CO_2 capturing in cement production

Johannes Ruppert, VDZ

Workshop CO_2-Infrastructure in NRW

Düsseldorf, 22. August 2019

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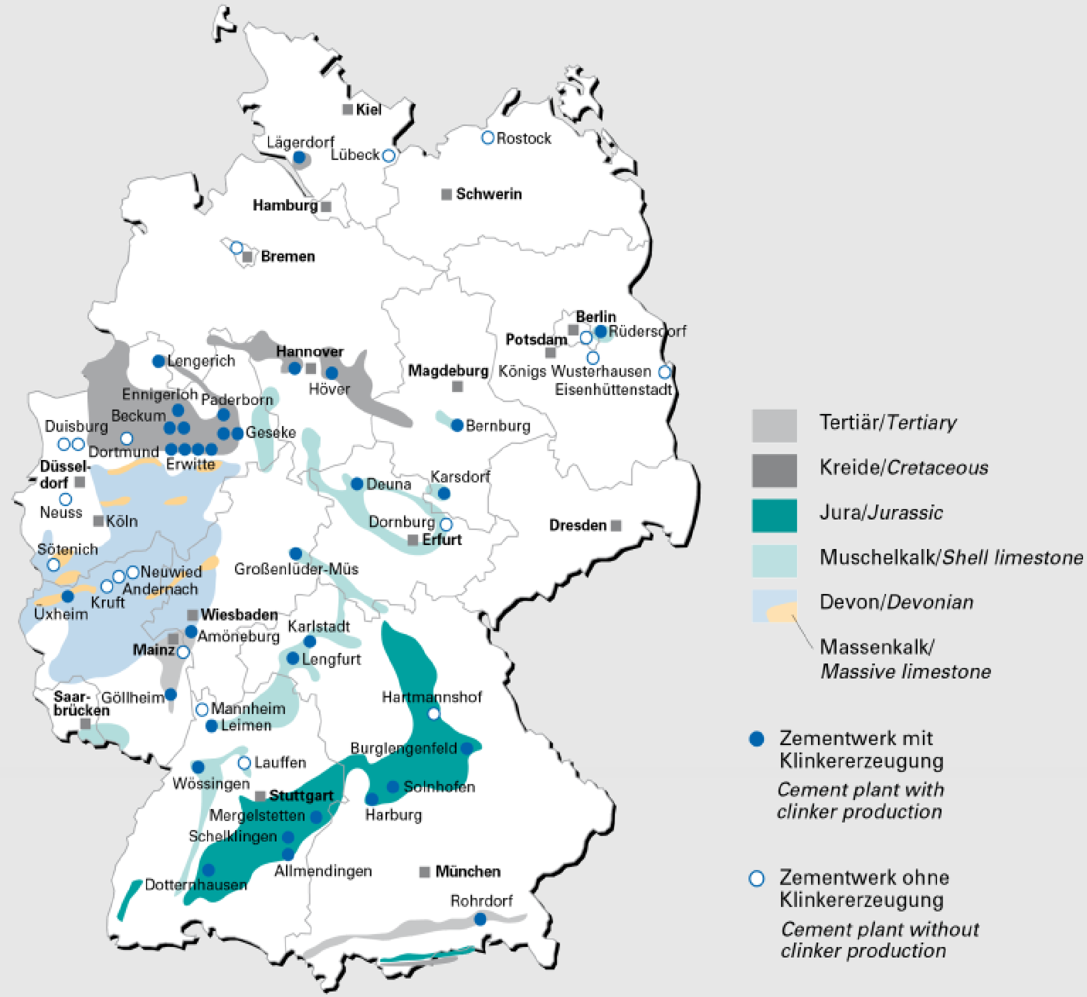
AGENDA

The German cement industry

- 20 companies, 53 cement works
  - ● cement clinker production 34
  - ○ grinding stations 19
- Cement production: 34 Mt *
- CO_2 emissions: 20 Mt CO_2
- Cement sales in Germany: 29 Mt *
- Turnover: 2,8 Bn €
- Employees: ca. 8.100



Sources: VDZ, Statistisches Bundesamt, DEHSt, * estimate

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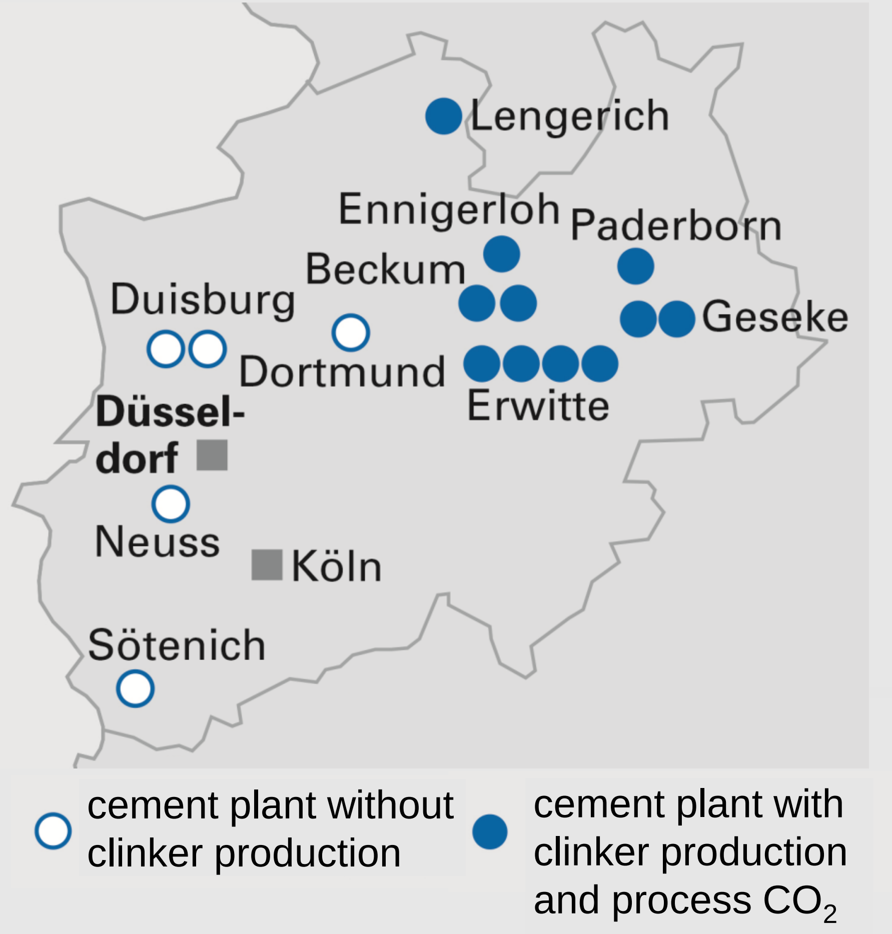
Cement clinker production in NRW

- 11 plants with production of cement clinker
- Direct relation to especially suitable limestone available in Westphalia
- Ca. 5,2 Mio. t CO_2 / year
- Intensive use of industrial by-products and alternative resources:
  - Blast furnace slag and fly ash as other main constituents in cement
  - Alternative fuels with biogenic carbon content



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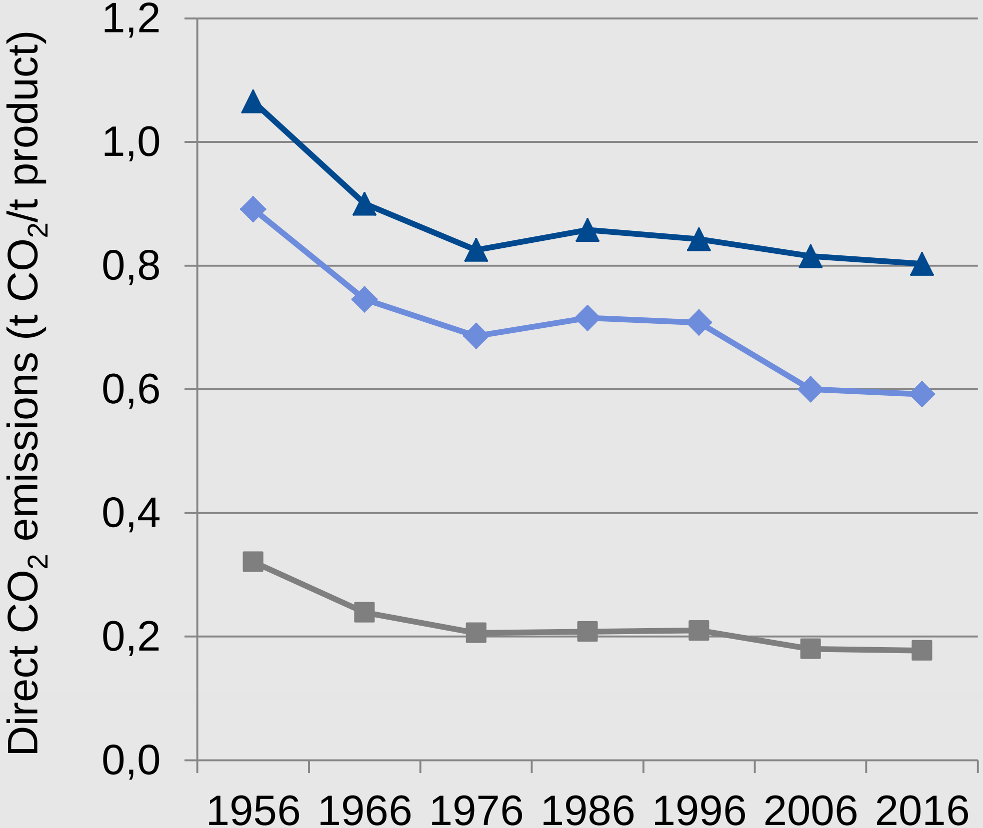
Cement is a CO_2 intensive product
Concrete is a CO_2 efficient product



Direct CO_2 emissions

estimate for Germany


t CO_2 / t cement clinker


t CO_2 / t cement


t CO_2 / m^3 concrete


3 - 10
t CO_2 / house

Share related to the use phase of a building: 2 - 12 %

CEMBUREAU, 2013: https://lowcarboneconomy.cembureau.eu/

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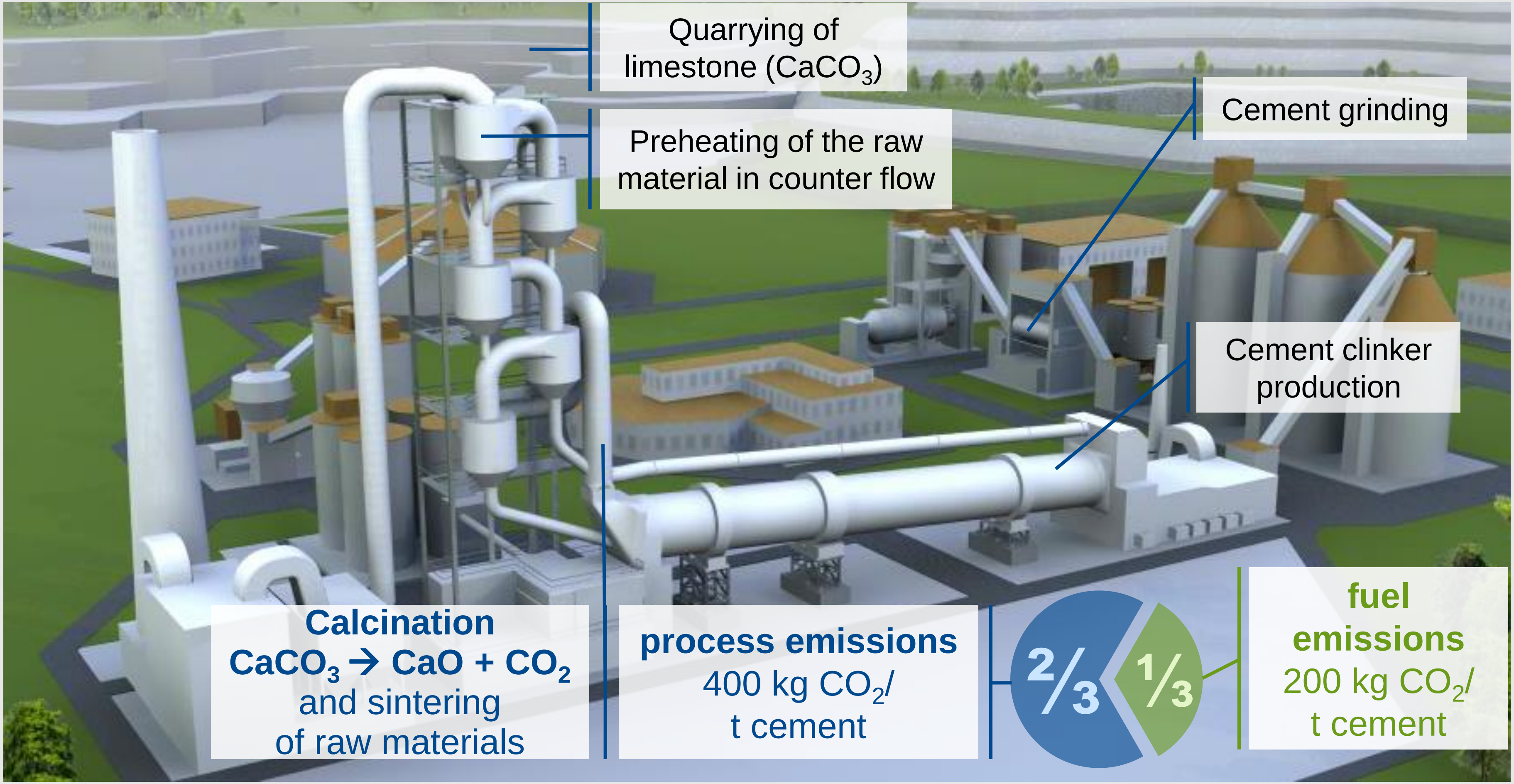
Process emissions in cement production



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AGENDA

1	Cement production and process emissions
2	**CO_2 abatement in the cement industry**
3	Carbon Capture – the ECRA project
4	Perspectives for CCS and CCU in the cement industry

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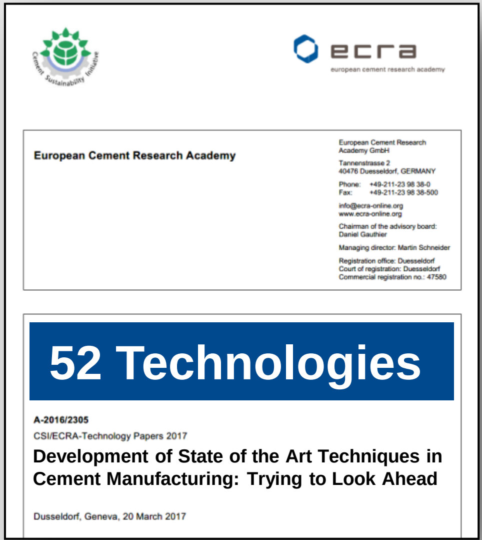
CO_2 and energy efficiency in the cement industry

CSI/ECRA Technology Paper 2017

- Thermal
- Electrical
- Grinding
- Alternative fuels and raw materials
- Use of clinker in cement
- New binding materials
- CCS
- CCU



Cement Sustainability Initiative

ecra
european cement research academy

European Cement Research Academy

European Cement Research Academy GmbH
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40476 Duesseldorf, GERMANY
Phone: +49-211-23 98 38-0
Fax: +49-211-23 98 38-500
info@ecra-online.org
www.ecra-online.org
Chairman of the advisory board: Daniel Gauthier
Managing director: Martin Schneider
Registration office: Duesseldorf
Court of registration: Duesseldorf
Commercial registration no.: 47580

52 Technologies

A-2016/2305

CSI/ECRA-Technology Papers 2017

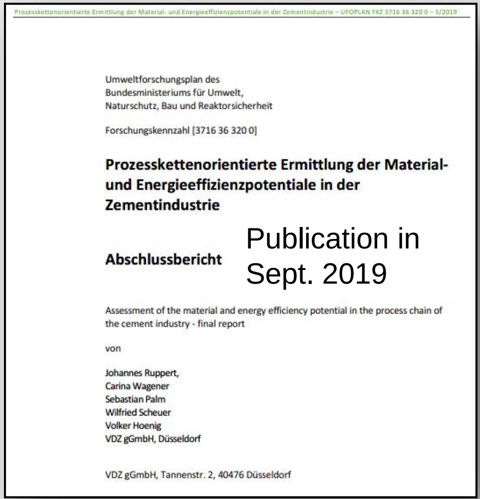
Development of State of the Art Techniques in Cement Manufacturing: Trying to Look Ahead

Dusseldorf, Geneva, 20 March 2017

https://ecra-online.org/research/technology-papers/

Material- and energy efficiency in the cement industry, VDZ/UBA study:

- Workshops with sector experts
- VDZ-Model2018, scenarios and examples for GE
- Plant optimisation, grinding, use of blast furnace slag
- CO_2 capturing
- New binding materials
- Concrete production, recycling



Prozesskettenorientierte Ermittlung der Material- und Energieeffizienzpotentiale in der Zementindustrie – UFOPLAN FKZ 3716 36 320 0 – 5/2019

Umweltforschungsplan des
Bundesministeriums für Umwelt,
Naturschutz, Bau und Reaktorsicherheit

Forschungskennzahl [3716 36 320 0]

Prozesskettenorientierte Ermittlung der Material- und Energieeffizienzpotentiale in der Zementindustrie

Abschlussbericht

Publication in Sept. 2019

Assessment of the material and energy efficiency potential in the process chain of the cement industry - final report

von

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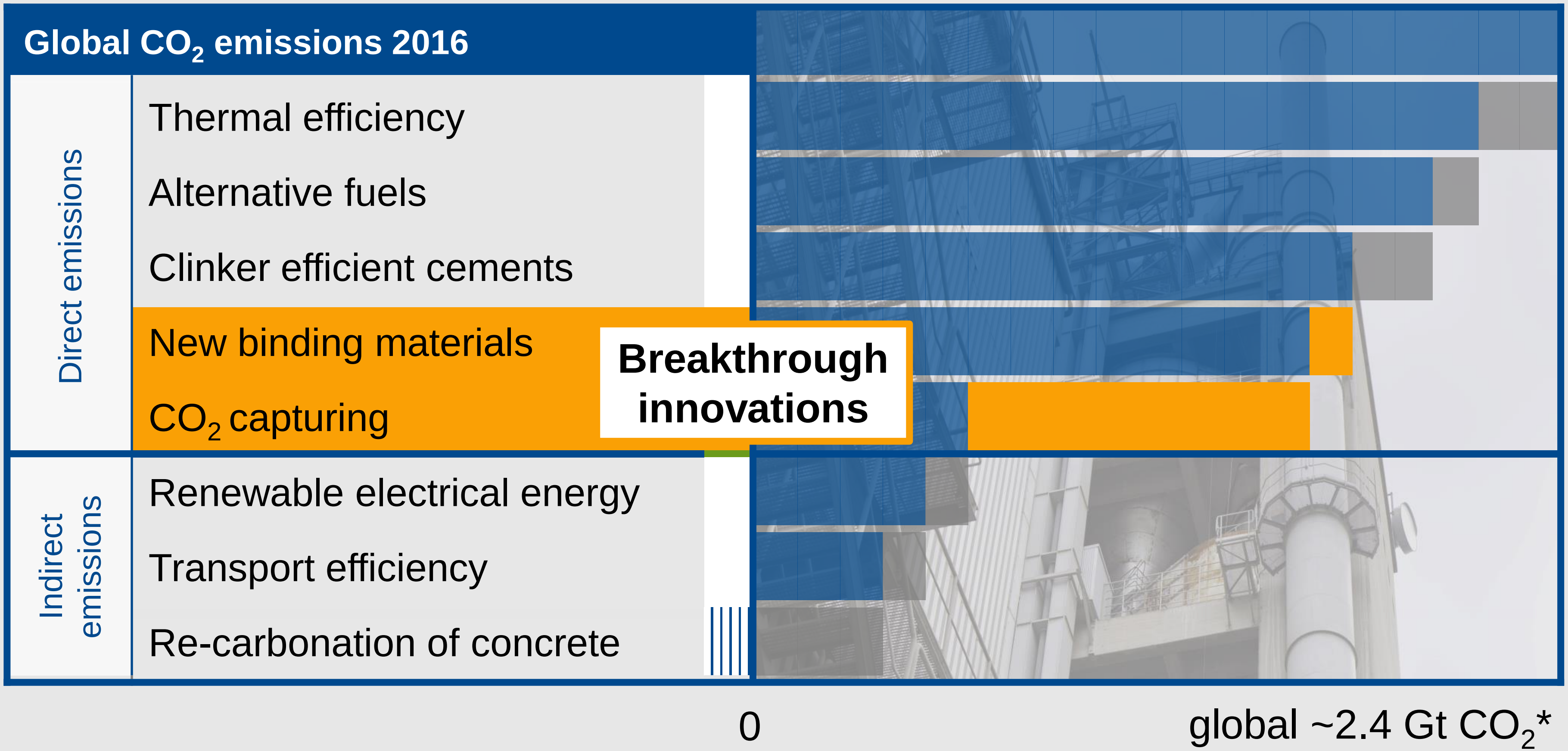
https://www.vdz-online.de/forschung/aktuelle-projekte/prozesskettenorientierte-ermittlung-der-material-und-energieeffizienzpotentiale-in-der-zementindustrie/

Net zero greenhouse gas emissions in cement production and application



Schematic diagram, * global CO_2 emissions estimate with statistical uncertainty
Schneider 2019: The cement industry on the way to a low-carbon future.
https://doi.org/10.1016/j.cemconres.2019.105792

AGENDA

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3	**Carbon Capture – the ECRA project**
4	Perspectives for CCS and CCU in the cement industry

European Cement Research Academy: Project on carbon capture in the cement industry

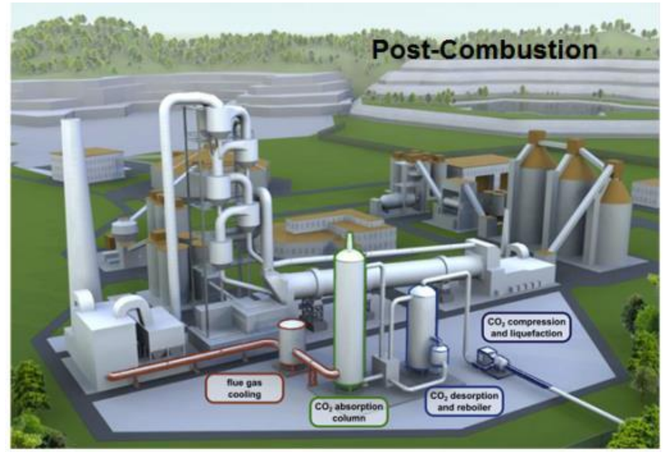
Phase I	Literature study (2007) ✓
Phase II	Study on technical and financial aspects of CCS projects, concentrating on oxyfuel and post-combustion technology (2007-2009) ✓
Phase III	Laboratory-scale / small-scale research activities (2009-2011) ✓
Phase IV	Appropriate pilot-scale plant design, capacity, set-up, cost estimation (2012-2016) ✓ Prepare pilot plant, technical and economic concept for retrofitting of a full-scale cement plant with oxyfuel (2017-2019)
Phase V	Next step: Build and operate pilot plants for industrial scale CO_2 capture technology demonstration at TRL 8 (time-frame: 3-5 years)
Phase VI	Demonstration plant at TRL 9 (time-frame: 3-5 years)

www.ecra-online.org/research/ccs

Technologies for CO_2 capture in the cement industry

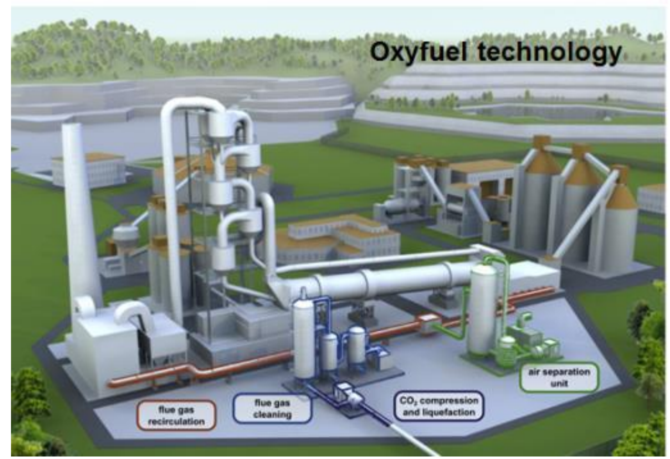
Post-Combustion Technology

- Tail-end separation of CO_2 from flue gas by e.g. chemical absorption, adsorption, membranes or Ca-looping
- Comparatively energy-intensive technology

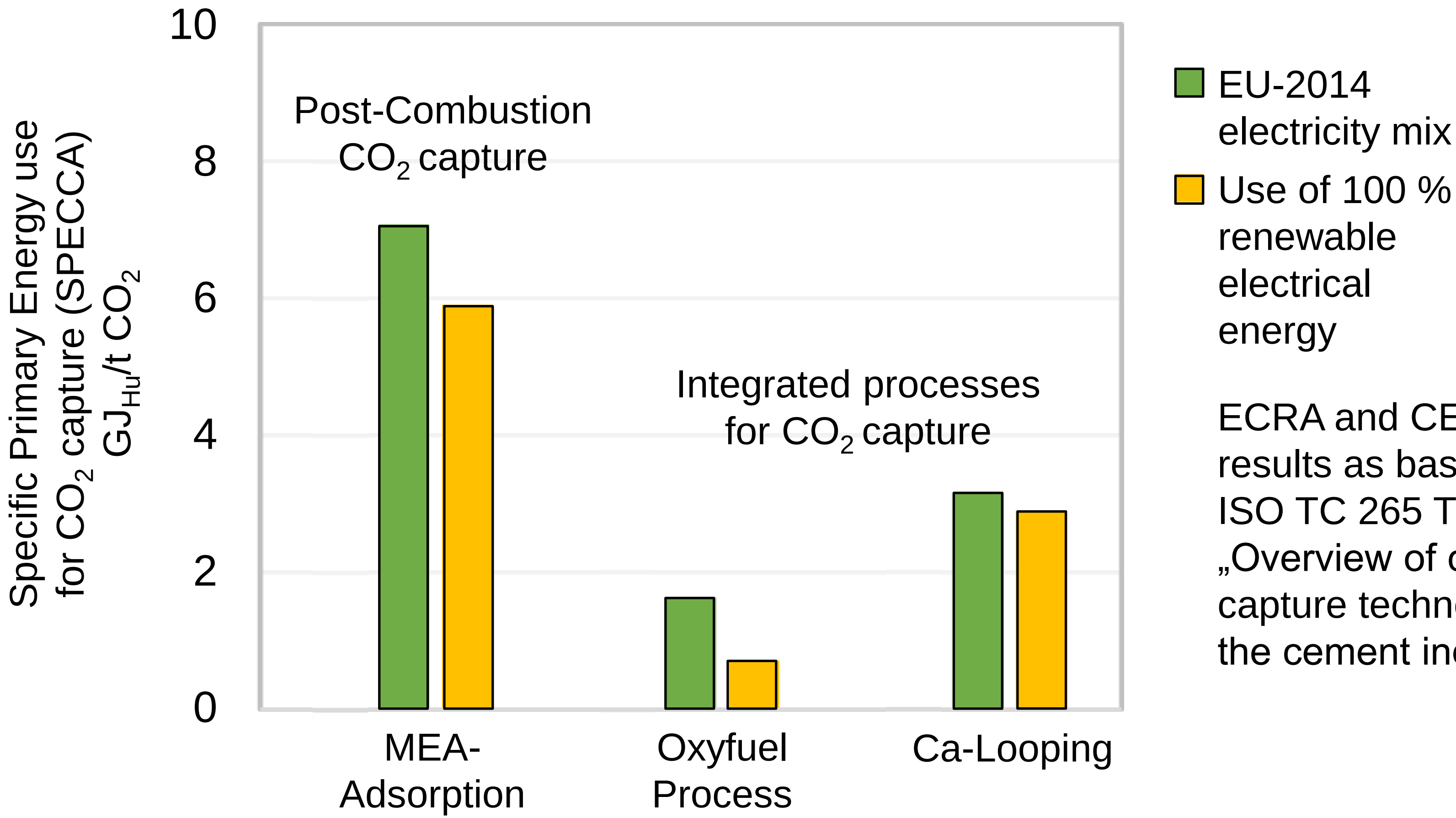


Oxyfuel Technology

- Integrated, combustion with pure oxygen in combination with flue gas recirculation to achieve high CO_2 concentration up to 80 vol%
- Lowest energy demand, electrical power
- Oxyfuel process requires major plant retrofit



Energy demand for CO_2 capturing in cement plants



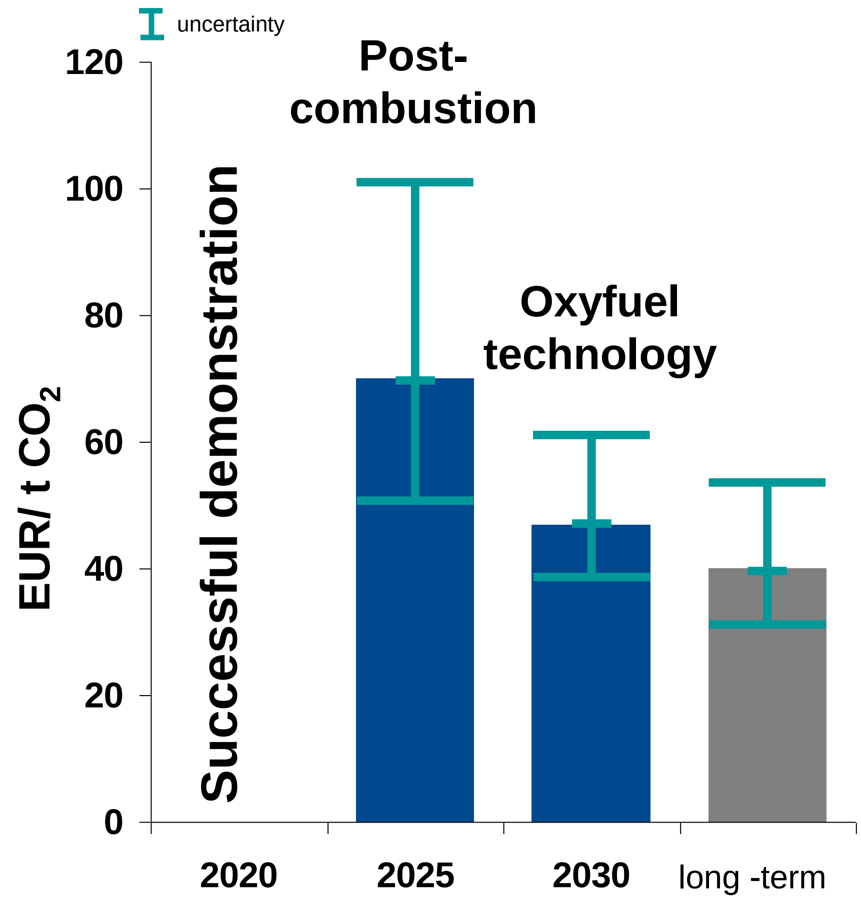
ECRA and CEMCAP results as basis for ISO TC 265 TR (2019) „Overview of carbon capture technologies in the cement industry"

based on M. Voldsund et al.: CEMCAP Techno-Economic and Retrofitability Analysis. In: European Cement Research Academy, ECRA; Research Group CEMCAP; Research Group CLEANKER, Ed. Presentations and Posters of the ECRA/CEMCAP/CLEANKER Workshop 2018 on Carbon Capture Technologies in the Cement Industry (Brussels 17 October 2018). Available at: https://ecra-online.org/research/ccs/presentations-and-posters/

Challenges of carbon capture

Costs and competitiveness

- Significant increase of production costs
- Competiveness of cement production threatened under current economic and legal conditions for carbon capture
- Demonstration at industrial scale needed
- Appropriate CO_2 infrastructure for storage and use



AGENDA

Storage and use of CO_2 from the cement industry

Geological storage of CO_2

- Required for CO_2 neutrality of cement production and use of cement in construction
- Re-direction of process related CO_2:
  - Offshore, e.g.. North Sea with appropriate CO_2 infrastructure
  - Local storages onshore?
- Potential for negative Emission shares (NET)
  - Up to 10 % biogenic CO_2 from use of waste biomass as alternative fuel (without additional production of biomass)
  - CO_2 absorption at the surface of concrete during its use phase

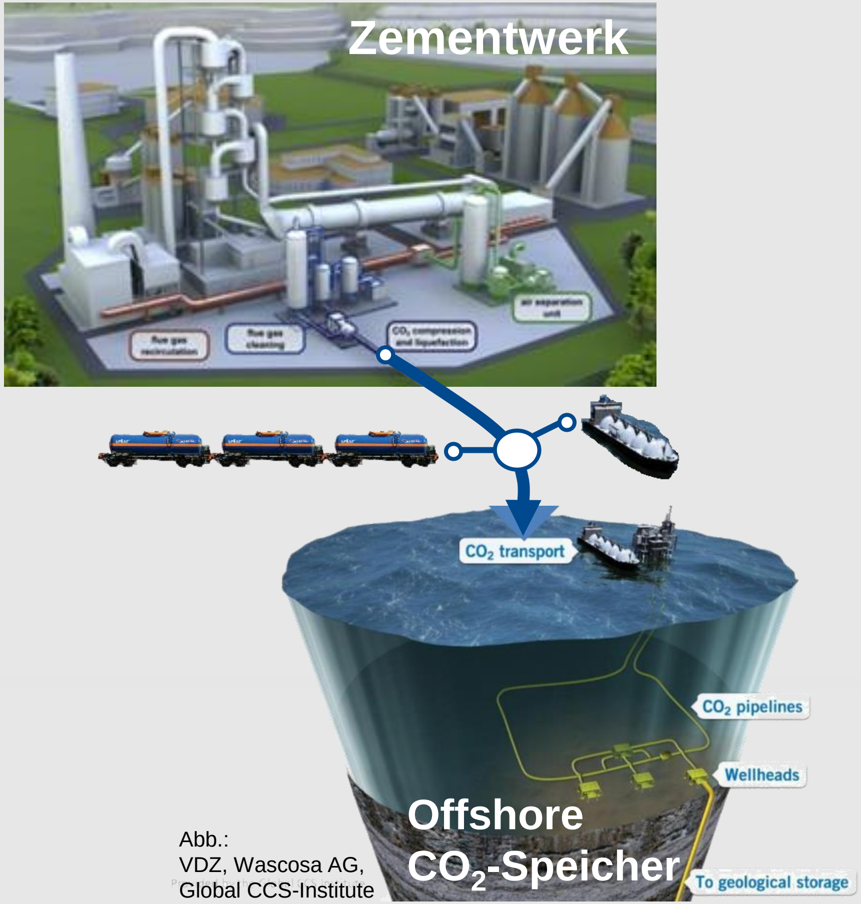


Abb.:
VDZ, Wascosa AG,
Global CCS-Institute

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Storage of CO_2 in concrete

- CO_2 absorption at the surface of concrete can be enhanced during concrete recycling
- Use of CO_2 in the application of cement in concrete production and in the production of precast concrete elements

Storage and use of CO_2 from the cement industry

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Carbon-use

- Raw material CO_2 as carbon source for products: Basic chemicals, methane, plastics, synthetic fuel
- Link to other industry sectors

IN4 CLIMATE .NRW

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Perspectives for CCS and CCU in the cement industry

ECRA/CEMCAP/CLEANKER Workshop in der Vertretung des Landes NRW in Brüssel, 2018
https://ecra-online.org/research/ccs/presentations-and-posters/

- 5 technologies for CO_2 capture facilitate plant specific solutions
- CO_2 capture can be applied to existing cement plants (Retrofit)
- Energy demand, technical and economic assessments are available:
  About double production cost for CO_2 neutral cement
- Create demand for CO_2 neutral cement as enhanced carbon leakage protection:
  E.g. by targeted tendering and requirements for the construction of new buildings
- CO_2 neutrality will require significant shares of CO_2 storage (CCS + CCU)
- Essential steps are the demonstration at industrial scale and an appropriate CO_2 infrastructure

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Thank you!

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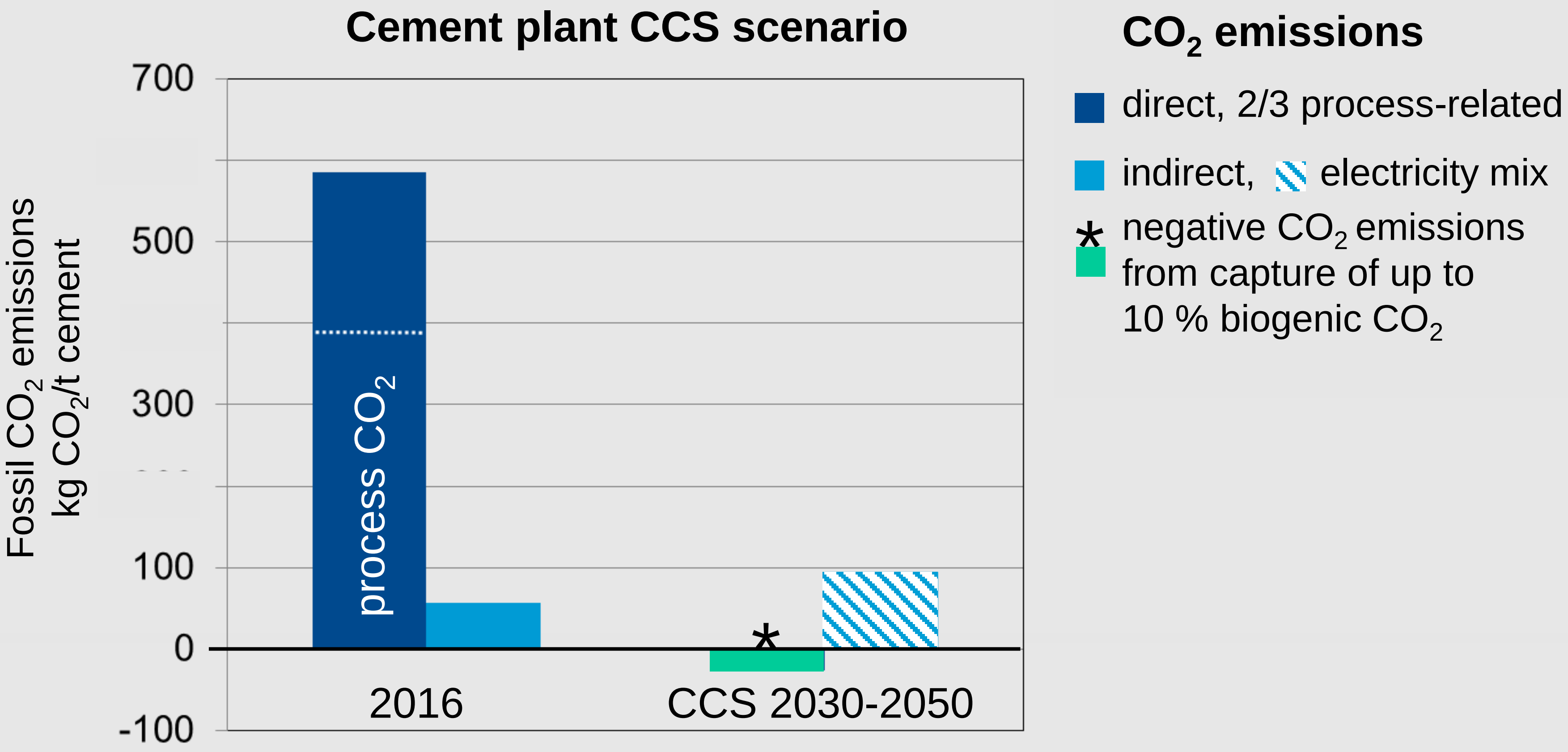
CCS & use of alternative fuels with waste biomass allow sustainable negative emissions technology (NET)



Ruppert, et al. Assessment of the material and energy efficiency potential in the process chain of the cement industry: Final report (UFOPLAN FKZ 3716 36 320 0). VDZ: Düsseldorf, 2019 (submitted). https://www.vdz-online.de/forschung/aktuelle-projekte/prozesskettenorientierte-ermittlung-der-material-und-energieeffizienzpotentiale-in-der-zementindustrie/

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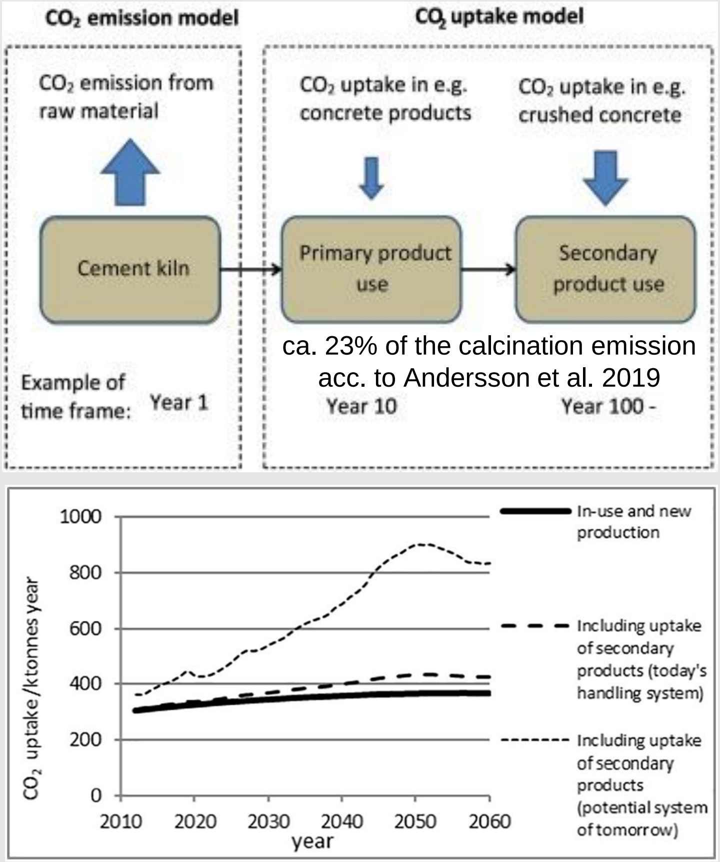
Concrete as a CO_2 sink during its life cycle and after use

- CO_2 uptake in concrete is a relatively slow process over many years
- Primary uptake is due to the hydrated Portland cement
- Also latent hydraulic concrete additions, such as blast-furnace slag and pozzolanic additions such as fly ash
- Potential for increased CO_2 uptake in end-of-life stages by demolishing, crushing, and storage



Andersson et al. 2019, https://doi.org/10.1016/j.cemconres.2019.105819

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CO_2-Minderungsmöglichkeiten in der Zementindustrie

Konventionelle Technologien	**Thermische Effizienz** ▪ Sehr hoch verglichen mit allen anderen Industrieprozessen / chemisch-mineralogische Grenzen **Alternative Brennstoffe** ▪ Geringerer Kohlenstoffanteil + hoher Biomasse-Anteil / energetische + stoffliche Verwendung **Klinkereffiziente Zemente** ▪ Senkung des Klinkeranteils im Zement / begrenzte Verfügbarkeit geeigneter Ersatzmaterialien **Alternative Rohstoffe** ▪ Einsatz bereits kalzinierter Rohstoffe / sehr begrenzte Verfügbarkeit geeigneter Materialien **Elektrische Effizienz** ▪ Sehr begrenzte Reduktionspotenziale / Zielkonflikte mit Markt- und Regulierungsanforderungen
Breakthrough Technologien	**Neue Bindemittel** ▪ Absehbar keine alternativen Zemente, um Portlandzement in größerem Umfang zu ersetzen **CO_2-Abscheidung (Carbon-Capture-Technologien)** ▪ Aussichtsreich, aber sehr hohe Kosten / CO_2-Speicherung bzw. CO_2-Nutzung bislang ungeklärt ▪ Oxyfuel ist wirtschaftlichste Carbon-Capture-Technologie für Zementherstellung (derzeit TRL 6) ▪ Demonstrationsprojekt (TRL 7/8) erfordert umfangreiche Mittel für Investition und Betrieb

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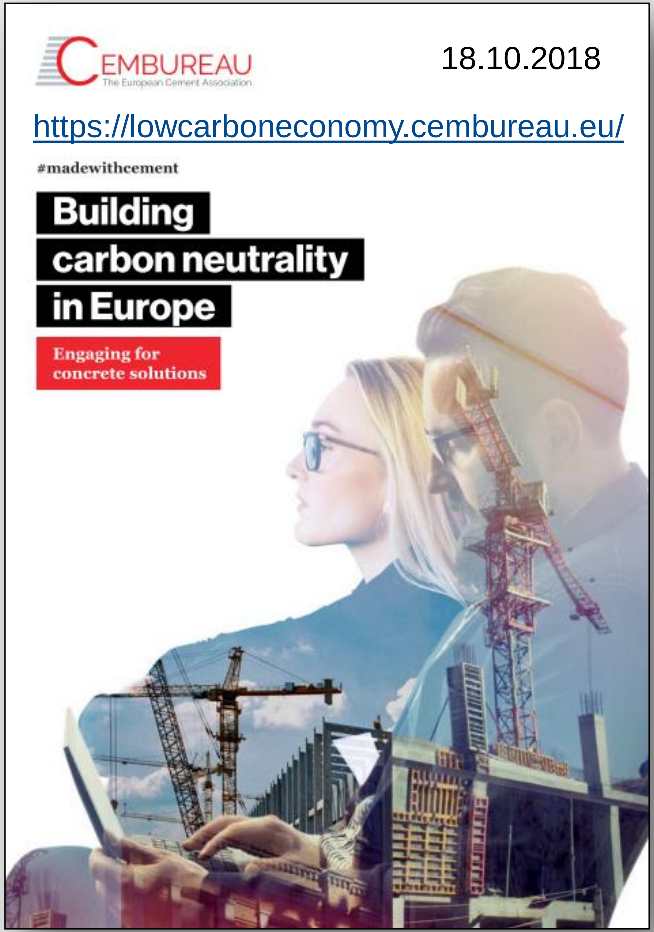
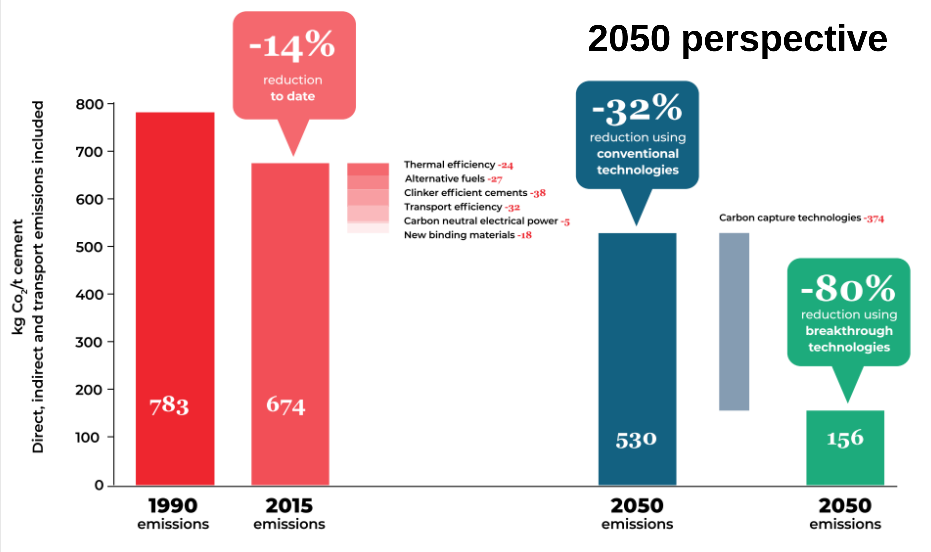
Building carbon neutrality in Europe



- Secure a level playing field with other regions and across industrial sectors;
- Based on lifecycle performance; material neutral
- Integrate both the supply and demand sides;



- Supports the development of breakthrough technologies and solutions, including through large-scale technology demonstration.

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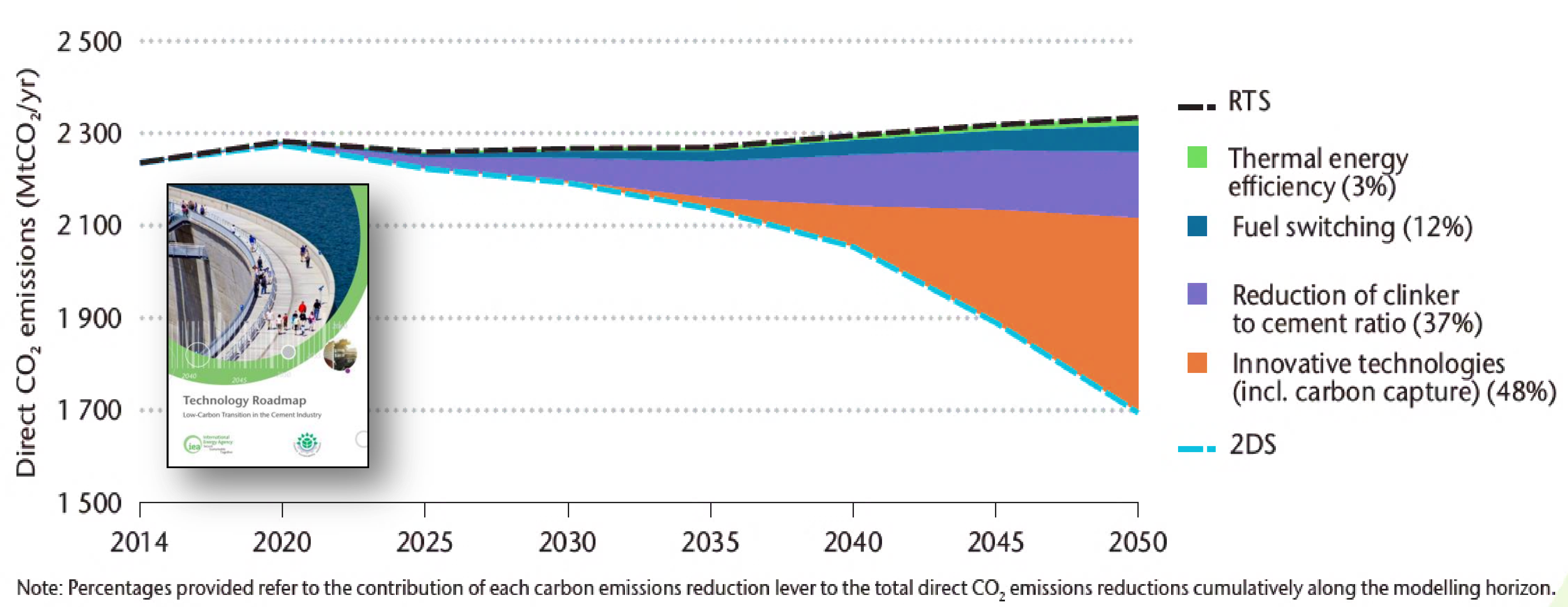
CO_2 reduction potential in the cement industry until 2050
IEA Cement Technology Roadmap 2018



CO_2 reduction potential in the global cement industry; Sources: IEA/CSI Technology Roadmap 2018: http://www.wbcsdcement.org/technology
CSI/ECRA Technology Papers 2017: https://ecra-online.org/research/technology-papers/

Without CCS the aim of climate neutrality can not be achieved
Requirements: Storage, Infrastructure and effective Carbon-Leakage-Protection

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