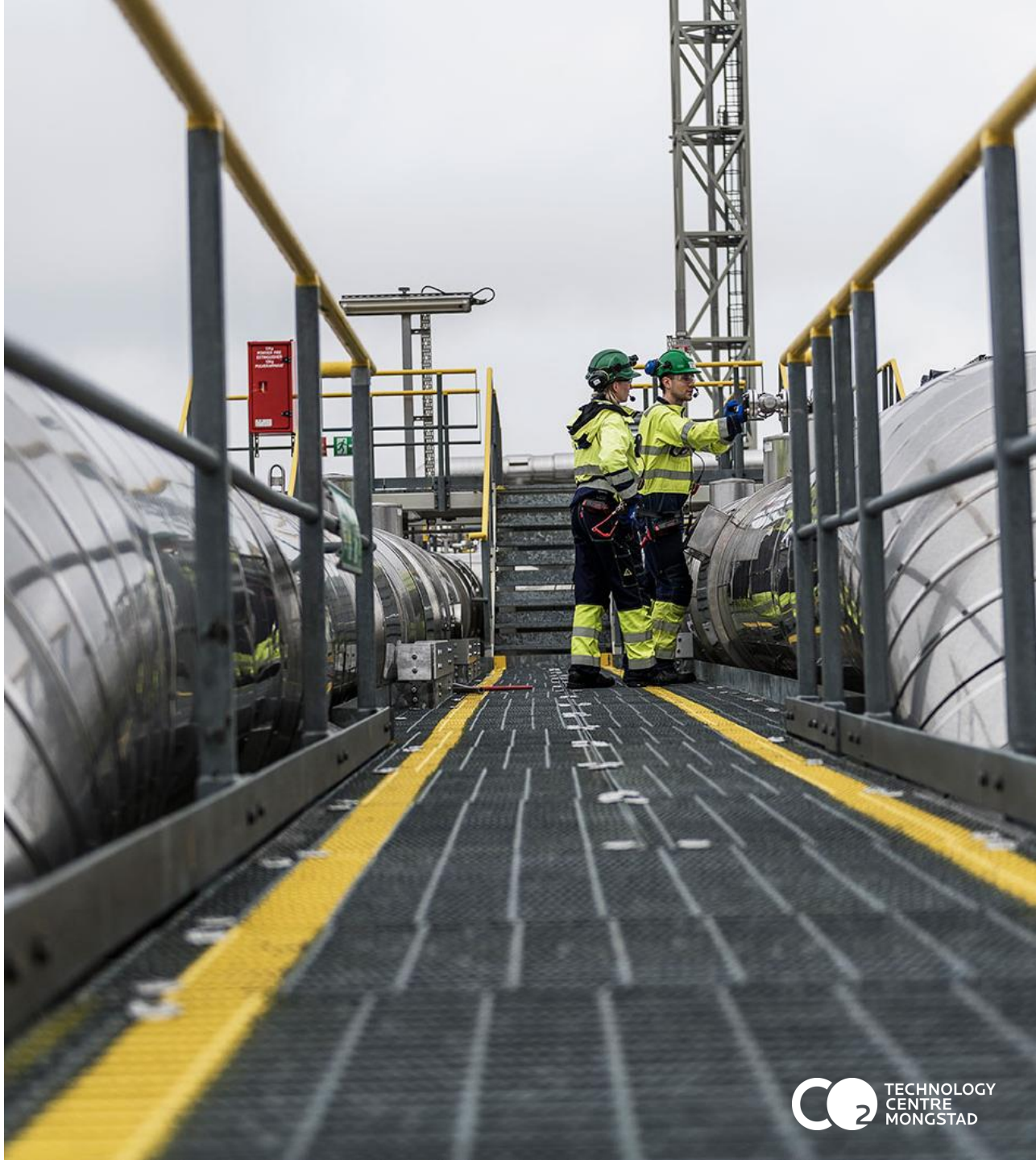
TCM’s operational experience

- Manning of operations
- Regularity of maintenance
- Frequency of major maintenance
- Costs and manning of scheduled stoppages
- Units/systems requiring more maintenance (e.g. Lean Rich Heat Exchanger where CO_2 flashing might occur, hot spots etc.)
- Recommended spares
- Major operational costs & challenges (e.g. solvent consumption)
- Potential of capture rate fluctuations (obligations to the user of CO_2)
- Efficiency of the plant over time (corrosion, fouling etc. & how they will affect heat transfer efficiency)



Clients of Advisory Services

OIL AND GAS CLIMATE INITIATIVE

fortum Oslo Varme

HEIDELBERG CEMENT

中英（广东）CCUS 中心
UK–China (Guangdong) CCUS Centre

sse

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The core strengths

- Unparalleled scale and flexibility at real world testing.
- Scope to test a large variety of technologies onsite, with a high focus on health, safety and environment.
- Comprehensive open-access datasets and industrial-scale baseline.
- Close partnerships with the industry.
- Trusted brand and a global leader built on public research.
- Strong integrity towards technology vendors and proven professionalism.

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