

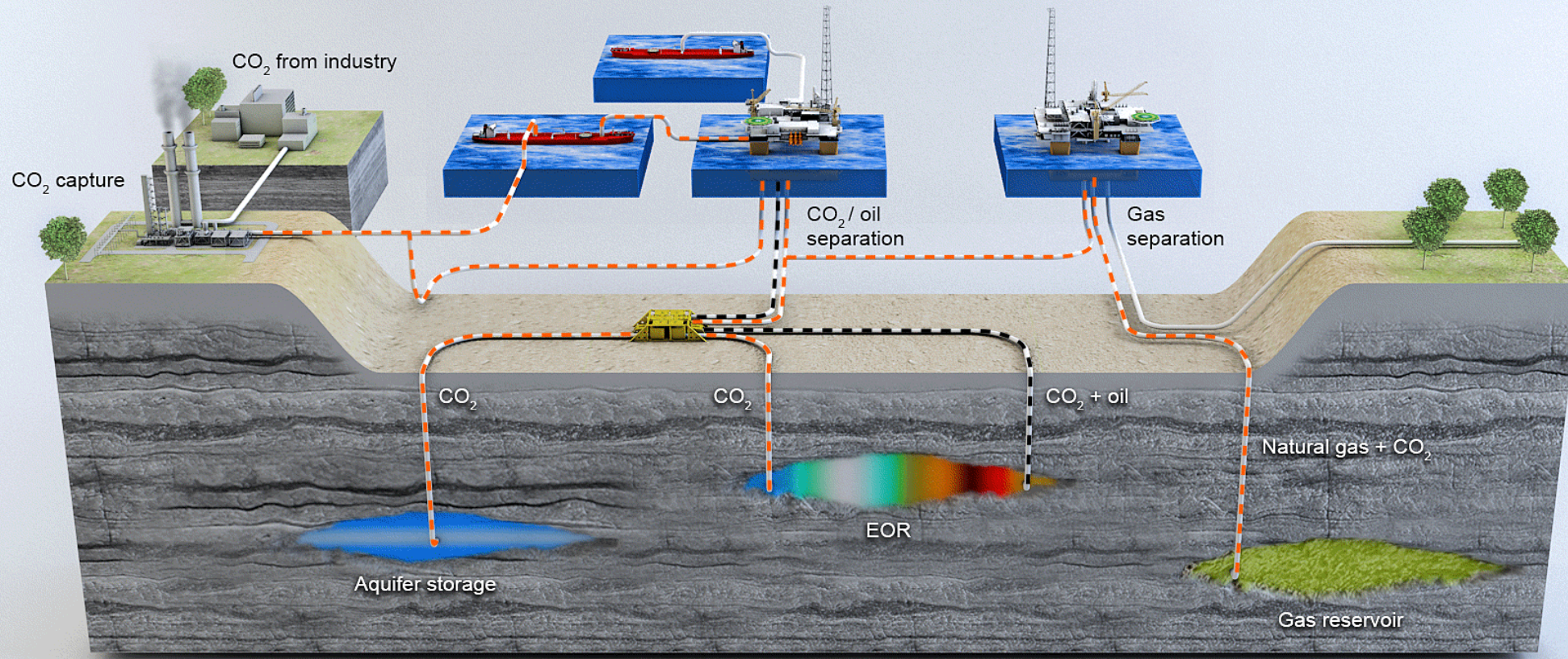
# Aker Solutions' Carbon Capture Technology – Improving Absorption Technology

HiPerCap Workshop, September 13, 2017  
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CCUS, Aker Solutions



# Carbon Capture, Utilization and Storage (CCUS)

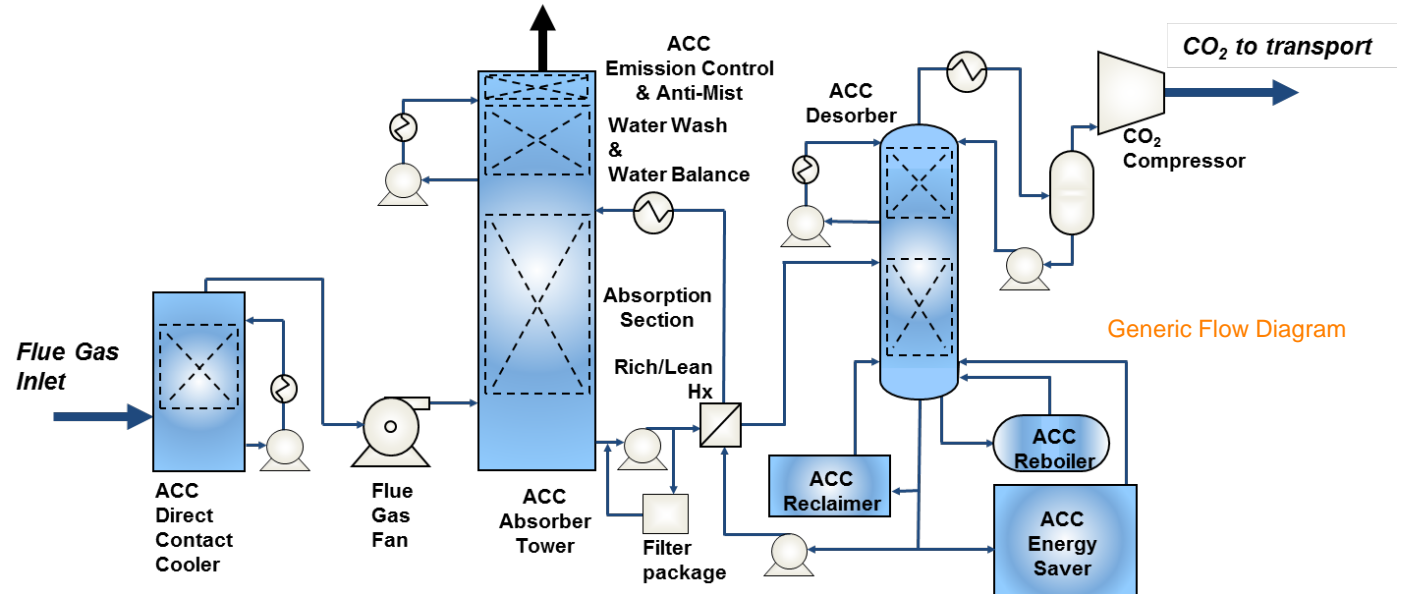
Aker Solutions offers technology and solutions for the entire carbon capture, utilization and storage value chain



# Carbon Capture Technology, Process Design and Equipment

## Advanced Carbon Capture™ Process

Full scale plant and process design, specification and delivery of proprietary equipment packages, solvent formulation, performance guarantees and licencing of technology. EPC partnering.



### Key Equipment

- Absorber Tower
- Desorber incl. reboiler
- Direct contact cooler
- Reclaimer
- Energy Saver

### Technology Characteristics

- Excellent performance data from coal, gas, cement and waste-to-energy plants
- 50 000 operating hours in six pilot plants globally
- Cost, energy and environmental focus
- Modularization

### Technology advantages

- Most mature
- Flexibility
- For retrofit and new built
- For various flue gases
- Lifecycle cost
- Verified improvements
- Excellent solvent performance

# Development and Qualification of ACC™ Technology

- Participation in many Norwegian and international research projects
- Large 8-year R&D program SOLVit to improve solvents and process technology
- Operation of Aker Solutions' Mobile Test Unit (MTU) since 2008 at various industrial emission sources
- Test & demonstration for 2 years at Technology Centre Mongstad (TCM)
- Comprehensive technology qualification programme executed
- Design matured through numerous engineering studies (CCM, Norcem CCS, Longgannet, Kårstø Demo, Port Tolle, etc.)



# MTU, Mobile Test Unit | Advanced CO<sub>2</sub> Capture Pilot

- Owned & Operated by Aker Solutions
- Test campaigns in industrial environment since 2008
  - Coal & gas power, refinery, cement industry and W-t-E
  - Over 20,000 operation hours



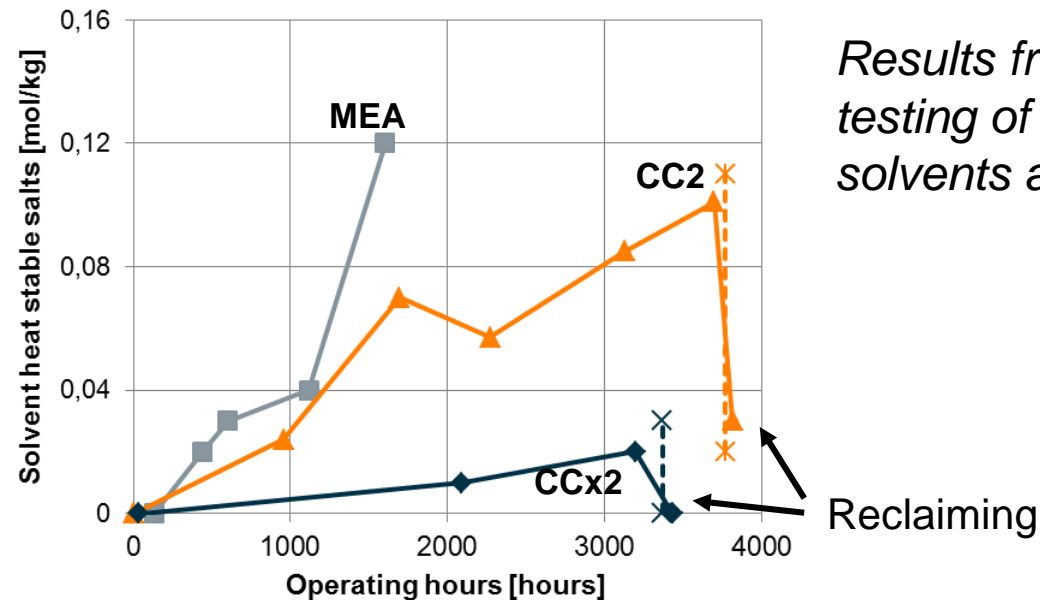
# Improved Energy Efficiency (SOLVit)

- A reduction of the energy consumption with **10-25%** has been demonstrated in pilot plants with SOLVit solvents, compared to project references “Bellingham plant” (NG) and Esbjerg pilot plant (Coal) using MEA
- Applying an advanced process flow sheet increases energy saving of SOLVit solvents with up to **35%** compared to reference



# Improved Solvent HSE and Degradation Performance

- Green solvents with improved HSE characteristics (non-toxic, nonhazardous for aquatic organisms, ready biodegradable, etc.) developed in SOLVit
- Consumption of MEA is almost 5 and 10 times higher than that of CC2 and CCx2, respectively, demonstrating the superior degradation resistance of the solvents developed in SOLVit
- Degradation rate (heat stable salts) in SOLVit solvents (especially for CCx2) remain very low after 3,300 operation hours

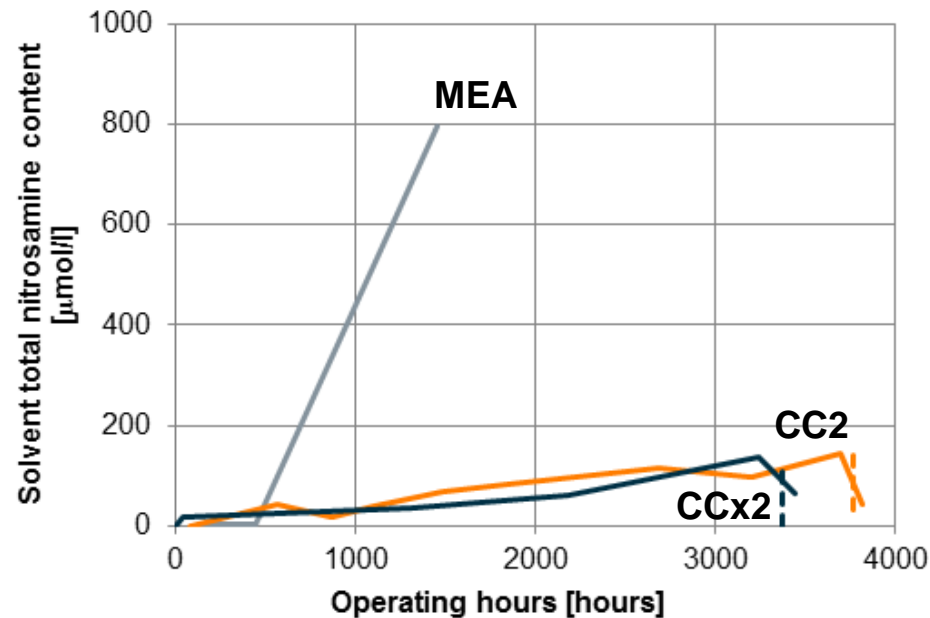


*Results from testing of SOLVit solvents at TCM*

Solvent	Total solvent loss (kg amine/ton CO <sub>2</sub> )
MEA	2.6
CC2	0.6
CCx2	0.3

# Reduced Formation of Harmful Degradation Products

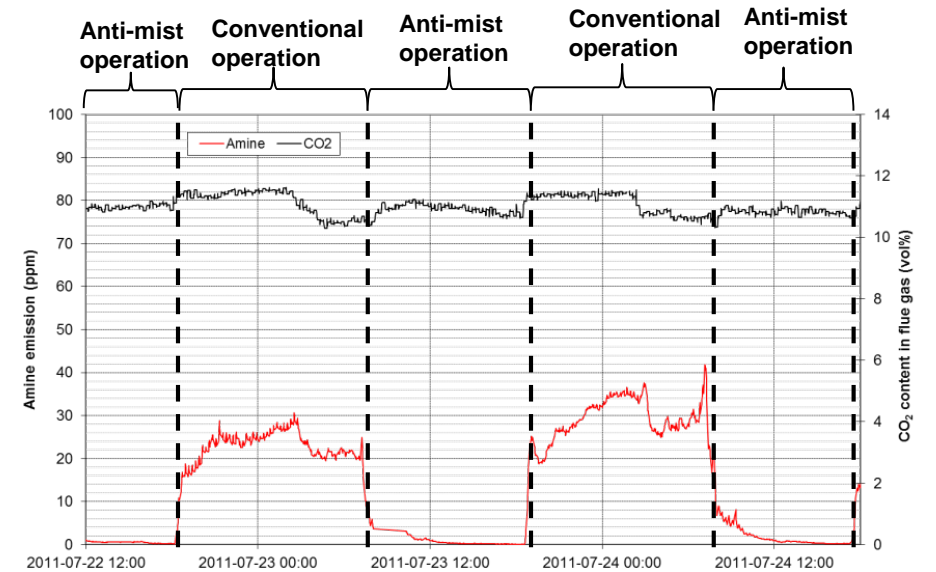
- CC2 and CCx2 are developed to be green solvents that is solvents with similar or better HSE performance than MEA
- Miniscule formation of harmful degradation products such as nitrosamines and nitramines



*Nitrosamine formation in solvent during long-term test campaigns at TCM*

# Improved Emission Control

- Very low emission of solvent amines (<1 mg/Nm<sup>3</sup>) with optimized water wash sections
- Low emission of ammonia and other volatile degradation products (e.g. alkyl amines) from selection of amines with low oxidative degradation rate
- Emissions of amine mist can be virtually eliminated with the ACC<sup>TM</sup> anti-mist design
- Control of nitrosamine emission through selection of amines that does not readily form nitrosamines
- If desirable, emissions of alkaline components can be almost completely eliminated (<0.01 mg/Nm<sup>3</sup>) with acid wash



*MTU test of anti-mist design at NCCC, Alabama*

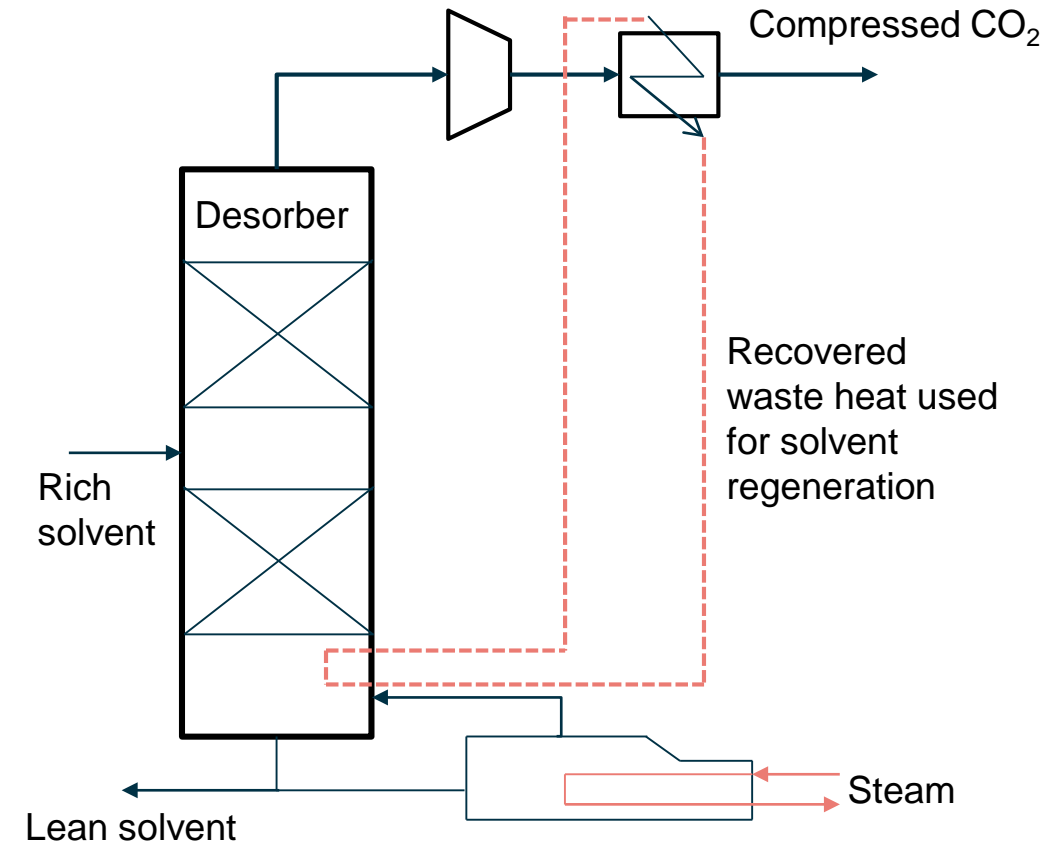


*MTU emission sampling at Norcem, Brevik*

# **Investigation of New Concepts for Further Improvement of Absorption Technology**

# Heat Integration with CO<sub>2</sub> Compression Plant

- Heat integration between CO<sub>2</sub> desorber and CO<sub>2</sub> compression plant may significantly reduce regeneration steam and cooling demands
- This solution is particularly relevant for industrial plants without or with limited steam supply system (e.g. cement)
- Aker Solutions have developed a heat integrated compression concept for the Norcem CCS demonstration project which reduces reboiler steam demand to ~2.0 MJ/kg CO<sub>2</sub>



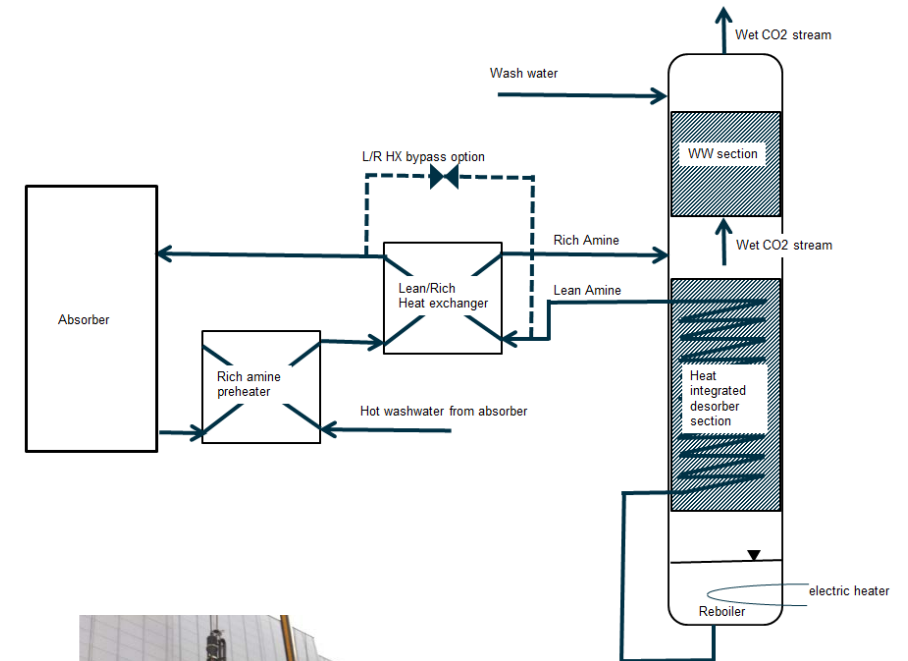
# Pilot Plant Test of Advanced Heat Integrated Desorber

Advanced heat integrated desorber developed and implemented in MTU (CLIMIT project “New desorber design”).

Main test findings:

- Able to reduce SRD by 10% at typical desorber pressure, and up to 14% reduction in SRD at slightly increased pressure (2-3 bara)
- Learned that there is a limited room for low grade heat recovery, the desorption process can not utilise all low grade heat available
- Other desorber configurations will not perform better, the limitations in low grade heat recovery are fundamental
- However other solvents and higher desorber pressure may increase the potential for utilisation of low grade heat

*Advanced desorber  
being installed at MTU*

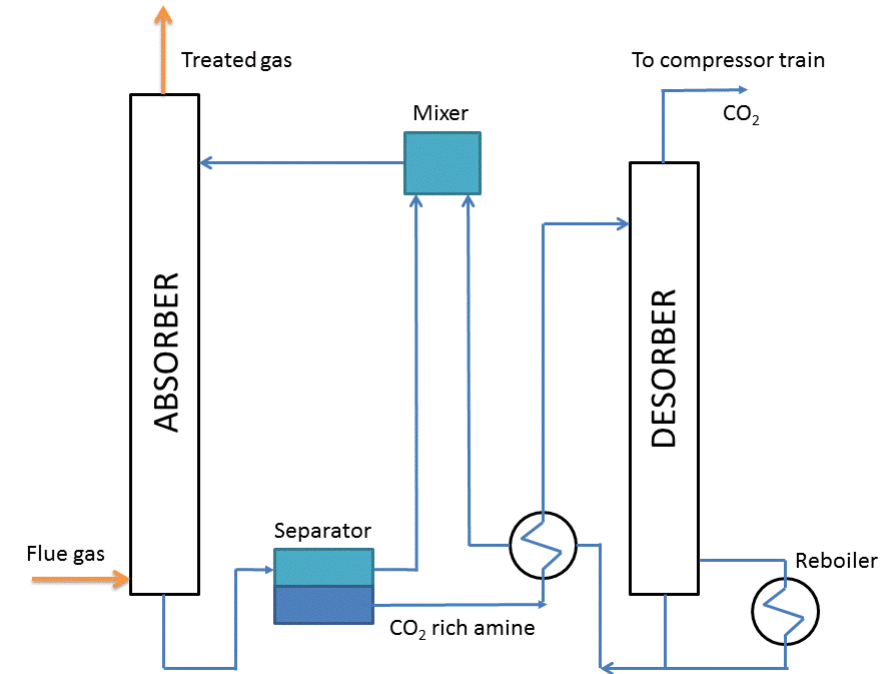


# Novel Biphasic Solvent Systems Tested in SOLVit

- Many promising biphasic solvent systems identified based on CO<sub>2</sub> absorption/desorption screening tests and equilibrium data,
- However many solvent systems were not feasible in practice
- Liquid two-phase systems (e.g. DEEA + MAPA) tested at realistic conditions in the Tiller pilot plant at SINTEF
- Best energy numbers were obtained in test runs without circulation of “light phase”
- Best energy number 2.7-3.0 GJ/ton, which is not significantly better than with the best single phase solvents



*Biphasic solvent*



*Sketch capture plant for biphasic solvent*

# **Case Study:**

## **Using Absorption Technology for CO<sub>2</sub> capture in the Cement Industry**

# Cement industry – A good candidate for CCS

- Cement industry is responsible for approx. 5% of global anthropogenic CO<sub>2</sub> emissions
- CO<sub>2</sub> emission from cement production is inevitable – approx. 60% originate from calcination of limestone (i.e. stuck with CO<sub>2</sub> emissions)
- Plants are in continuous operation at high load factor
- Absorption processes are also attractive for the cement industry:
  - High CO<sub>2</sub> content gives more compact and competitive capture plants
  - Potential for waste heat recovery for solvent regeneration
  - Tail end process => does not interfere with the clinker burning process unlike oxy-fuel combustion, carbonate looping, etc.



*Norcem's cement plant in Brevik, Norway*

# Qualification of ACC™ Technology and Concept Development for a Cement Kiln

## - Norwegian CCS Demonstration at Norcem, Brevik

- Performance of ACC™ capture technology has been verified during 18 months of pilot plant testing (MTU) at Norcem's cement plant in Brevik:
  - Stable operation on flue gas from cement kiln demonstrated
  - Easy to obtain 90% CO<sub>2</sub> capture due to high CO<sub>2</sub> content in flue gas (17-20%)
  - No negative influence of capture plant performance observed due to presence of trace level pollutants from the cement kiln
  - Low solvent degradation and emissions
- Concept developed for a 400,000 tpa CO<sub>2</sub> capture plant from the Brevik plant (nearly 50% of annual emissions) incl. compression, liquefaction, integration, intermittent CO<sub>2</sub> storage and ship loading
- Capture plant driven solely by waste heat recovery from cement process and compression plant



### Norcem:

- Part of HeidelbergCement Group
- One of three candidates for Norwegian CCS demo project
- Aker Solutions is selected by Norcem as provider of CO<sub>2</sub> capture technology for a 400,000 tpa demo plant

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