Framework of the CEMCAP Project

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CEMCAP Structure

Framework, evaluation, management and dissemination (M1-42)

- Project management, dissemination and exploitation SP1
  - Project management and coordination WP1
  - Dissemination and exploitation WP2

Framework and comparative analysis SP2
- Comparative capture process analysis WP4
- Post-capture CO₂ management WP5
- CEMCAP framework WP3

Technology development and demonstration → TRL6 (M1-36)

Oxyfuel capture retrofit SP3
- Oxyfuel modelling and optimisation WP6
- Oxyfuel burner technology WP7
- Calciner technology for oxyfuel capture WP8
- Oxyfuel clinker cooler prototype WP9

Post combustion capture retrofit SP4
- Chilled ammonia process (CAP) WP10
- Membrane-assisted CO₂ liquefaction WP11
- Calcium looping (CaL) capture WP12
CEMCAP Framework Document: Objectives

- to define a reference cement kiln where different CO₂ capture technologies could be applied,
- to define boundary conditions (e.g. energy prices, investment related basis values, CO₂ quality), assumptions (e.g. by reference location) and sensitivities (e.g. capture rates) to compare capture methods,
- to assemble a framework for simulations and evaluation of full-scale cement plants with CO₂ capture; several capture cases/scenarios will be employed for the technology evaluation,
- to define key performance indicators (KPIs) for benchmarking; these will include (but are not limited to) energy consumption, required/produced heat, required/produced power, cost of CO₂ captured, cost of CO₂ avoided and other financial parameters.

The framework document is based on the preliminary work of the EBTF which had developed a framework for benchmarking of power plants with CO₂ capture.
## WP3: CEMCAP Framework

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Title</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3.1</td>
<td><strong>CEMCAP preliminary framework for comparative techno-economic analysis of CO\textsubscript{2} capture from cement plants</strong></td>
<td>Month 4</td>
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<tr>
<td>D3.2</td>
<td><strong>CEMCAP framework for comparative techno-economic analysis of CO\textsubscript{2} capture from cement plants</strong></td>
<td>Month 21</td>
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</table>
CEMCAP Framework Document: structure

- Introduction
- General Definitions and Conditions
- ECRA Reference Cement Plant
- Capture Technologies
- Capture Utilities
- CO₂ Capture Rates
- CO₂ Specifications
- Economic Parameters
- Key Performance Parameters
- Sensitivity Analysis
Characteristics of the reference cement plant

The reference kiln system is based on Best Available Techniques (BAT) standard including:

- 5-stage cyclone preheater
- precalciner with tertiary air duct
- modern grate cooler
### Specifications for the reference plant

<table>
<thead>
<tr>
<th>Location</th>
<th>Europe</th>
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</thead>
<tbody>
<tr>
<td>Production Capacity</td>
<td>1 Mio. t clinker/y (3,000 t/d)</td>
</tr>
<tr>
<td>Cement production</td>
<td>1.36 Mio t cement/y</td>
</tr>
<tr>
<td>Clinker/cement factor</td>
<td>73.7 %</td>
</tr>
<tr>
<td>Raw meal/clinker factor</td>
<td>1.6</td>
</tr>
<tr>
<td>Spec. fuel consumption</td>
<td>3,280 kJ/kg clinker</td>
</tr>
<tr>
<td>Spec. total electricity demand</td>
<td>97 kWh/t cement</td>
</tr>
<tr>
<td>Spec. electricity demand for clinker production</td>
<td>65 kWh/clinker (≈ 48 kWh/t cement)</td>
</tr>
<tr>
<td>Raw material moisture</td>
<td>6 %</td>
</tr>
</tbody>
</table>
Specifications for the reference plant

VDZ has provided data about the

- raw meal composition
- clinker composition
- fuel characteristics for coal and RDF
- flue gas composition / characteristics

Two fuel scenarios will be included:

- 100 % coal
- 70 % coal / 30 % RDF

### Exhaust gas component

<table>
<thead>
<tr>
<th>Carbon dioxide CO₂</th>
<th>Unit</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen O₂</td>
<td>vol.-%</td>
<td></td>
</tr>
<tr>
<td>Humidity H₂O</td>
<td>vol.-%</td>
<td></td>
</tr>
<tr>
<td>Sulphur dioxide and sulphur trioxide, expressed as SO₂</td>
<td>vol.-%</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>mg/m³</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>240</td>
</tr>
</tbody>
</table>
## Reference Plant - typical CO₂ emissions

<table>
<thead>
<tr>
<th>Description</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ from electricity</td>
<td>0.5 - 0.7 t CO₂/MWh</td>
</tr>
<tr>
<td>Specific indirect from electricity</td>
<td>0.049 - 0.068 t CO₂/t cement</td>
</tr>
<tr>
<td>Spec. direct CO₂ from clinker production (incl. biogenic CO₂)</td>
<td>0.828 t CO₂/t clinker (based on 30 % substitution by alternative fuel mix)</td>
</tr>
<tr>
<td>Spec. direct CO₂ from clinker production (excl. biogenic CO₂)</td>
<td>0.804 t CO₂/t clinker (based on 30 % substitution by alternative fuel mix)</td>
</tr>
<tr>
<td>Total spec. CO₂ emissions incl. electricity</td>
<td>0.66 - 0.68 t CO₂/t cement</td>
</tr>
</tbody>
</table>
Available waste heat from a 3,000 t/d BAT plant:

- Preheater exit gas: 22 MW (whereas only 70% is usable heat above 100°C)
- Cooler exhaust air: 13.6 MW
- Wall losses: 10.6 MW

Remaining heat can be used for steam production and/or generating of electrical power

User:
- Raw material drying
- Fuel preparation

E.g. wall losses
CO₂ capture technologies

Capture technologies:

- Base case: MEA absorption
- Oxyfuel
- Chilled Ammonia Process (CAP)
- Membrane assisted liquefaction (combination of two different separation technologies)
- Calcium Looping (CaL)

Capture rates:

- 90 % / 60 % / optimal rate for each technology
CO\textsubscript{2} capture utilities

- Steam production:
  - steam produced from heat recovery in the cement power plant
  - steam import from external source
  - steam production in CHP gas turbine system
  - natural gas fired boiler
- Electricity
  - CO\textsubscript{2} emissions from electricity production
  - cost of electricity
- Integrated power production (CaL, oxyfuel)
- Air separation unit
  - focus on cryogenic oxygen production
- Refrigeration systems
CO₂ specifications

Transport:
- Pipeline transport
- Ship transport

Further destination / utilisation:
- Storage
- EOR
- Utilisation (MeOH, Urea, etc.)
- Mineralization

CO₂ conditioning:
- Compression
- Liquefaction
Key Performance Parameters

- Energy and environmental performance indicators
  - direct specific primary energy consumption, indirect specific primary energy consumption
  - specific electric power consumption
  - direct CO$_2$ emissions, indirect CO$_2$ emissions
  - CO$_2$ capture efficiency, CO$_2$ avoided

- Economic indicators:
  - cost of clinker
  - cost of CO$_2$ avoided
  - cost of clinker with carbon tax

- Other indicators (e.g. space requirements)
Sensitivity Analysis

Due to the uncertainty and the time-place dependency of some assumptions, sensitivity analyses will be performed on the following parameters:

- fuel price
- electricity price
- steam supply
- carbon tax
- CAPEX of the new technologies
- financial parameters (interest rate, inflation rate, economic life, etc.)