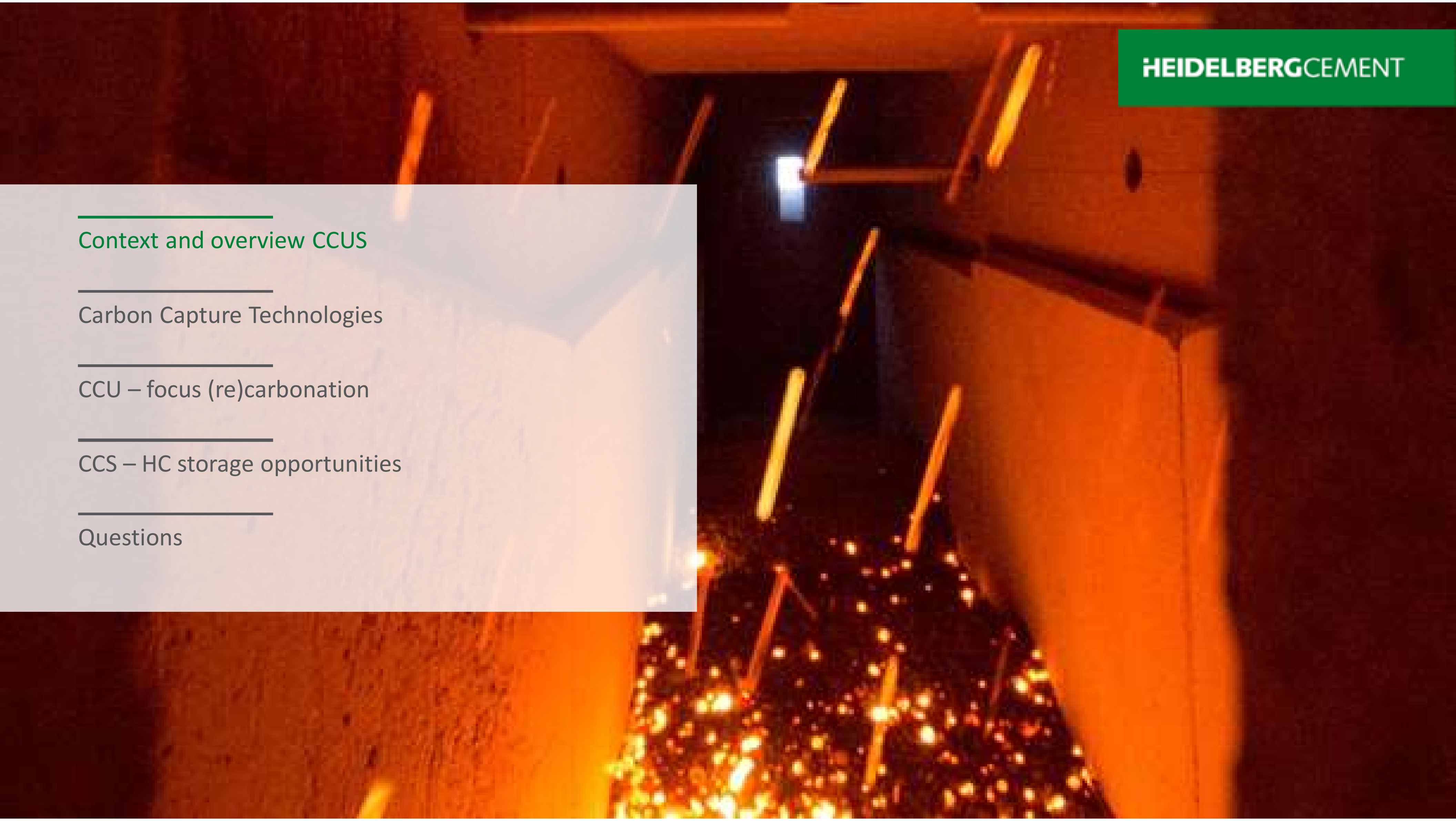
CCUS Deployment HeidelbergCement

Jan Theulen
Global Environmental Sustainability
June 2020



Context and overview CCUS

Carbon Capture Technologies

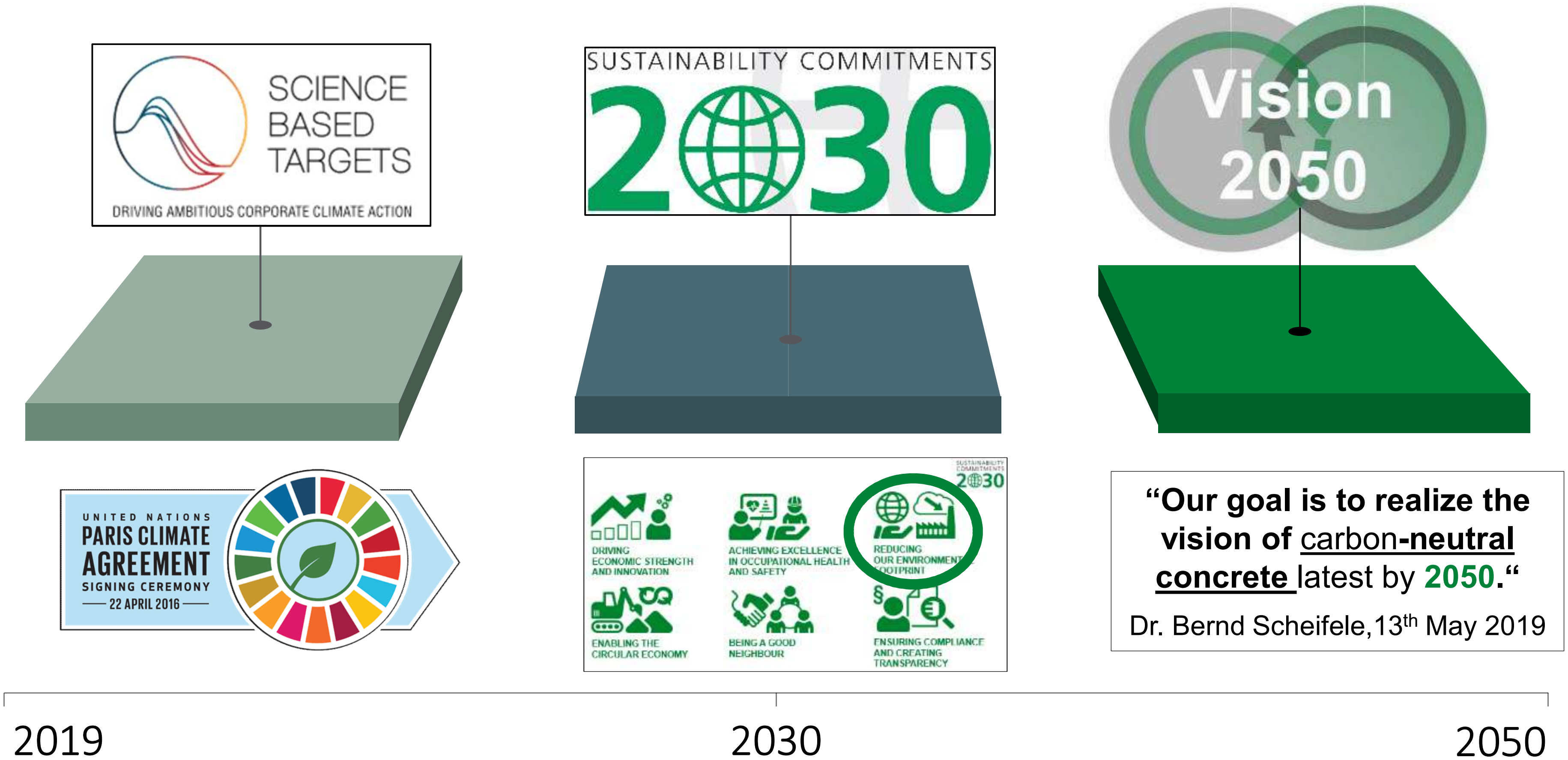
CCU – focus (re)carbonation

CCS – HC storage opportunities

Questions

THREE STAGES FOR HEIDELBERGCEMENT

Taking Responsibility in Climate Change



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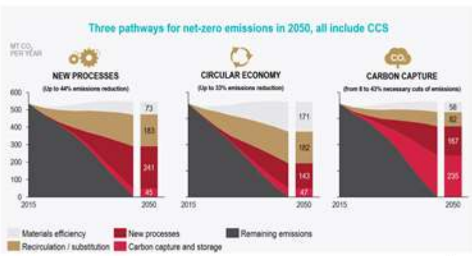
CCUS is 'just' one element of a Carbon Neutrality Strategy

Management cycles HeidelbergCement

- 2030 Sustainability Commitments -30%
- Carbon Neutrality Vision 2050
- Scenario – studies (like IEA etc.)



- Roadmaps
- (Financial) metrics
  - Internal CO_2 pricing
  - Funding Opportunities EU + local
  - Investment criteria

Technology options

- CO_2 – avoidance; traditional
  - Biomass + Energy efficiency
  - Alternative materials (e.g. fly-ash)
- CO_2 – avoidance; advanced
  - Calcined clay to replace clinker
  - Recycled concrete fines as raw mat.
  - (Partial) electrity / H_2-use in kiln
- CC



- CO_2 – use
  - Recarbonation / concrete hardening
  - Micro-algae + other uses
- CO_2 storage (on/off-shore, logistics)

Regulations and markets

- Regulations
  - EU-ETS development
  - Carbon Tax
  - Border adjustments
- Public procurement Low Carbon
- Willingness customers to pay premium
- Market developments
  - Construction efficiency (due to pre-cast and modular units)
  - Advanced concrete manufacturing reducing level of cement / m3

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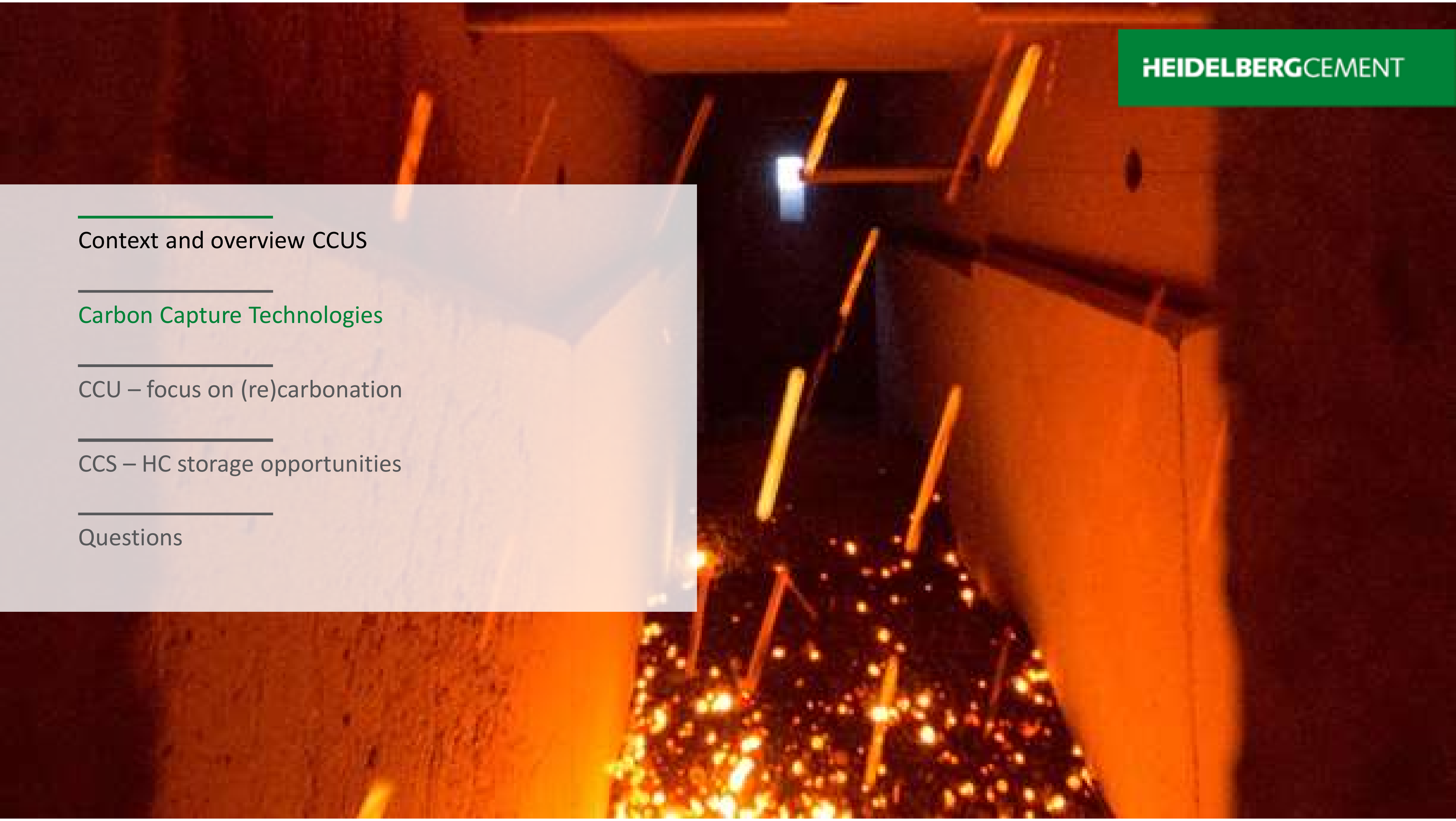

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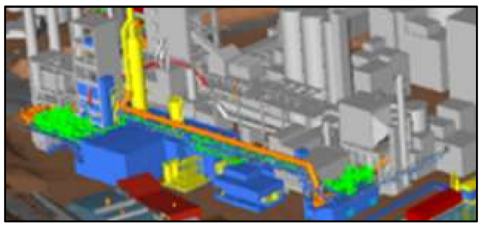
3 parallel technologies at different maturity level and outlook

Post Combustion Capture - Amine

- Project 1: Brevik Norway



- Project 2: Edmonton Canada

- Optimizations
  - Better synergy with existing kilns
  - Efficient (biomass) heat sources
  - CIP: amine efficiency etc.

Oxyfuel

- Project 1: CI4C Germany


HeidelbergCement, Buzzi Unicem-Dyckerhoff, Schwenk Zement and Vicat found Oxyfuel Research Corporation

Written by Global Cement staff
12 December 2019

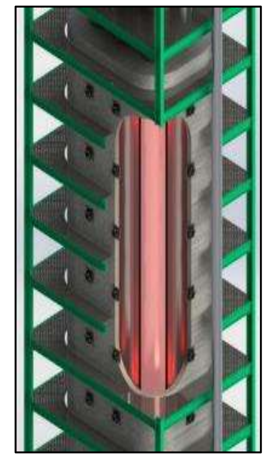
- Project 2: R&D in AC²OCEM

- Optimizations
  - Optimize ASU – Oxyfuel – CPU
  - CPU optimization itself (from 85% to 99% pure CO_2)

Direct Separation Technology

- LEILAC-1

- LEILAC-2



- Optimizations
  - Scaling-up
  - Integration into kiln line (quality + mass and energy balance)
  - Electrification + biomass / H_2 use

Expected development of costs for CCUS versus EU-ETS price forecast

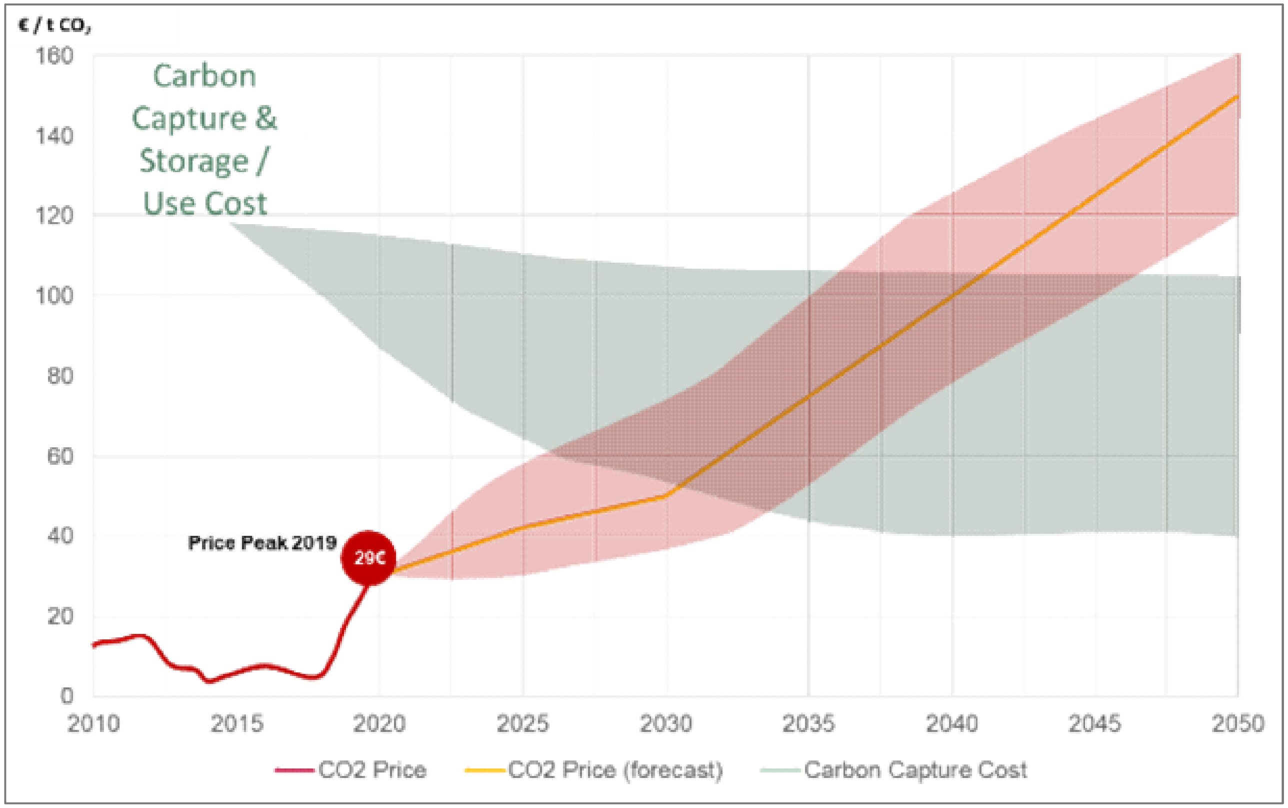
Cost gap analysis

Costs of CCUS will go down due to:

- Repeating same technology
- Involvement low cost countries
- Improvement proven technologies
  - Amine capture optimization
- Maturing new technologies
  - Oxyfuel
  - LEILAC

EU-ETS price will go up

Within 10 – 15 years lines will cross



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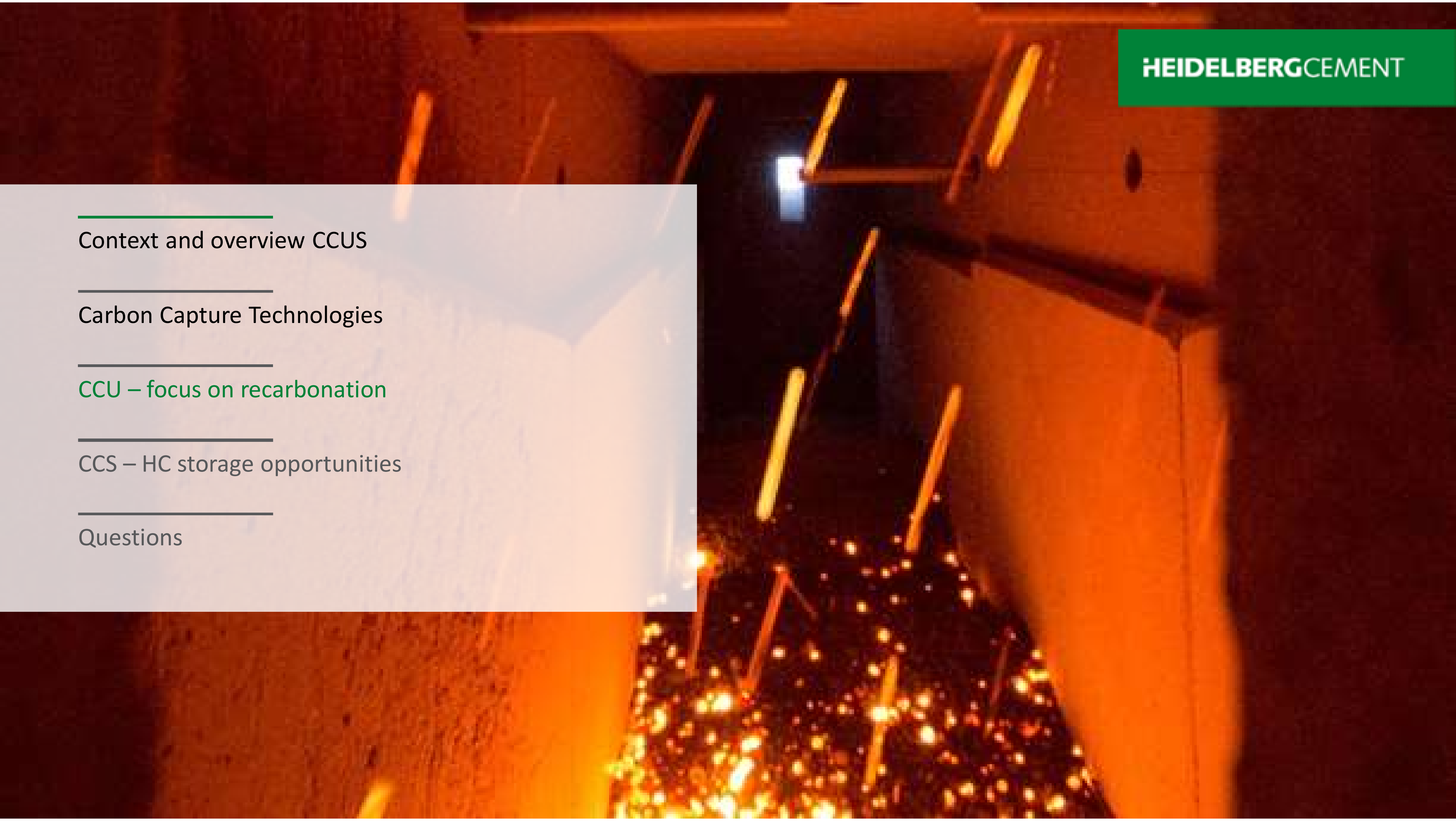

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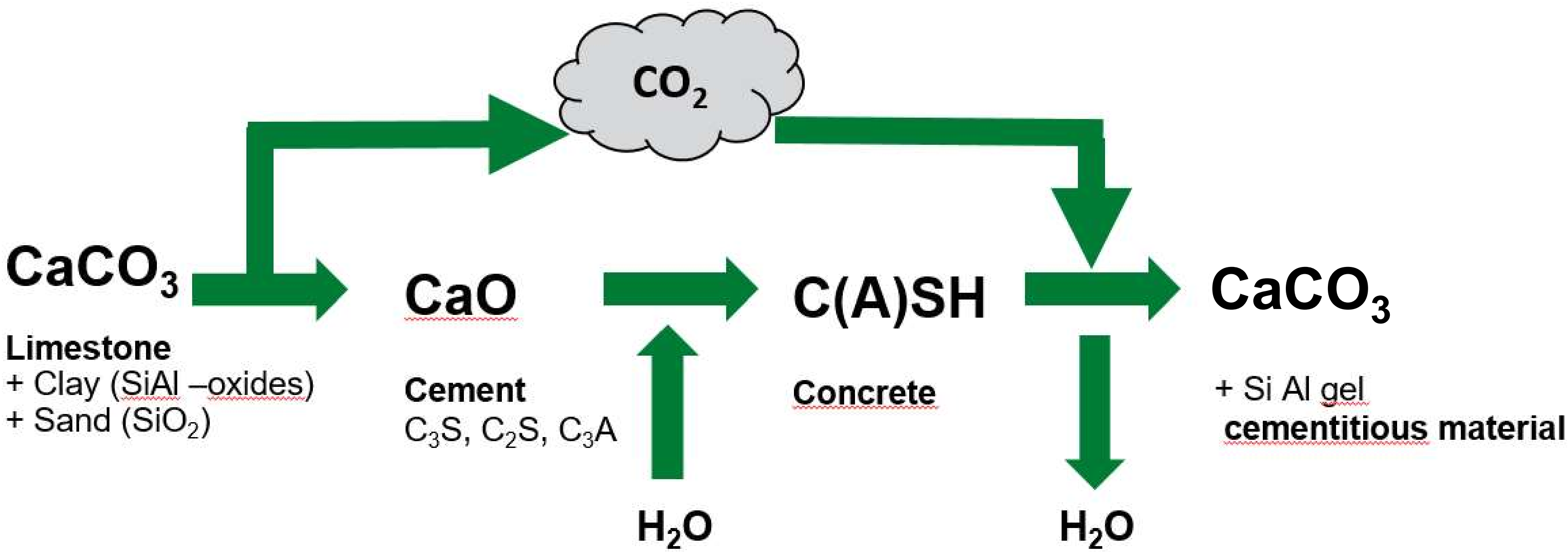
(Re-) Carbonation – the CO_2-cycle of concrete



- The calcination of limestone is a very energy demanding process
- As usual in chemistry: What takes a lot of energy in one direction goes easily the other way around

A simple formula: From limestone to limestone

(RE-)CARBONATION

Concrete carbonates naturally and sequestrates CO_2

In its service life concrete absorbs 10-15% of its original CO_2 emission

- In standard concrete this is limited to a few mm by the dense structure to ensure durability
- In more open structures (blocks, roof tiles) or surface applications (mortars) the uptake is much faster

Upon recycling and storage the fresh surfaces take up CO_2 rapidly and another 10-15% are bound

The above figures are scientifically widely accepted and also acknowledged in EN 15804 for Environmental Product Declaration

Discussions are initiated to get the re-carbonation also accepted for national IPCC reporting

Between 20 and 25% of the process CO_2 is bound back into concrete in its life-cycle

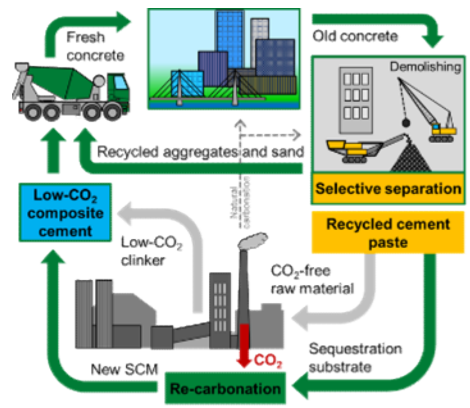
Enforced carbonation key enabling technology for carbon neutrality

With enforced carbonation the natural process can be accelerated substantially and industrially used at scale

- by using flue gas (~ 25% CO_2) or captured CO_2 (> 90%) concentrations are up to 2000 times higher than in atmosphere (~ 410 ppm) and thus reactions much faster
- by separation and high concentration of the paste with higher fineness and surface

Enforced carbonation can be applied at two stages of the concrete life cycle

- Carbonation hardening of concrete goods or precast elements in the production phase
- Advanced recycling of concrete with carbonation of the paste fraction and use as SCM at the end of its useful life



Carbonation of recycled paste and carbonation hardening enable utilization of CO_2 in our value chain

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German BMBF supports C^2inCO_2 project with 3.2 m€ (total 6 m€ R&D)

Four main aspects will be tested in lab and in demo-units

Selective separation
Advanced recycling --> high-quality recycled aggregates, sand and high purity Recycled Cement Paste (RCP).

RCP as raw material
1st part of RCP will be used as a CO_2-free raw material for clinker production replacing limestone.

Enforced carbonation of RCP
2nd part of RCP will be used for CO_2 mineralization from the flue gases from the clinker production process, further lowering the emissions associated with its production.

Carbonated RCP as SCM
The carbonated pozzolanic RCP will be used as a cement constituent partially replacing clinker in low-CO_2 cement

Funding
Bundesministerium für Bildung und Forschung

Industry
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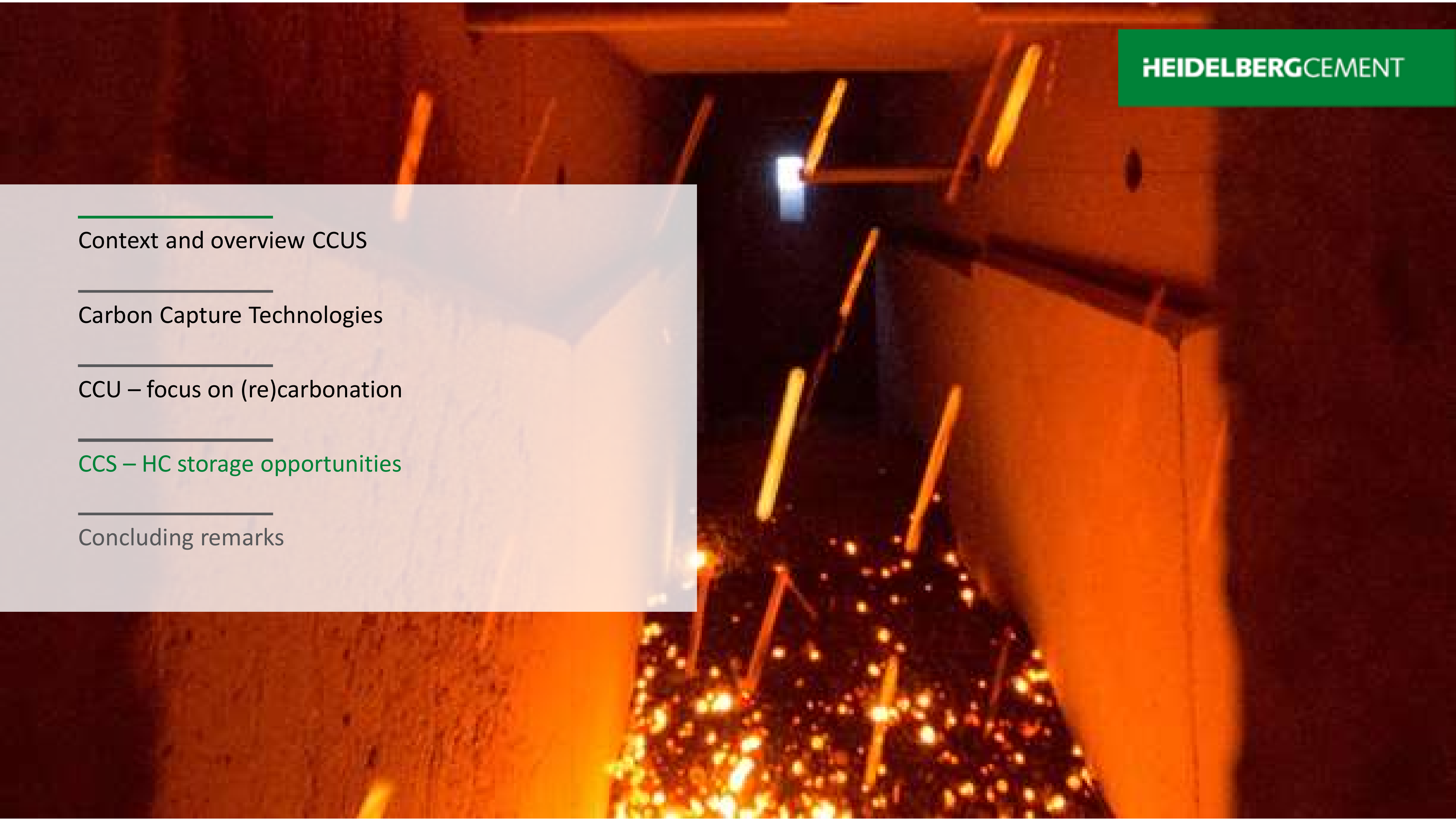
LOESCHE
thyssenkrupp

Academia
Fraunhofer
RWTH AACHEN UNIVERSITY
Bauhaus-Universität Weimar



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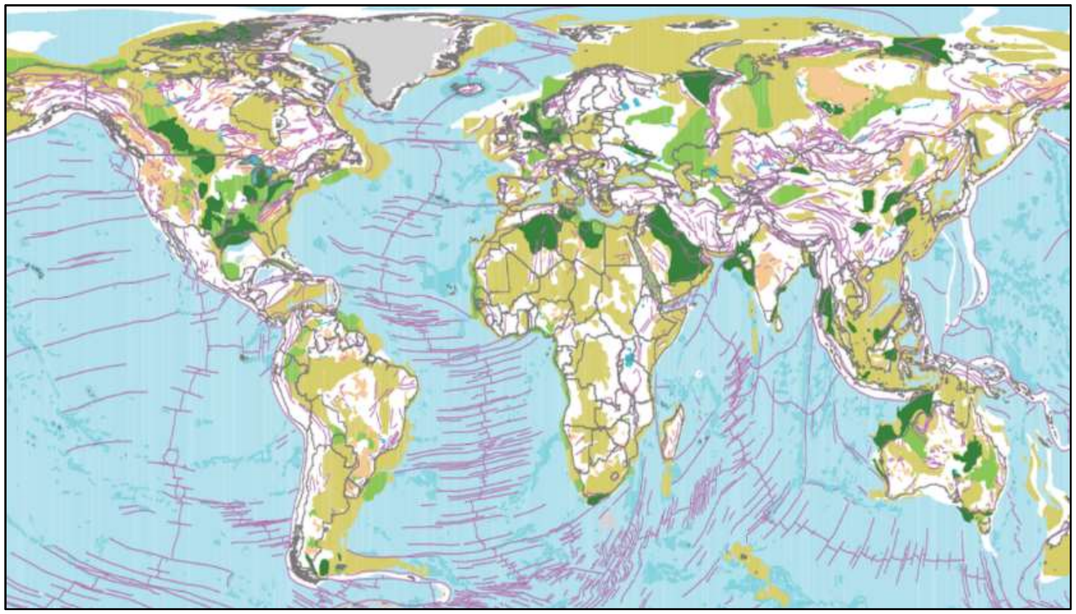
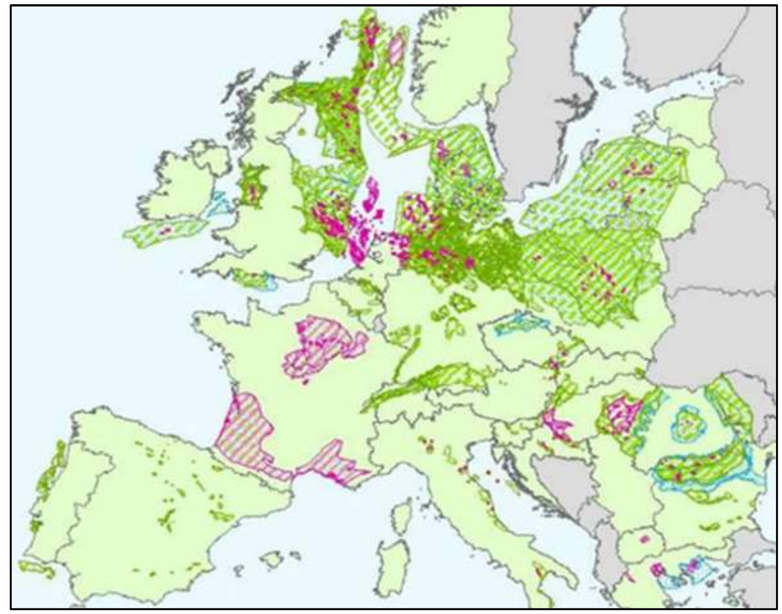
Concluding remarks

More and more info available for Storage Options



Source: IEA / GCCSI / Geogreen 2011



Source: CO2Stop assessment Storage Atlas EU

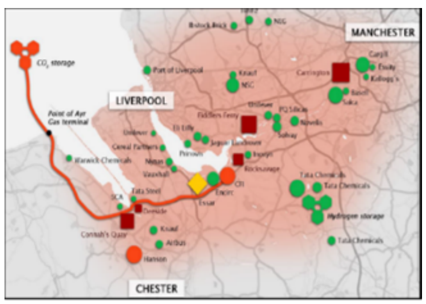
Two types of CCS Projects; each requiring different approach

CO_2 - Cluster / hub projects, existing or new

Infrastructure (pipeline, ships) and CO_2 injection is managed by independent party

Open access for CO_2-emittors

CO_2 ‘just’ need to meet project-specifications



Port of Rotterdam

gasunie

ebn

Storage location to be developed for a single user

Evaluation of a suitable storage location is key

Collaboration with Geological institutes is mandatory

Co-development with (local) operator of the injection well

Deep understanding of the national legal and policy on CCS

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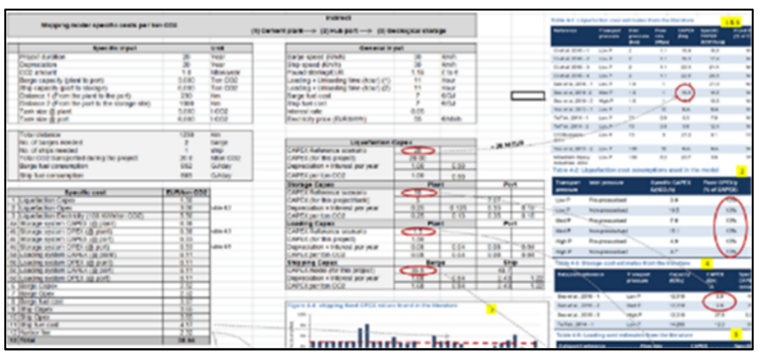
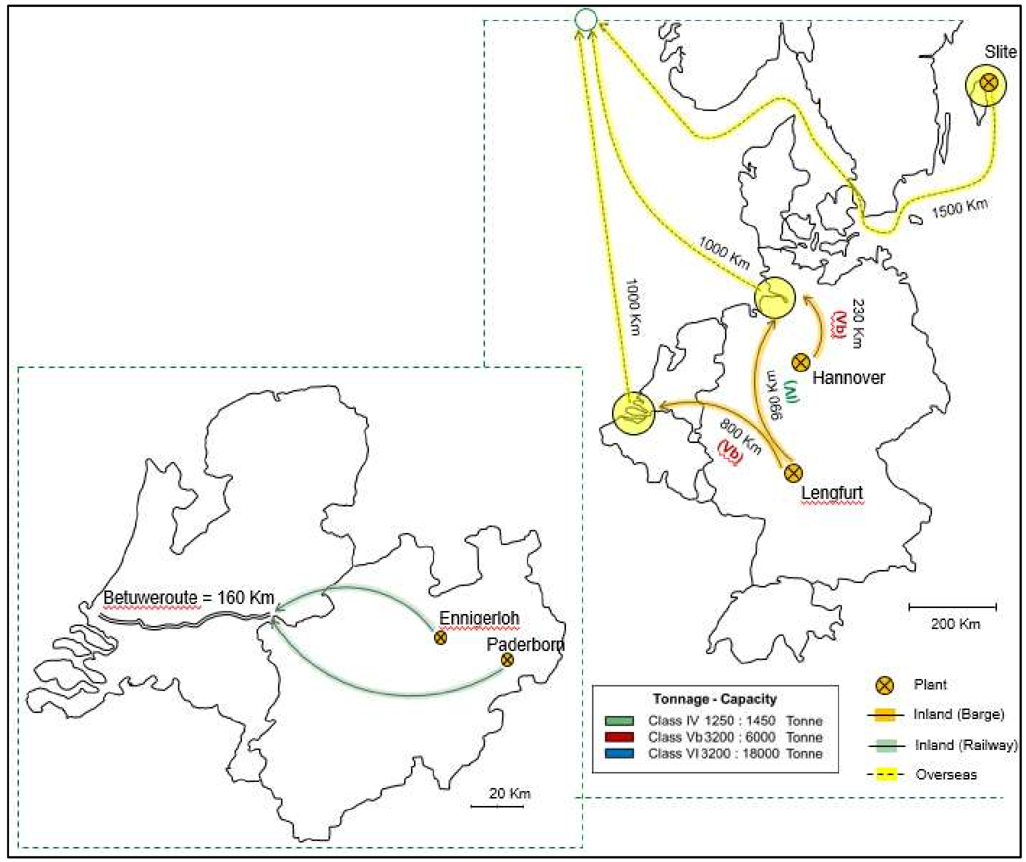
HeidelbergCement studied costs and possibility of CO_2-logistics

Evaluate best transport routes

Quantify the costs of each transport route (ship/train/pipeline or combinations):

- Liquefaction at -20° + interim storage
- Loading
- Ship / train transport
- Unloading + Storage
- Final injection





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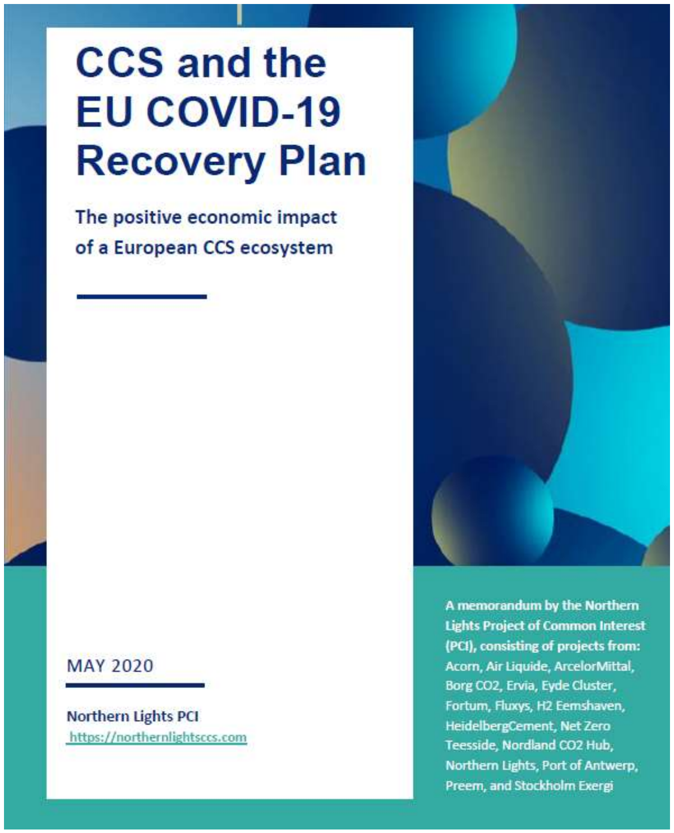
Northern Lights potential outlet for 4 HeidelbergCement plants


CCS and the EU COVID-19 Recovery Plan

The positive economic impact of a European CCS ecosystem

MAY 2020

Northern Lights PCI
https://northernlightsccs.com

A memorandum by the Northern Lights Project of Common Interest (PCI), consisting of projects from: Acorn, Air Liquide, ArcelorMittal, Borg CO2, Ervia, Eyde Cluster, Fortum, Fluxys, H2 Eemshaven, HeidelbergCement, Net Zero Teesside, Nordland CO2 Hub, Northern Lights, Port of Antwerp, Preem, and Stockholm Exergi

Equinor, Shell and Total sign off on building world's first carbon capture network

International oil giants hand in $685m Northern Lights plan to Norwegian government to develop project to capture 5 million tonnes of CO2 a year from European heavy-emitters

15 May 2020 14:37 GMT *UPDATED 17 May 2020 1:34 GMT*
By **Darius Snieckus**

Some of the projects being developed within the Northern Lights CCS network and PCI

	Transport & storage	CO2 capture projects								
Company	Equinor, Shell, Total	Fortum	Heidelberg Cement				Arcelor Mittal	Borg CO2	Ervia	Stockholm Exergi
Project	Northern Lights	Oslo	Norcem	Cementa Slite	Hannover	CBR Lixhe	Gent Carbalyst	Borg	Clusters	Stockholm
Country	Norway	Norway	Norway	Sweden	Germany	Belgium	Belgium	Norway	Ireland	Sweden
CO2 emissions										
Total ktpa	N.A	460	800	1800	640	1200	390	700	3500	900

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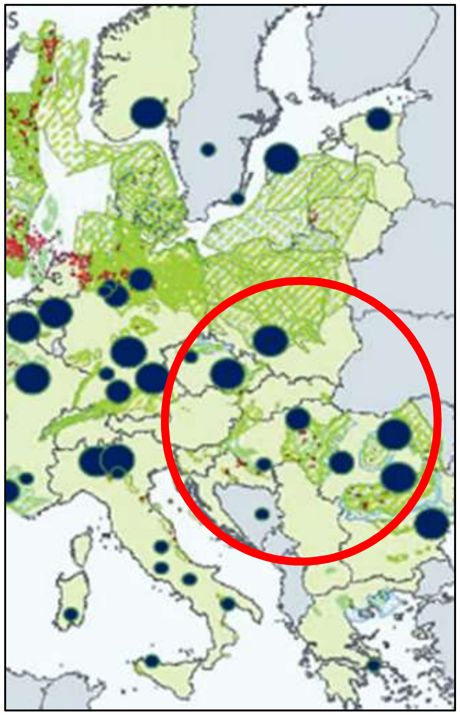
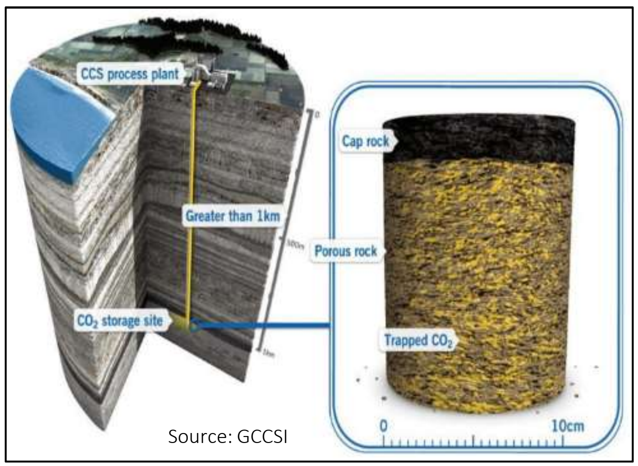
Storage location evaluation

Landlocked plants Eastern EU need local storage

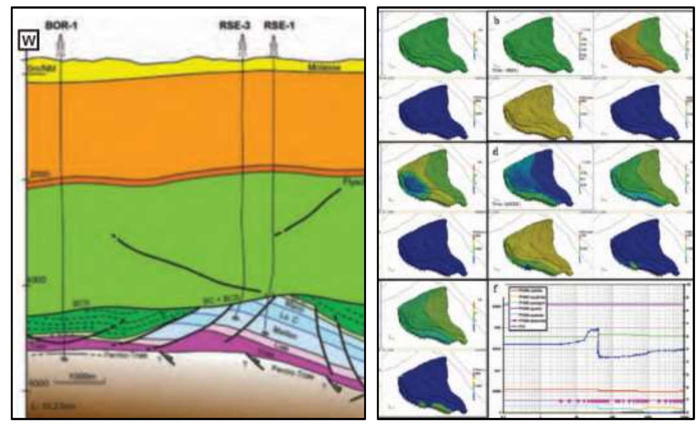


Geological suitability of a storage location

- Find location with porous rock + cap rock
- Analyze sensitivity against seismic activity
- Collect data of existing wells
- Review nearby impacts (Natura 2000, population, drinking water reservoirs etc.)
- Build a 2D and 3D simulation model
- Run simulations + develop monitoring
- Start physical exploration works
- Implement test-wells
- If all safe: site geological suitable



Source: GCCSI



Source: TOTAL (Lacq CCS demonstration)

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Study legal, regulatory and policy aspects and work hard on social acceptance

Protests and tests both

Source: Greenpeace, protest in Lower Saxony - G

Source: GFZ Potsdam: test drilling in Ketzin - G

Legal and Regulatory

- EU directive on CCS
- E.g.: maximum 1% leakage in 100 yr
- National regulations / procedures

Policies

- EU: EU-ETS, Innovation Fund
- USA: 45Q-bill, DOE-grants

Source: GCCSI

Social acceptance

- Basis different per country
- Local acceptance has to be deserved
  - Public hearings
  - Direct and indirect information (multiple channels)
  - Listen to feelings not only facts count
- Collaboration with NGO's, Universities

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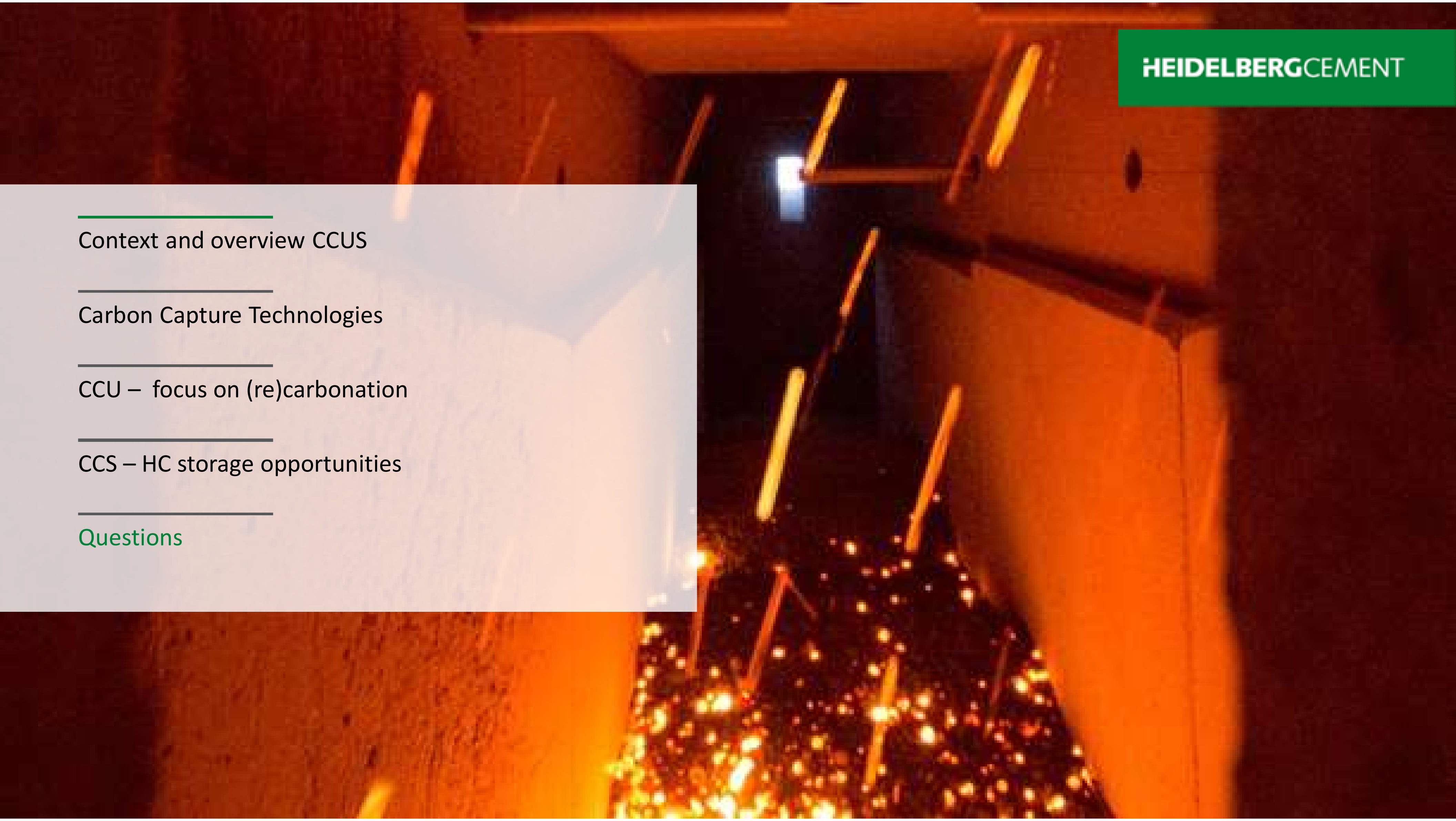

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