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Accelerated deployment of integrated CCUS chains based on solvent capture technology

Qualification of the CESAR1 solvent for commercial deployment within the HEU project AURORA

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Hanne Kvamsdal – SINTEF

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Outline

1. Introduction to AURORA and AURORA technology (video)
2. Project overview
3. CESAR1 solvent
4. AURORA technology for reducing emission in cement plants
5. Technology qualification and knowledge gaps
6. Pilot testing
7. Summary and conclusion

1. Introduction

2. Project overview (1)

- AURORA project partners
- 12 partners from 6 European countries
  - Greece, Italy, France, Belgium, UK, and Norway
  - Representing a broad range of experts and important CCUS stakeholders

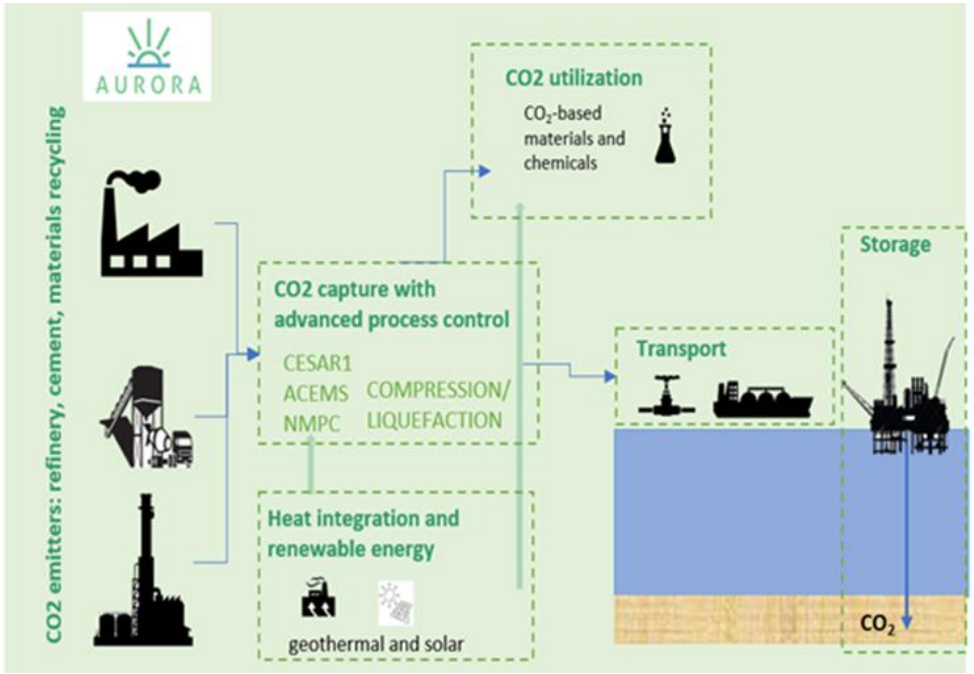
Figure 3-3: Map of AURORA partners.

2. Project overview (2) AURORA consortium

Research/ Academia	SINTEF, NTNU, Norway; TECHNOLOGY CENTRE MONGSTAD – catching our future; UNIVERSITY OF CAMBRIDGE, United Kingdom; SAPIENZA UNIVERSITÀ DI ROMA, Italy
Industry/ Technology provider	TotalEnergies, France; slb Capturi, (Former ACC) Norway; MOTOR OIL, Greece; HERACLES A MEMBER OF HOLCIM GROUP; umicore, Belgium
SME	CYBERNETICA, Norway; euroquality, France

2. Project overview (3) Facts

- Horizon Europe Innovation Action project (*HE-CL5-2022-D3-01-15: Decarbonising industry with CCUS*)
- Project period:
  - 01.01.2023-30.06.2026 (31/2 years)
- Project overall budget:
  - 16 258 397 EURO
- Funding from EC:
  - 12 196 763 EURO (Research/Academia 100% covered, the rest 70% covered



2. Project overview (4) Project concept

Increase cost-efficiency by 50%

Increase controllability and flexibility

Increase the environmental performance

Ensure safe full CCUS chains

Increase social awareness on climate change mitigation technologies

AURORA optimised CESAR1 & Capture process

Innovation 1: Holistic optimisation of solvent composition, process design, emission monitoring and control, and solvent management

Innovation 2: Validated models

Innovation 3: Enhanced waste heat integration in carbon capture for reduced external heat demand and operational costs

Innovation 4: Advanced control system for reduced OPEX and optimized performances

Innovation 5: CESAR1 as the new benchmark technology

4 pilot-scale demonstrations

Tiller

TCM

MTU

Cement

Materials recycling

& Assessment of full CCUS chains for cluster development in 2 countries in Europe

Cement

Refinery

Materials recycling

Replicability and transferability ensured

Complete and validated system (TRL8) towards first-of-a-kind capture plants

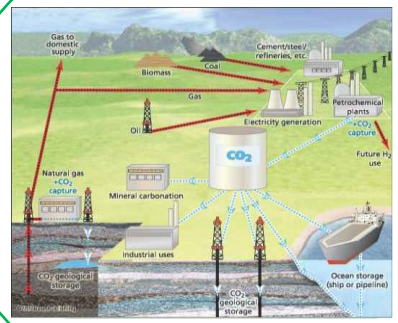
Socio-economic impact

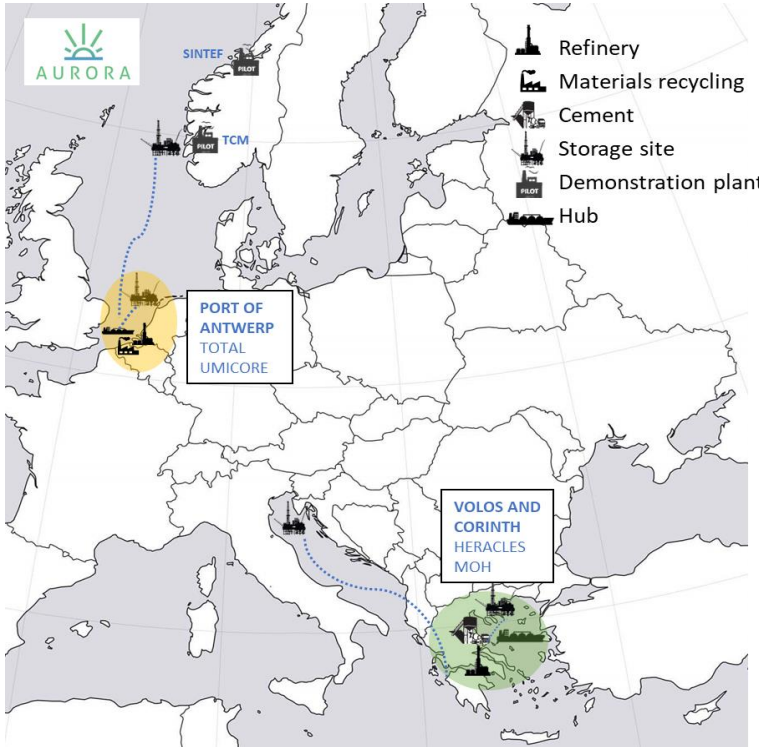
Project overview (5) Clusters and CCUS chain assessment

Refinery

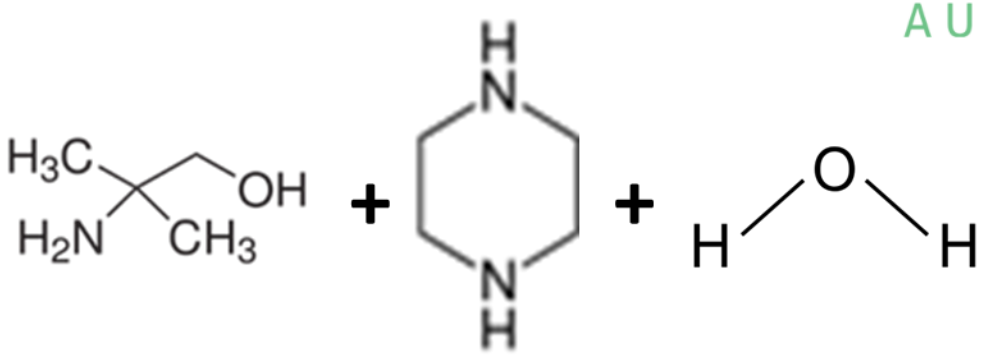
Cement

Materials recycling





3. CESAR1 solvent (1)



- What is the CESAR1 solvent?
  - 2 amines in a water solution:
    - 27wt % 2-amino-2-methylpropanol (AMP), 13wt% Piperazine (PZ), and 60% water
- The CESAR1 solvent was first developed in the CESAR project 15 years ago
- Has been studied in many projects since then
- AURORA will close important knowledge gaps to
  - Extensive deployment in various type of industries
  - Establish as the new benchmark for capture technologies

3. CESAR1 solvent (2)

- CESAR1 pros:
  - Decent energy performance
  - Very stable
    - not easily degradable
  - Very flexible
    - can be used for a range of flue-gas conditions
    - capture rate of CO_2 up to 98-99% without any significant increase in specific reboiler duty (SRD)
  - Non-proprietary solvent
- CESAR1 cons:
  - Two amines in water, a bit more complex to model
  - Strict control of emission to minimize solvent losses and environmental impact
  - May precipitate at certain process conditions

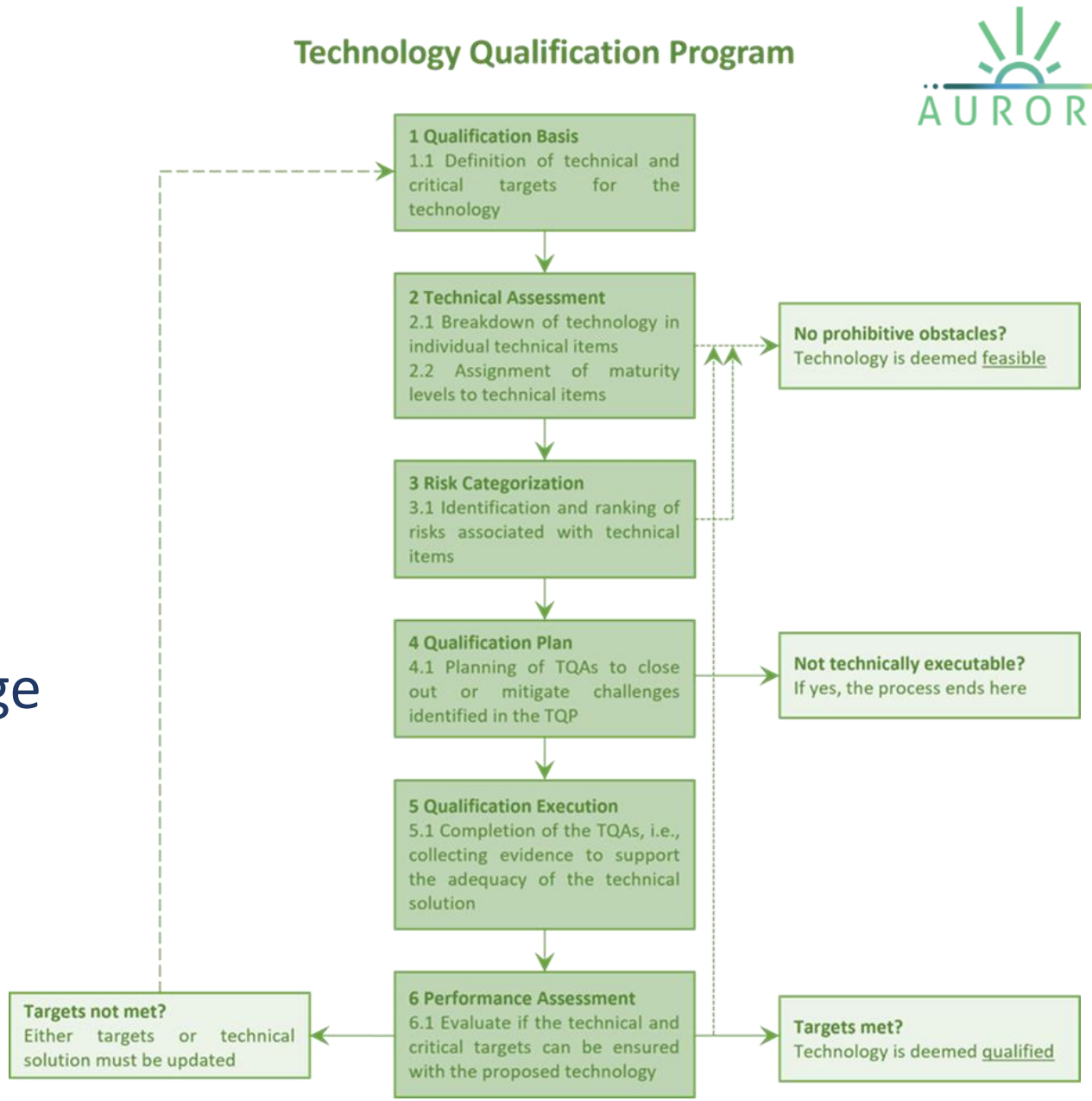
4. Why AURORA technology for reducing CO_2 emission in cement plants

- Capture plant can be easily integrated as an end-of pipe solution
  - Requires no large modifications of existing cement plant
- Well suited for the CO_2 concentration in the flue gas
- Solvent based capture technologies the most mature and proven technology
- The energy requirement is mostly low-temperature heat
  - If steam not available:
    - excess low-temperature heat can be exploited both in cement and capture process
    - possibly also in combination with heat pumps (still a bit immature for industrial applications)
- SOx, NOx and particulates in the flue-gas will partly be removed in the pre-scrubber (DCC)
  - Probably site specific, but will be checked out in the AURORA project through the pilot testing
  - Maybe some additional pre-treatment of the flue-gas will be necessary

5. Technology qualification and knowledge gaps (1)

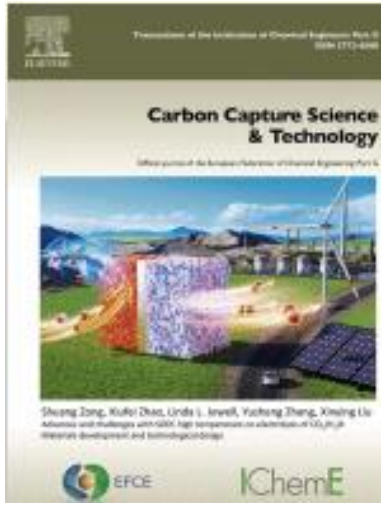
Strategy for technology qualification program (TQP)

1. Define basis
2. Technology assessment
3. Risk Categorization
4. Plan for closing knowledge gaps
5. Qualification execution
6. Performance assessment



5. Technology qualification and knowledge gaps (2)

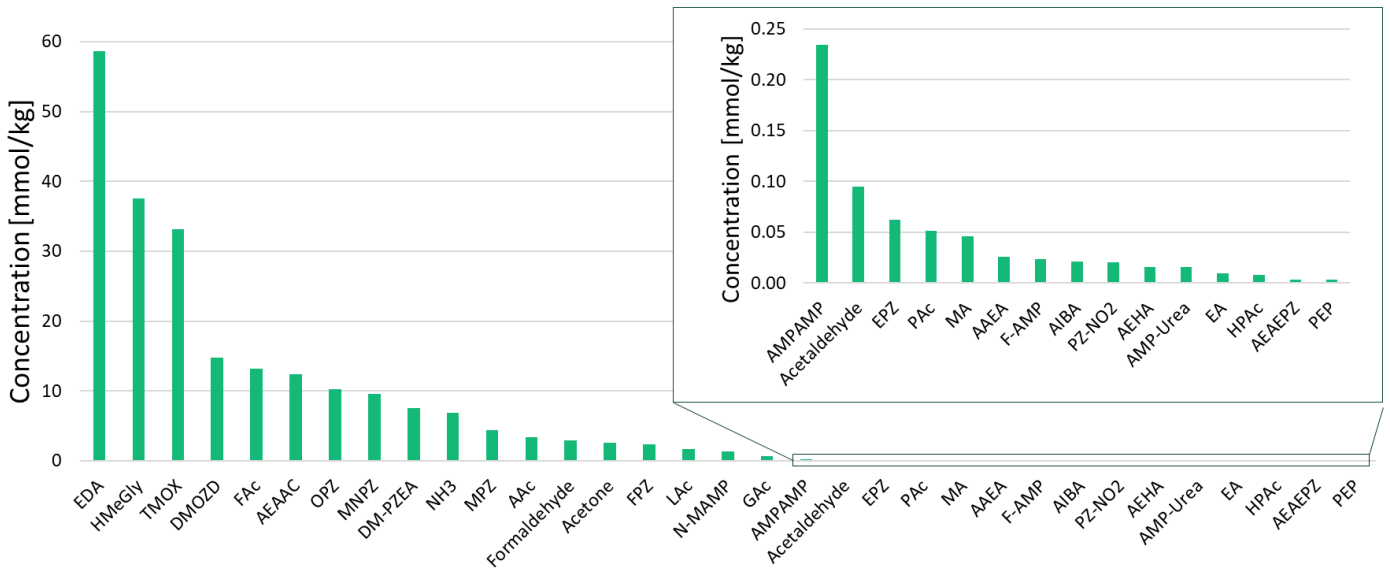
- The specific TQP for AURORA listed in a report
  - Soon to be published at our web-site: www.aurora-heu.eu
- Important knowledge gaps are identified especially related to
  - Technical elements in the capture process
  - Aspects associated with the CESAR1 solvent
    - Data for modelling of the performance
    - Modelling of the performance
    - Degradation of the solvent
    - Pilot testing
    - A review journal publication has been issued: https://doi.org/10.1016/j.ccst.2024.100290



5. Technology qualification and knowledge gaps (3)

- Closing knowledge gaps:
  - Experiments in the lab to cover broader ranges for the solvent (e.g., concentrations, loading of CO_2, and temperature)
  - Extensive degradation tests to identify mechanisms and the specific degradation compounds to close the nitrogen balance (35 identified)

From presentation at GHGT-17 by Vanja Buvik (SINTEF)



6. Pilot testing at Tiller CO2Lab (owned by SINTEF)

- Biomass or propane incineration: 30-40 kg CO_2/h
- Full industrial column height (20 cm diameter)
- Very flexible as designed for various solvents
- Flue gas: CO_2 11 vol.-%, O_2 4 vol.-%, but can vary by recirculation of captured CO_2
- Focus in AURORA:
  - CO_2 concentrations in flue gas not covered in pilot earlier
  - Mimic AURORA end user's flue gas
  - Amine emission monitoring and control including special analyses in the lab
  - Dynamics and advanced process control
  - CO_2 compression and liquefaction

6. Pilot testing with the MTU at site (owned by slb Capturi)

- Capacity: 100–200 kg/h of CO_2 product
- Testing at two industrial sites, HERACLES's cement plant in Volos, Greece and UMICORE's materials recycling plant in Antwerp, Belgium
- Focus in AURORA
  - Performance testing for upscaling effects from Tiller pilot
  - DCC temperature variation and check of SOx/NOx and particulates
  - Desorber pressure variation
  - Dynamic operation
  - Acid wash
  - Solvent reclamation including special analyses in the lab

6. Pilot testing with at TCM (Technology Centre Mongstad

- Flue gas from CHP and cracker: 10 t CO_2/h
- World largest test facility
- Focus in AURORA
  - Performance testing for upscaling effects from Tiller pilot and MTU
  - Emissions and degradation rate monitoring including special analyses in the lab
  - Dynamic operation
  - Foaming and precipitation

7. Summary and conclusion

- The work in AURORA will qualify the CESAR1 solvent and the associated process for commercialisation and deployment in CO_2 capture plants
- AURORA covers many aspects important for full-scale design and operation to close knowledge gaps and reduce risks in future absorption-based CO_2 capture plants
- Absorption based technology has already been implemented at the Brevik plant
- Will test the technology with CESAR1 solvent at a cement plant in Greece
- The absorption-based technology with CESAR1 solvent is indeed something the cement industry should consider for reduced emission of CO_2

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QUESTIONS?

Thank you!

Hanne Kvamsdal – SINTEF

Contact : Hanne.Kvamsdal@sintef.no

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