CCS achievements at TCM

Presented to CSLF Technical Group March 26, 2014, Seoul, Korea

by

Lars Ingolf Eide

Coordinator, International CCS Test Centre Network

WHO OWNS TCM?

20%

75.12%

2.44%

2.44%

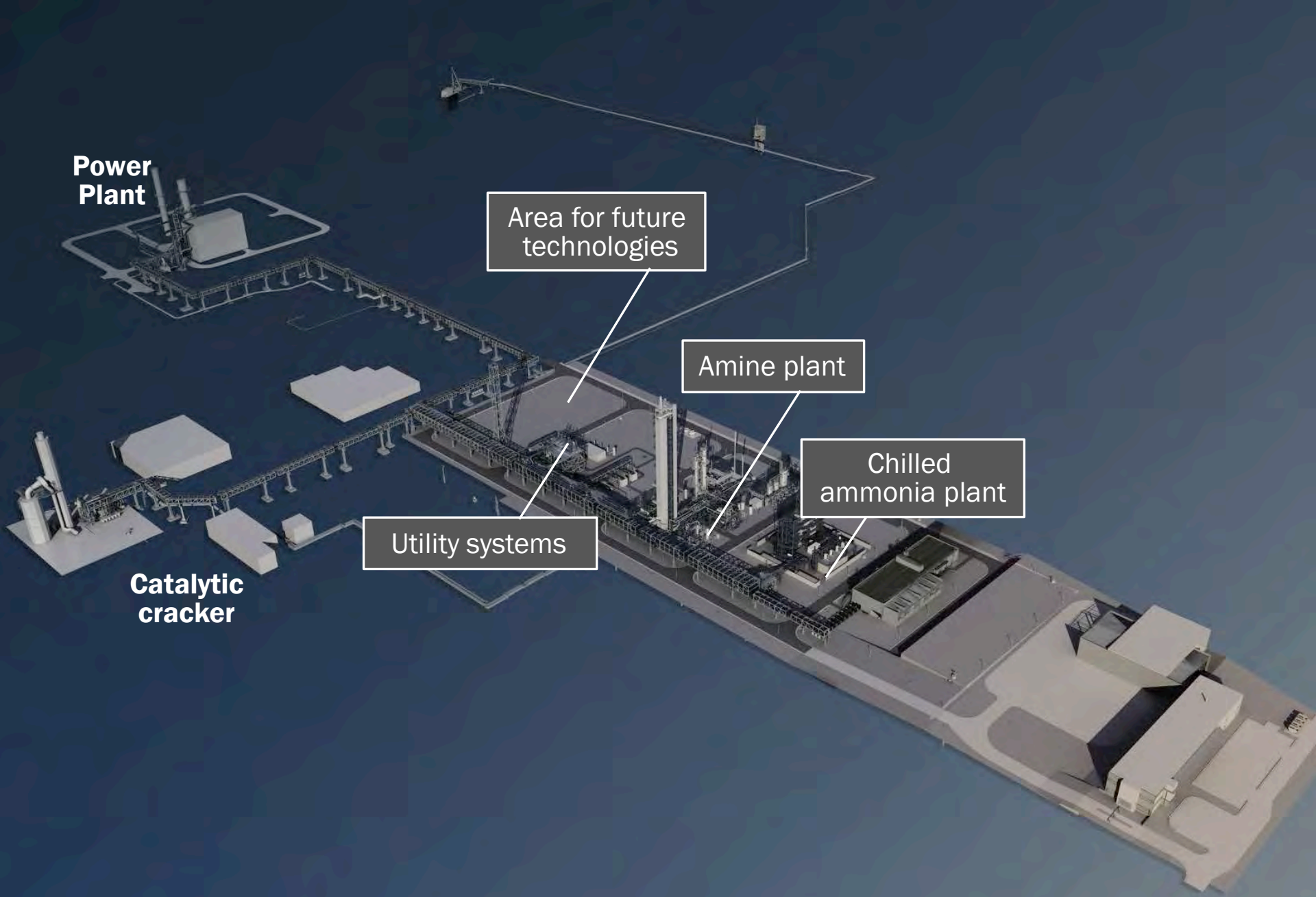
TCM GOALS

Reduce the cost and the technical, environmental and financial risks of implementing full scale CO2 capture technology

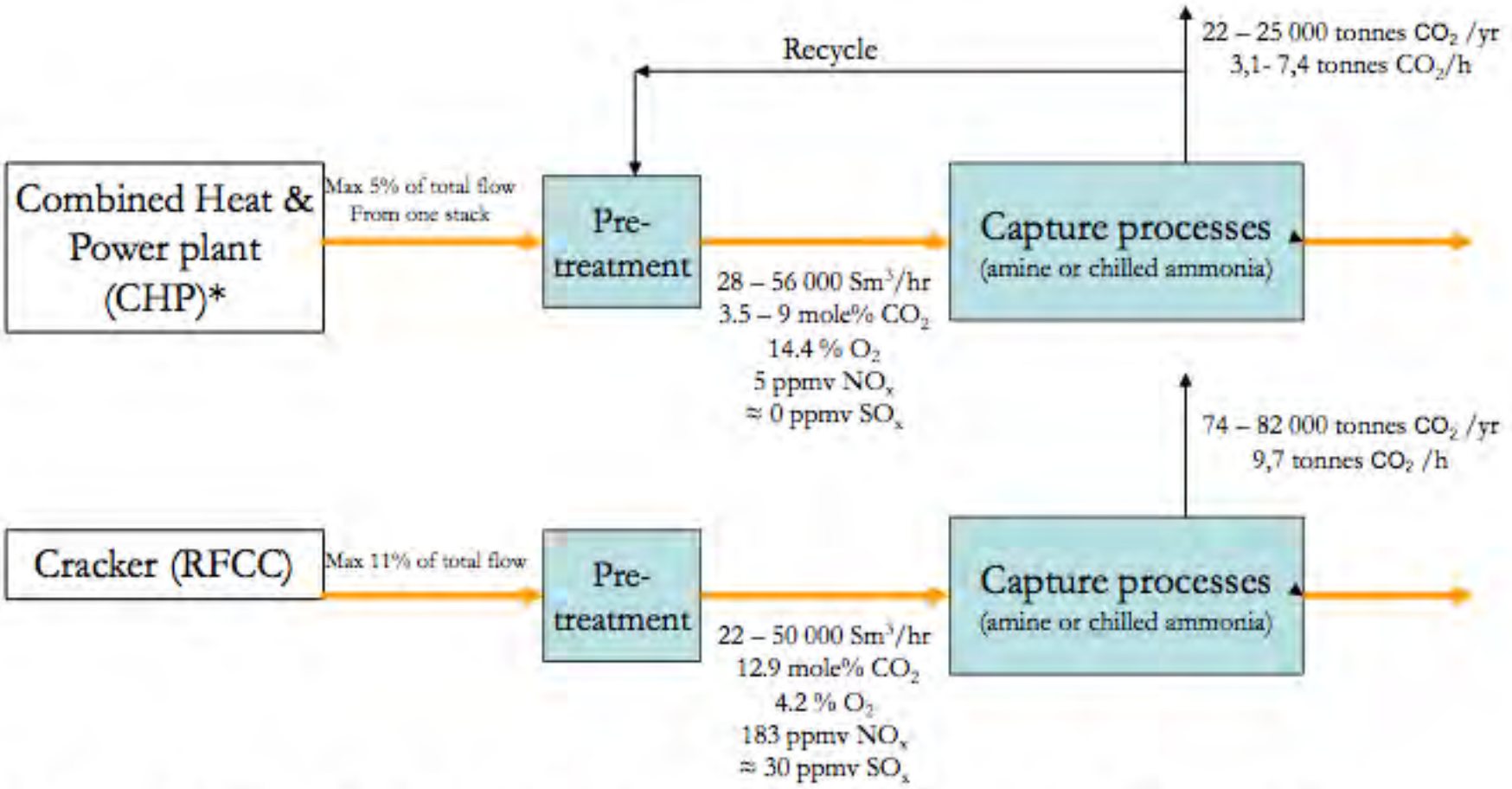
Test, verify and demonstrate CO_2 capture technologies owned and marketed by vendors

Be a key player in the development of the emerging market for CO_2 capture technology


catching our future


Power Plant
Area for future technologies
Amine plant
Chilled ammonia plant
Utility systems
Catalytic cracker

Two flue gas sources

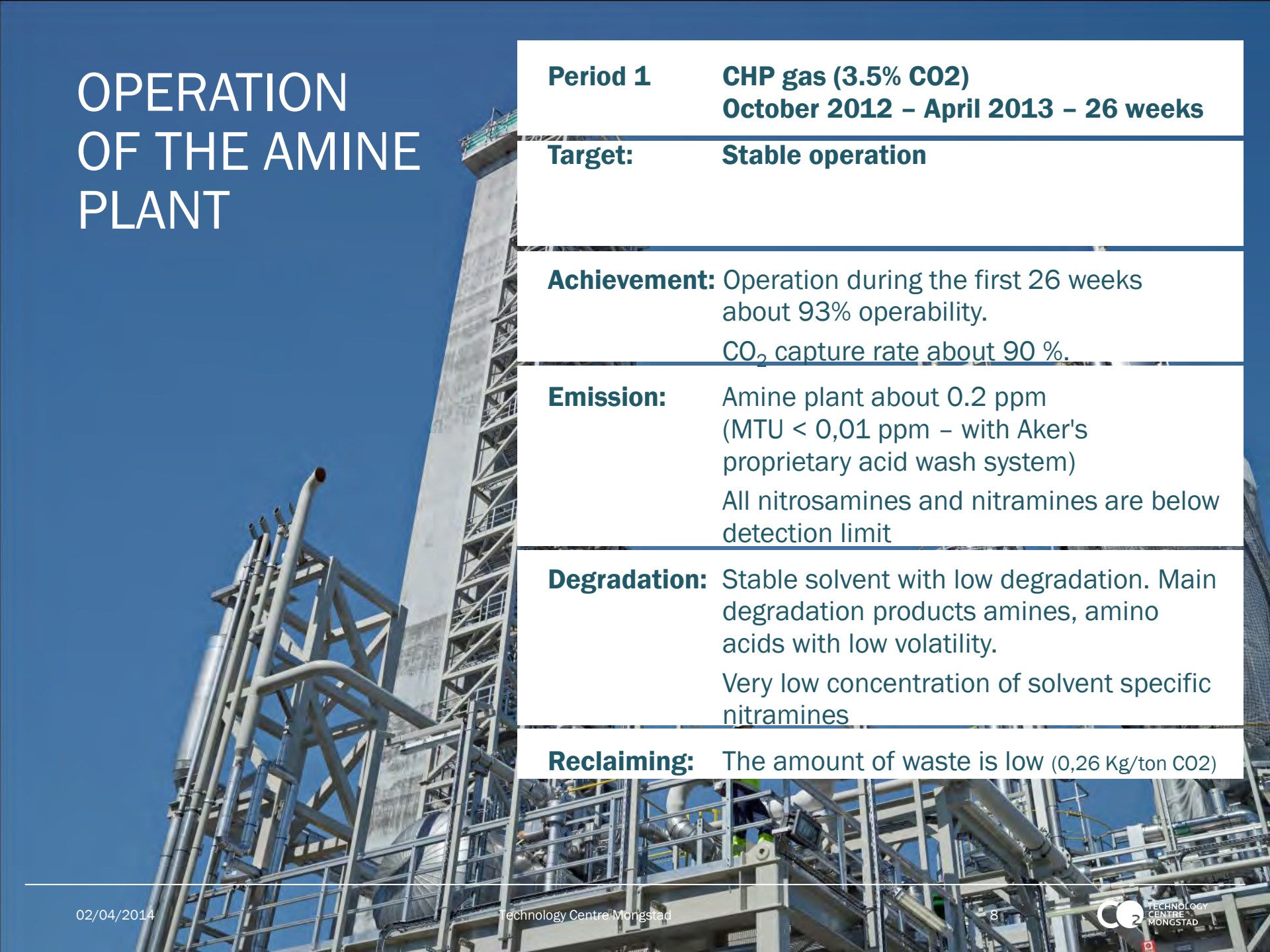


Relevant for a number of industrial processes including gas and coal fired power plants.

Current status at TCM

- 3 plants, 2 technology vendors, several campaigns conducted
- Amine Plants, operated in collaboration with Aker Solutions
  - S21 campaign
    - 8 months
  - MEA campaign
    - 3 months
    - Results to be openly published (!)
  - S26 campaign
    - Commencing March 2014
- Aker Solution's Mobile Test Unit (MTU)
  - Operated solely by Aker Solutions
- Chilled Ammonia Plant, operated in collaboration with Alstom
  - Alstom's CHP campaign
    - 7 months,
  - Alstom's RFCC campaign
    - Commencing January/February 2014

OPERATION OF THE AMINE PLANT



Period 1	**CHP gas (3.5% CO2)** **October 2012 – April 2013 – 26 weeks**
Target:	**Stable operation**
Achievement:	Operation during the first 26 weeks about 93% operability. CO_2 capture rate about 90 %.
Emission:	Amine plant about 0.2 ppm (MTU < 0,01 ppm – with Aker's proprietary acid wash system) All nitrosamines and nitramines are below detection limit
Degradation:	Stable solvent with low degradation. Main degradation products amines, amino acids with low volatility. Very low concentration of solvent specific nitramines
Reclaiming:	The amount of waste is low (0,26 Kg/ton CO2)

OPERATION OF THE AMINE PLANT

Period 2 – RFCC gas (~ 13 % CO2)

Tests gave MIST generation with emissions above permit

Preliminary conclusions:

- To high SO_3 and SO_2 concentration generate mist, leading to high Amine emissions

Alternative solutions considered:

- Reduce SO_3 and SO_2 by filters
- Prevent mist by process development

Period 3 MEA campaign on CHP (3.5 % CO2)- NOV- 2013 – MARCH - 2014

Targets: Develop the plant base line, explore the operation window and optimize the process

Design/scale up:

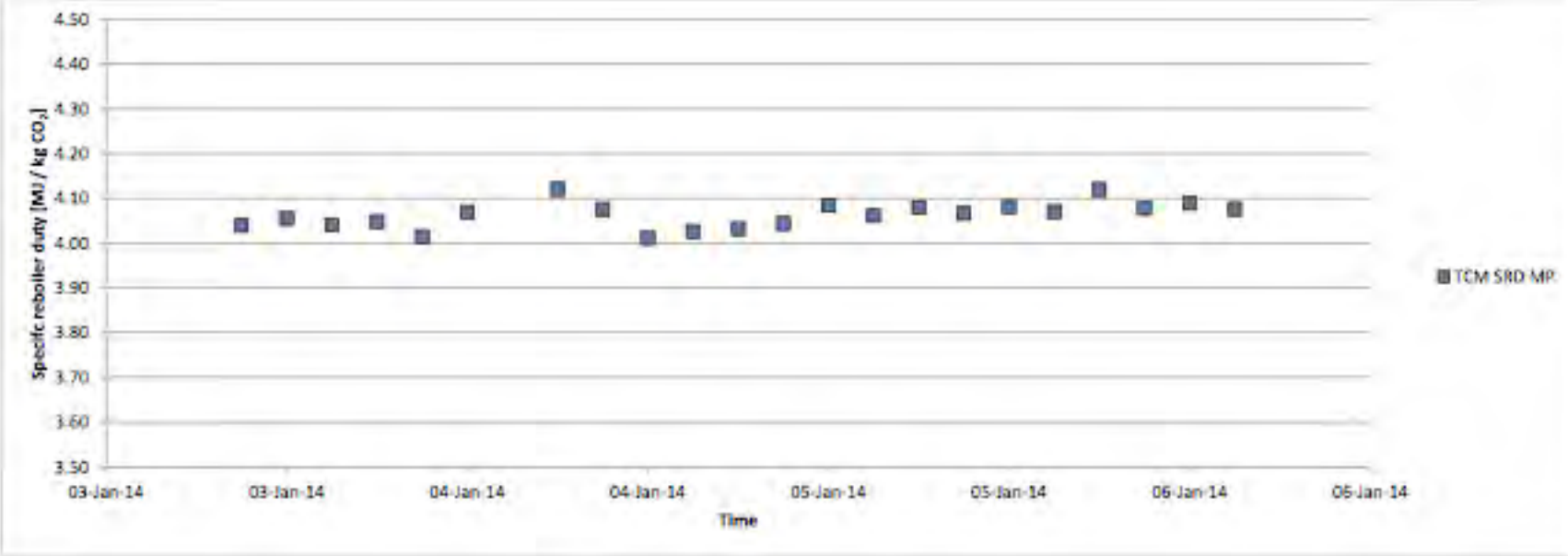
- Confirmation of scale up calculation
- New process data to optimise scale up models

Monoethanolamine at gas-fired turbine flue gas (3.5% CO2)

- Aqueous monoethanolamine (MEA)
  - Utilized for many years for different purposes in the industry
- TCM and Aker Solutions are testing MEA in the Amine plant
  - Considerable scale of 60.000 Sm3/day of flue gas
  - Results will be openly published
- Verification work of
  - Electric Power Research Institute (EPRI); verification protocol
  - FORCE Technology; gas phase compositions and flows
  - University of Oslo; amine and amine degradation products emissions
- Preliminary results at 85% CO2 capture from gas-fired turbine flue gas
  - 30 wt% aqueous MEA: about 4.0 MJ/kg CO2
  - 40 wt% aqueous MEA: about 3.5 MJ/kg CO2
- First-of-a-kind results in the world!

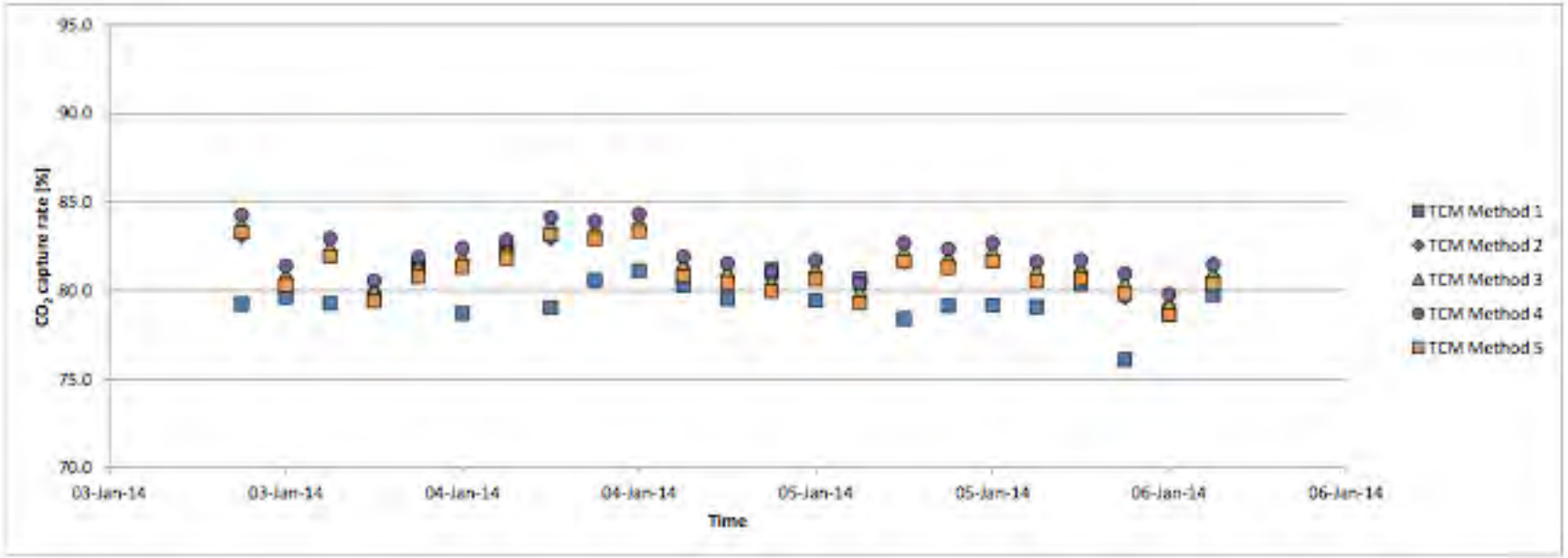
Sneak peak results

- Specific reboiler duty (SRD)
  - About 4.0 – 4.1 MJ/kg CO2 based on 30wt% aqueous MEA
  - Further reductions based on 40wt% aqueous MEA



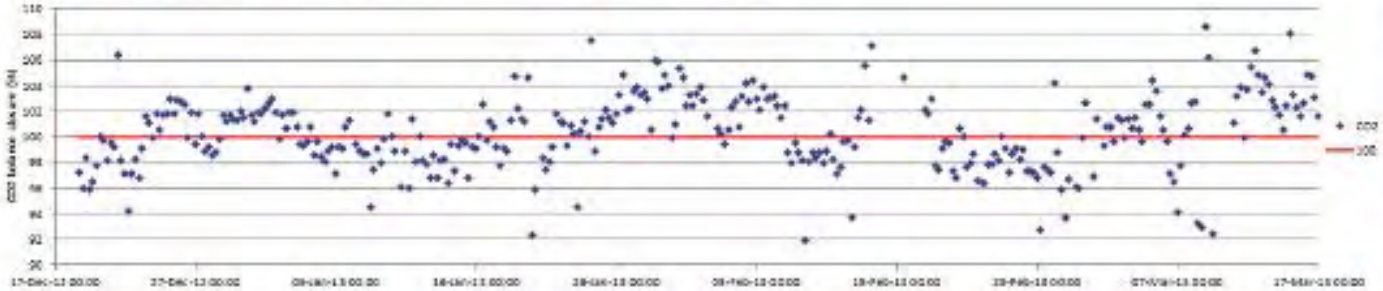
Sneak peak results

- CO_2 capture rates
  - 80%-85%
  - Heavily instrumented; several methods of calculations



CO_2 MASS BALANCE

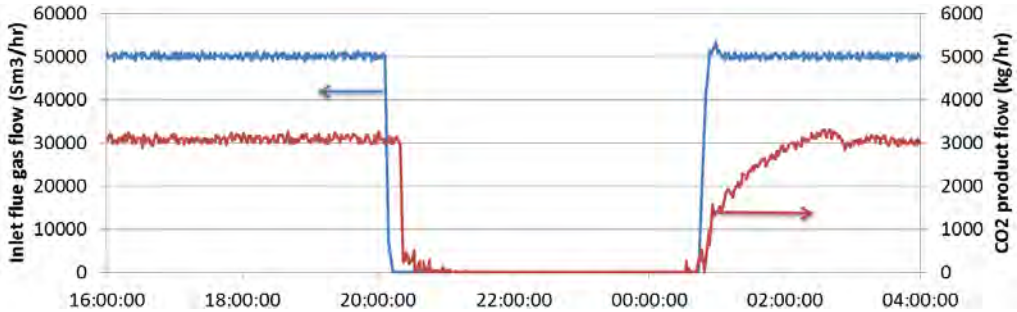
- Extensive work carried out to achieve high mass balance accuracy
  - Different types of flow meters investigated
- Currently a well understood CO_2 mass balance of about ±4%
- (CO_2 abs out+CO_2 product)/CO_2 inlet*100



DYNAMIC OPERATIONS OF THE AMINE PLANT

- Testing the capture during dynamic transitions, replicating a fluctuating grid power consumptions
- Supporting growth of renewables

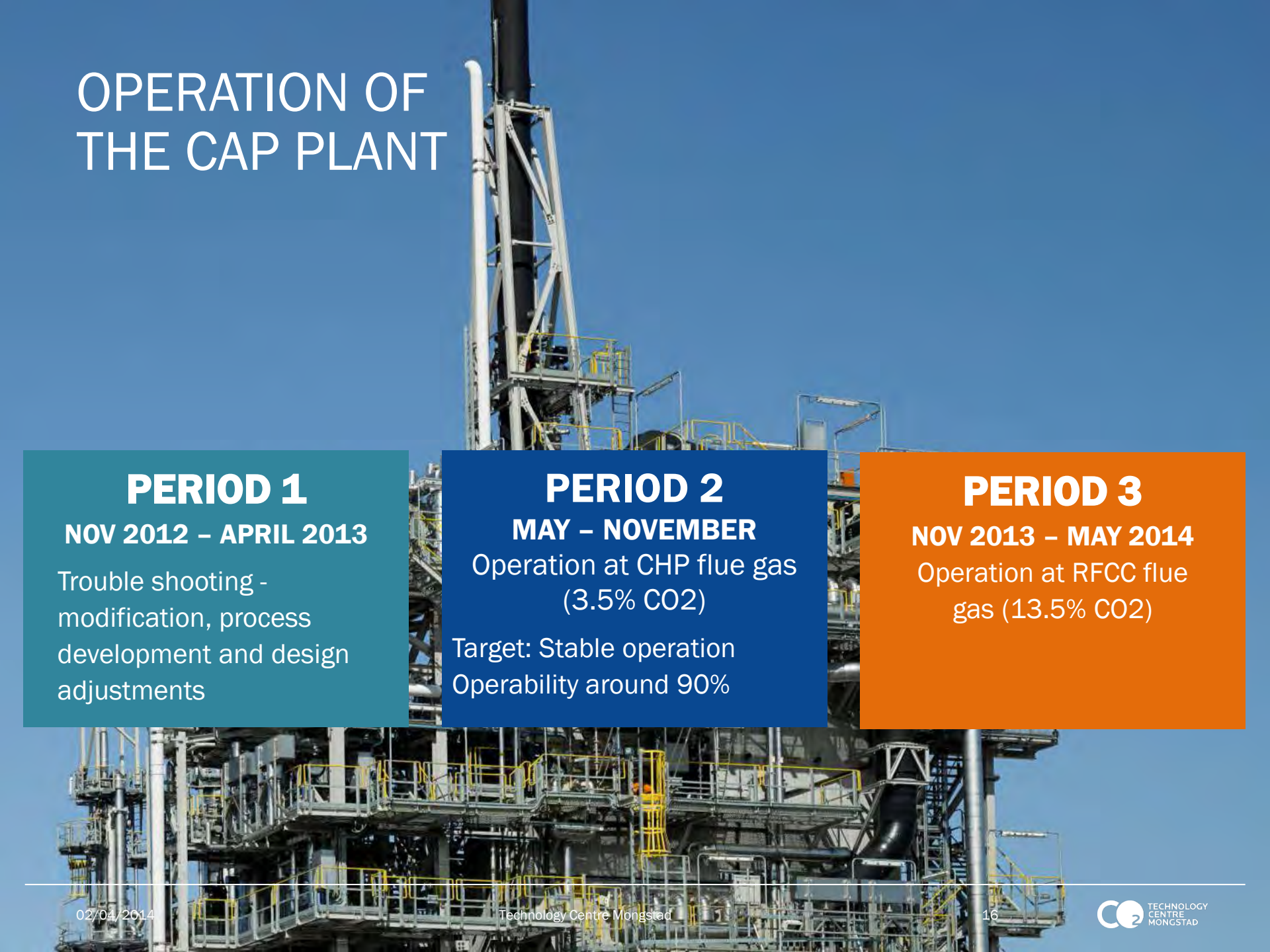
- The graph below shows an example of tripping and starting the amine plant.
  - ability to go from zero to full speed in 1.5 – 2 hours after trip



REDUCTION OF TECHNICAL RISK

- Operational experience from more than 14,000 hours of testing (Amine and CAP plant combined)
- Developed documented and transferable experiences with respect to operation, start-up, shut downs, emergency shut downs etc. All available to the CCS community.
- Developed simulation tools for the total facilities based on NH3 and MEA, (to be used in the planning, operation and evaluation of day to day activities at)
- Established an available analytical laboratory tool box
- Operated with zero injuries and environmental impacts
- Toolbox for process monitoring including emissions
- Established a good network with national and international institutes and research organisations. More than 55 external studies have been performed

OPERATION OF THE CAP PLANT



PERIOD 1

NOV 2012 – APRIL 2013

Trouble shooting - modification, process development and design adjustments

PERIOD 2

MAY – NOVEMBER

Operation at CHP flue gas (3.5% CO2)

Target: Stable operation
Operability around 90%

PERIOD 3

NOV 2013 – MAY 2014

Operation at RFCC flue gas (13.5% CO2)

Alstom's Chilled Ammonia Process

- Results are confidential and proprietary of Alstom
- Results
  - TCM has demonstrated the Alstom CAP technology
  - Successful and stable operations of more than 3000h
  - No environmental or health risk
  - Very low emissions
- Alstom's RFCC campaign commencing

Reducing risks

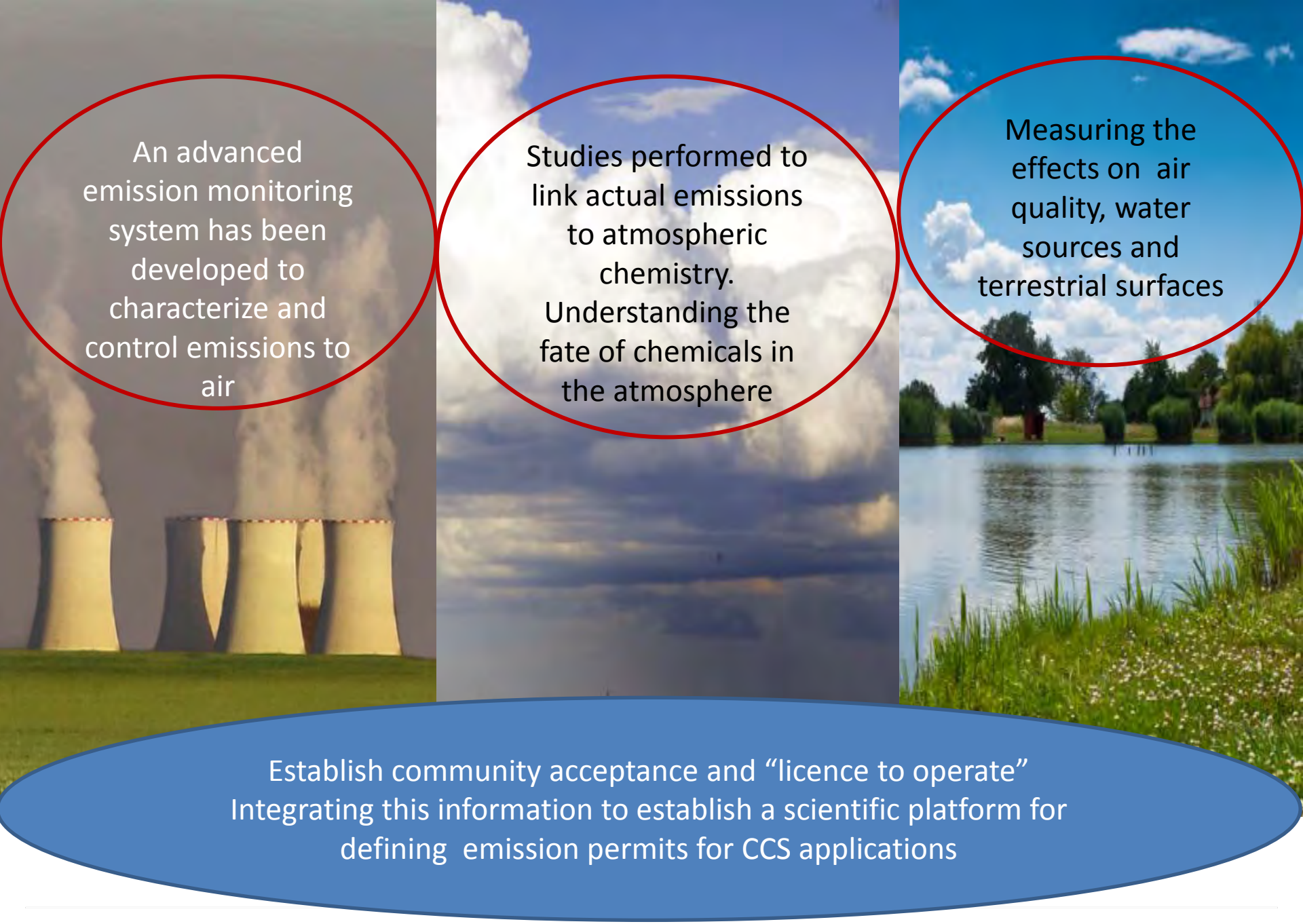
TECHNICAL RISK

ENVIRONMENTAL RISK

FINANCIAL RISK

REDUCING TECHNICAL RISK

REDUCING ENVIRONMENTAL RISK



An advanced emission monitoring system has been developed to characterize and control emissions to air

Studies performed to link actual emissions to atmospheric chemistry. Understanding the fate of chemicals in the atmosphere

Measuring the effects on air quality, water sources and terrestrial surfaces

Establish community acceptance and “licence to operate”
Integrating this information to establish a scientific platform for defining emission permits for CCS applications

REDUCING FINANCIAL RISK

REDUCTION OF FINANCIAL RISK

Have confirmed successful operations of a scaled up plant

- CAP plant;
  - Process development from a precipitating system to a solution based technology
  - Energy optimization
  - Design modification for preventing salt precipitation
- Amine plant
  - Material selection. Gasket material needs to be replaced in certain areas. Material selection for other key components verified
  - Constructed and verified the use of concrete absorbers with polymer (PP) lining. Experienced and verified the easiness of repairing leakages i.e. welding and change parts of the PP lining
- Achieved knowledge from two different construction methods (modular and on site construction)
- The TCM simulation tool is to be verified by testing with real exhaust in our industrial sized test units.
- Established a good embryo for a future industrial CO2 cluster of vendors, supply industry, academia

SHARING CARBON CAPTURE KNOWLEDGE

TCM launched the first International Test Centre Network to accelerate CCS technology development,

- Sharing knowledge of developments, construction and operational experience
- Establishing benchmarks and performance indicators
- Promoting technology certification and standardization

TCM HAS A SOLID PLATFORM GOING AHEAD

- TCM is working with major companies for further utilization of the Amine test plant
- Alstom continue their test and process development throughout 2014
- TCM is working with a number of innovative companies to develop the available test area

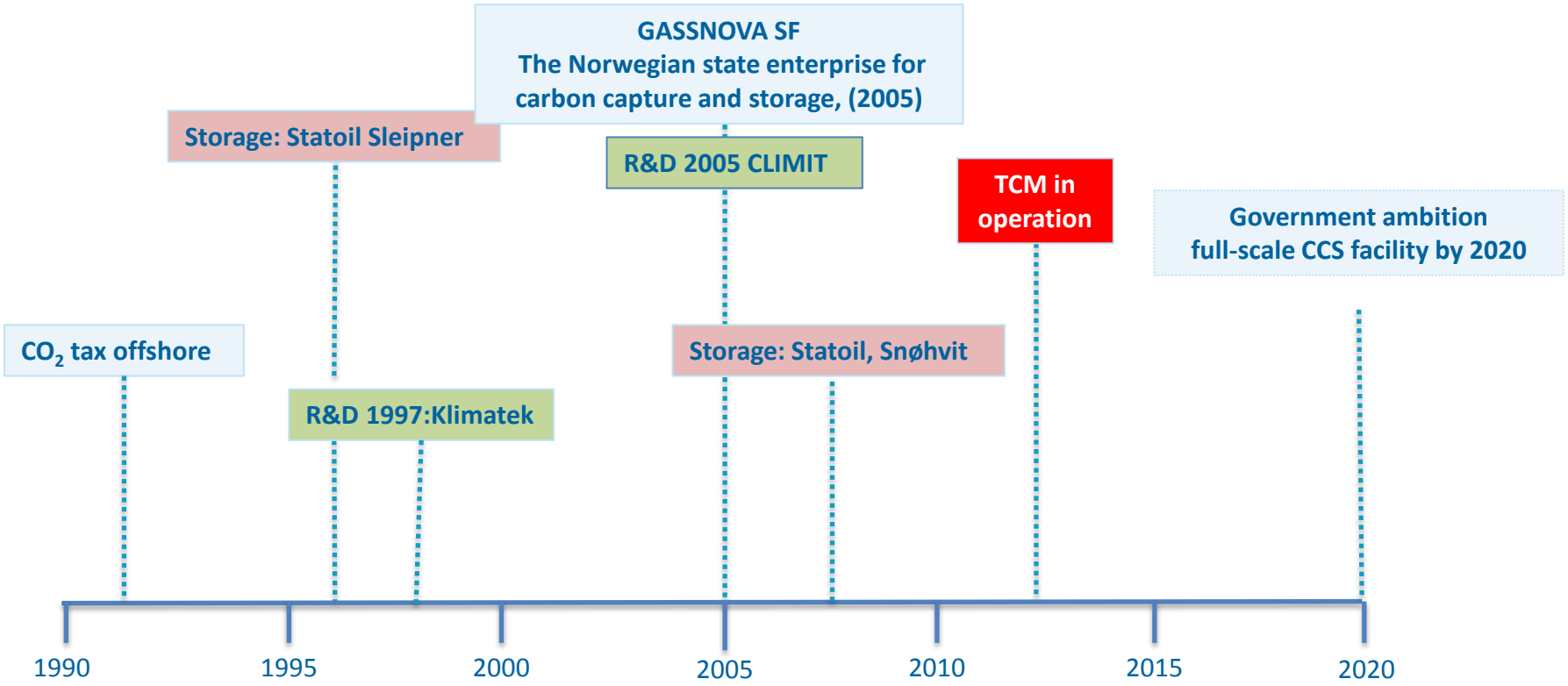
and

TCM has proven its key role in reducing;

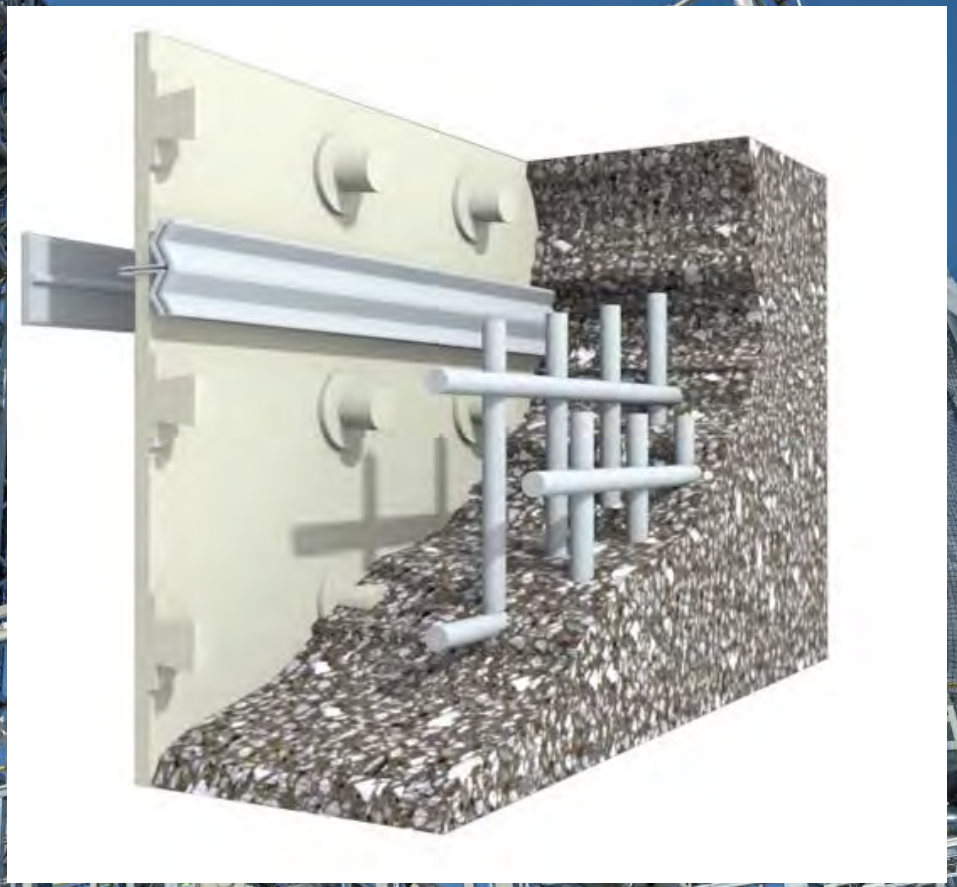
- Environmental risk
- Technical risk
- Financial risk


Thank you
TECHNOLOGY
CENTRE
MONGSTAD

CO_2 history in Norway 1990-2020



OPERATION OF THE AMINE PLANT



TECHNOLOGY CENTRE MONGSTAD

Milestone Mongstad III during the week 5th to 9th of May 2014