Carbon Capture Utilisation and Storage for
The Cement Sector

CEM CCUS Initiative Webinar

Thursday 21 January 2021, 14:00 – 15:00 CET
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AGENDA

1. Welcome & Introductory Remarks
   - Jarad Daniels
     Director, Office of Strategic Planning, Analysis, and Engagement
     U.S. Department of Energy
   - Claude Lorea
     Cement Director
     Global Cement and Concrete Association

2. Industry views
   - Jamie Gentoso
     CEO – US Cement
     LafargeHolcim US
   - Rob van der Meer
     Director of EU Public Affairs
     Heidelberg Cement
   - Tongbo Sui
     VP Sinoma International, DG of Sinoma Research Institute
     Sinoma - CNBM

3. Panel Discussion and Q&A Session
Jarad Daniels leads the Office of Strategic Planning, Analysis, and Engagement within the Department of Energy (DOE) Office of Fossil Energy, including domestic programs and international engagements conducted in close collaboration with industry, academia, and multi-lateral organizations.

Mr. Daniels has twenty-five years of experience with the DOE, managing advanced technology programs and working in several national laboratories throughout the United States. His expertise includes domestic and global energy and environmental technologies, policies, and programs.

Mr. Daniels holds a Master of Science degree in Chemical Engineering from the University of California at Berkeley.
Claude Lorea  
*Cement Director*  
Global Cement and Concrete Association

Ms Loréa leads all aspects of GCCA’s work related to cement. She drives the association’s work to continuously improve the sustainability performance of the industry through innovation, as well as developing and sharing good practices and global guidelines. Ms Loréa also leads GCCA’s innovation workstream and managed the establishment of Innovandi, the Global Cement and Concrete Research Network. She has developed a special interest and expertise in CCUS and international climate policy, as well as regulatory requirements and trends.

Ms Loréa is a member of the GCCA executive team based at the headquarters in London and recently launched the ‘women in cement and concrete network’. Ms Lorea joined the GCCA from the European cement industry body, CEMBUREAU where she led on key work for more than a decade.

Ms Loréa gained a degree in Civil Engineering from the University of Brussels.
Jamie Gentoso is the Chief Executive Officer for the US Cement organization of LafargeHolcim. An accomplished leader and a registered Professional Engineer, Jamie is responsible for all cement product lines, overseeing an organization of approximately 2,800 employees, 15 cement and grinding plants and more than 100 cement terminals across 43 states. She holds a degree in civil engineering and a master’s in business, both from The University of Michigan.

Ms. Gentoso is passionate about the cement/concrete industry, enhancing its contributions to society and reducing its impact on our environment. She sits on the Board of Directors for several industry organizations, including the Portland Cement Association, Ready Mix Concrete Foundation, the Concrete Industry Management (CIM) program and many others in the past. She is a lifelong athlete, enjoys running, outdoor activities and spending time with her 3 school aged children.
Rob van der Meer is Director EU Public Affairs at HeidelbergCement. As chemical engineer he started his career in public services as responsible for environmental permitting with focus on emissions to the air, for the Provincie Limburg in the Netherlands.

In 1996 he started in the cement industry as a process engineer in the Maastricht plant of ENCI. Later (2004) he was appointed CO2 coordinator for HeidelbergCement in Heidelberg (Germany).

Since 2007 he is in charge of EU Public Affairs in the department of Group Communications & Investor Relations of HeidelbergCement in Heidelberg (Germany).

Rob van der Meer graduated in 1991 as a chemical engineer from the Technical University Twente in the Netherlands.
Tongbo Sui
*Vice President of Sinoma International, DG Sinoma Research Institute*
*Sinoma*

Dr. Tongbo SUI, born in November 1965, is currently vice president of Sinoma International Engineering Co. Ltd for technical innovation. He has been intensively engaged for over 20 years in R&D of low energy & low CO2 clinker cements (mainly in reactive belite-rich clinker and belite-ye’elimite clinker system) as a solution to addressing cement and concrete sustainability.

He is also visiting professor at Tongji University of China, University College London of UK and senior advisor of China Cement Association, and active in international organizations as co-chair of Working Group 5 for Cement Innovation under Global Cement and Concrete Association, and member of ACI, ASTM, RILEM & ICT.

He is the recipient of various academic awards including awarded national expert by the State Council, the 2nd class national prize for technological invention awarded by the State Council for the R&D of low energy and low emission reactive belite-rich Portland cement, and international award for the outstanding contribution to the technology for cement and concrete sustainability issued at Seville, Spain.
The Clean Energy Ministerial (CEM) is a global process

**90%** Clean energy investments

**75%** Global CO₂ emissions

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**The CEM CCUS Initiative**

*Lead countries:* Norway, Saudi Arabia, the United States and United Kingdom

*Participating CEM members:* Canada, China, Japan, Mexico, Netherlands, South Africa and United Arab Emirates; in addition, the European Commission is an observer

*Industry:* oil and gas, cement, steel, ...

*Financial institutions:* private banks, investment firms, multilateral banks (MDBs)

*Organizations:* Carbon Sequestration Leadership Forum (CSLF), International Energy Agency (IEA), IEA Greenhouse Gas R&D Programme (IEAGHG), Mission Innovation (MI), Global CCS Institute (GCCSI), and Oil and Gas Climate Initiative (OGCI)
CEM CCUS Initiative: accelerating CCUS together by:

1. Actively including CCUS within Clean Energy Ministerial agenda and global clean energy discussions.

2. Bringing together governments, the private sector and the investment community.

3. Facilitating identification of both near and longer-term investment opportunities.

CCUS: positive energy – but we must keep the wheel turning!

EMERGING POLICY and AMBITIONS

- 30+ countries with “net-zero” ambitions by ~2050!
- EU: 2050 net-zero target; CEF, Innovation Fund etc.
- NOR: Gov. investment in Longship & Northern Lights
- UK: GBP800m fund & business models
- NL: SDE++ and EUR100m EU support
- US: 45Q tax credits
- China: 2060 net zero target
- JP: 2050 net-zero; commercialise CCUS by 2030
- UAE: ADNOC to ramp up CCUS by 500% by 2030
- ...

PROJECT DEVELOPMENT SPEEDS UP

- 20 projects today
- 30 new projects announced since 2017: US, Europe, Middle East, Korea, China, Australia, New Zealand etc.
- 16 projects closest to implementation (FID in 12 months) represent USD27bn in investment
- Joint infrastructure → hubs emerging as a way forward, with common transport and storage infrastructure for a multitude of capture facilities

COLLABORATION REMAINS CRITICAL

- Knowledge-sharing between projects, countries and regions
- Exploiting regional synergies, strategies and investment
- “Three-legged stool”: government, industry, finance sector all have their role to play

RESETTING STRATEGIC NARRATIVE

- From “burden” to “opportunity”
- Decarbonise hard-to-abate industry sectors
- CCUS as partner in low-carbon hydrogen production
- CO2 removal & CCUS as offset for emissions elsewhere
- Decarbonise existing power assets with long lifetime

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CCUS: a critical solution across many sectors and industries

• CCUS is far from only being a power-sector technology...

• ...in fact, its role is more important in heavy industry, including cement, where a large share of emissions are process-related

• In 2019, the process emissions were 2.5Gt globally, equivalent to India’s total annual emissions
  • 63% of these emissions were from the cement sector

• CCUS is a central solution to reduce process emissions, particularly in the cement sector
GCCA Climate Ambition
Towards carbon neutral concrete
Concrete’s essential role in the modern world

Population growth and increasing urbanisation will drive a growing global requirement for critical infrastructure over coming decades.

- This includes the need for crucial amenities such as clean water and sanitation.

- It is also anticipated that there will be a significant increase of built floor space, including the provision of safe dwellings.

- At the same time there is a growing need for resilient construction to protect our cities and natural environment from a changing climate.

Concrete is vital to meeting these challenges and for providing sustainable development.
How can carbon neutral concrete be achieved?

- Eliminating our direct energy-related emissions and maximising the co-processing of waste from other industries, which substitutes the use of fossil fuels involved in cement manufacture.
- Reducing and eliminating indirect energy emissions through renewable electricity sources where available.
- Reducing process emissions through new technologies and deployment of carbon capture at scale.

We believe in the coming decades, we can provide society with carbon neutral concrete. We are already working to achieve this and recognise the need to accelerate our actions today.

In the coming years we can achieve carbon neutral concrete by:

- Reducing the content of both clinker in cement and cement in concrete, as well as more efficient use of concrete in buildings and infrastructure.
- Reprocessing concrete from construction and demolition waste to produce recycled aggregates to be used in concrete manufacturing.
- Quantifying and enhancing the level of CO$_2$ uptake of concrete through recarbonation and enhanced recarbonation in a circular economy, whole life context.
GCCA’s policy framework for action on cement and concrete

This includes measures which:

• Promote investment in state-of-the-art technology for new and retrofit plants.

• Facilitate increased use of waste and by-products as alternative fuels and raw materials; enable governments and industry to work together to implement circular economy strategies and promote waste avoidance, collection and sorting, pre-treatment, recovery, recycling and co-processing.

• Support the research and development of breakthrough technologies as well as the acceleration and scaling-up of proven efficient low carbon technologies, with a particular focus on CCUS and new and alternative binders. Policies should help mitigate the risk through investment mechanisms.

• Promote cooperation between government and industry to develop CO₂ transport and storage infrastructure.

• Drive the demand for sustainable building materials by helping to stimulate market demand for innovative products by construction contractors and customers.

• Support life-cycle assessment-based methodologies, tools and databases to enable a whole-life based approach to procurement. Appropriate sustainability assessment methods using life cycle analysis are to be preferred in public and private tendering.

• Recognise at national level the uptake of CO₂ by existing concrete in the built environment.

• Energy performance of buildings calculation methods should be sophisticated enough to take account of thermal mass.

• Electricity systems should facilitate demand response, i.e. interaction between the grid and households, where the consumer enjoys a share of the cost savings.

• Enable revision of building codes and regulations to facilitate the adoption of innovations without jeopardising safety and durability and recognising the increased need for resilience in the built environment.

• Establish the means of recognising that the resilience of the built environment can contribute to favourable social and economic benefits for society.

• Establish the means of recognising that concrete can contribute to favourable emission benefits in other sectors of the economy.

• Access to recycled concrete for utilisation for recarbonation.
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3. Panel Discussion and Q&A Session
LafargeHolcim Fast Facts

- ~75 countries
- ~2,300 operating sites
- ~72,000 employees
- CHF 26.7 billion net sales (Like-for-like)

The world’s global leader in building materials and solutions

- Net Zero pledge
- SBTi validated 2030 targets
- ESG Sustainalytics rating
- Green Solutions: 1/3 of our sales

Leading the way in sustainable construction

- Global R&D center in France
- 5 regional R&D hubs
- 50% of R&D in green construction
- 40% of Patents in green construction

All figures represent FY 2019
Our Net Zero Roadmap

Driving green construction with net zero pledge

- 2022 Target: 610 kg CO₂ net emissions
- 2030 Target: 475 kg CO₂ net emissions

LafargeHolcim performance vs. Sector average

2050 and beyond...
Demand is driven by population growth, urbanization, improved living standards and sustainable construction

By 2050 population is expected to grow **22%** to 9.7 billion. **2.5 billion** more people are expected to live in cities.

Concrete remains the best building material providing the greatest durability, longevity, resilience and the lowest embodied energy and carbon intensity versus other materials.

G20 leaders have pledged an astounding USD 5 trillion to fight the economic consequences of COVID-19. Infrastructure and building will be a natural choice for policymakers on where to invest.

This brings a huge opportunity to “Build Back Better”
Our building blocks to net zero

- Getting ready to scale up CCUS technologies
- Accelerating green solutions
- Expanding wind turbines and solar panel farms
- Driving efficiency from automation to AI
- Maximizing traditional levers

Carbon capture
Green products
Plants of tomorrow
Renewable energy
Clinker factor and alternative fuels

1990 2000 2010 2020 2030 2040 2050 and beyond
LH CCUS Projects

Other projects
Additional +15 projects to test different capture and usage technologies
Carbon Capture Utilization and Sequestration Solutions (CCUS) - How we’re multiplying our efforts to achieve our ambitions

Fostering >20 Industry & Government Partnerships

Technology developers
Chemical and other industries
Green Energy producers
Governments
Universities
Startups

& Furthering these core Factors

Public Acceptance
Renewable Energy
Infrastructure
Regulatory Frame
Governmental Support
Funding
Regulators & Governments Must Play a Role

Policy Must Support CCUS:

- Continued investment in research & Innovation is necessary to capture CO2 both in scale & economically
- Innovation for novel use of captured CO2 must continue
- Investment in CO2 transport & storage infrastructure
- A Price on Carbon can be an effective way to stimulate reduction however it must be...
  - Effective - Focus on reduction outcomes
  - Market Based - Economy Wide
  - Durable & Responsive - adapt over time
  - Do no harm - support competitiveness within the economy
  - Promote Equity - distribute costs & benefits as well as promote investment in disadvantaged communities

Moving towards a zero CO2 economy through a cross-sectoral value chain approach
By 2030, LafargeHolcim will

- Accelerate use of low-carbon & carbon-neutral products, incl. ECOPact and Susteno
- Recycle 100m tons of waste and byproducts for energy and raw materials
- Scale up the use of calcined clay and develop novel cements with new binders
- Double* waste-derived fuels in production to reach 37%
- Reach 475 kg net CO2 per ton of cementitious material
- Operate its first net-zero carbon cement production facility

* Compared to 2018 baseline
Our goal is to realize carbon neutral concrete by 2050 at the latest.
SUSTAINABILITY AT HEIDELBERGCEMENT

Carbon neutrality by 2050 requires a variety of localized approaches

1) Natural carbonation is the absorption of CO$_2$ from the atmosphere during the lifetime of a concrete construction.

- Conventional measures
- Circular economy & innovative products
- CCU/S & kiln electrification
- Natural carbonation

1990 2020 2030 2040 2050

Remaining emissions

kg CO$_2$/ m$^3$ concrete
CHALLENGE NUMBER 1

Resource and energy-efficient capture to get from 20% to > 95% CO₂

**TRL 8**

Post combustion (Amine)

Early Stage:
4 research projects in Europe

Pre-industrial:
Edmonton, Canada

Industrial/commercial:
Brevik, Norway

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**TRL 5**

Oxyfuel

Early Stage:
Preparatory research work done together with ECRA/UMONS

Pre-industrial:
Ci4C, Germany

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**TRL 6**

Direct separation (LEILAC)

Pilot: LEILAC-1, Belgium

Pre-industrial:
LEILAC-2, Germany
CHALLENGE NUMBER 2

Resource and energy-efficient use of CO$_2$

Source: IEA 2019
CHALLENGE NUMBER 2

Resource and energy-efficient use of CO₂

Source: IEA 2019
C H A L L E N G E  N U M B E R  3

CCS offshore and onshore safe sequestration

Northern Lights

HyNet

Porthos

Onshore location + acceptance to be developed by HC with partners

Evaluation suitable storage locations
Team-up with Geological Institutes
Co-development with (local) Storage Solution Provider (oil/gas world)
Deep understanding of the national laws and policy on CCS
Societal Acceptance is a pre-requisite
3 Fundamentals for decarbonation

1. Technical requirements
The four elements for emissions reductions in cement industry have to explored to the maximum:

   1. Recarbonation and mineralization, for which 100% recycling will be needed.
   2. Traditional emissions reductions measures: alternative fuels, thermal and electrical energy efficiency, renewable electrical energy, etc.
   3. New and improved low carbon cementitious binders: clinker substitution, cement substitution, new binders, new clinkers, etc.
   4. Carbon capture followed by use and/or (geological) storage

   We are convinced that from technical perspective carbon neutrality of concrete can be reached.

2. Infrastructure...
   ... for CO₂, H₂, renewable electricity and recycled concrete is urgently needed.

   This is not a cement specific issue (apart perhaps for the CO₂ infrastructure and recycled concrete) but a general necessity for energy incentive industries.

   Delay of infrastructure necessities endangers the carbon neutrality ambitions for 2050 (and before)

3. Economical feasibility / livability of carbon neutral products
Legislation and policies framework secure economical basis for energy intensive industries to become carbon neutral as soon as possible.

   Long term predictability of legislation + Whole life cycle basis of carbon costs + Fair level playing field
CCUS key pillar for Carbon Neutrality 2050....
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Unless otherwise indicated, the financial information provided herein has been prepared under International Financial Reporting Standards (IFRS).

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“Operating EBITDA” definition included in this presentation represents “Result from current operations before depreciation and amortization (RCOBD)” and “Operating Income” represents “Result from current operations (RCO)” lines in the annual and interim reports.
Outline

Part I: Exemplified CCUS Innovation in China Cement Sector
Part II: Policy & Future perspective
Part I:

Exemplified CCUS Innovation in China Cement Sector
1. **CCUS-Cement** (CalciumLooping)

**Demo Project 2014:** Taiwan Cement Corporation, technically supported by Industrial Technology Research Institute (ITRI)

**Test Results:**
- The CO2 capture rate: + 1 t/h;
- The CO2 capture efficiency higher than 85% for 7 hours. The accumulated time of unit operation test in this pilot plant = 600 hours;
- and that for the fully-continuous looping test is more than 300 hours

2. CCUS-Cement (Post combustion)

Demo Project: Anhui Conch (chemical adsorption)

- 1st Trial Production: Oct. 22-29, 2018
- Kiln capacity: 4500t/d
- CCS capacity: 50kt/y of CO2; industrial and food grades;
- Type of CO2 sorbent: AEEA
- CO2 capture efficiency: 95%
- Power consumption: 270kWh/t CO2

*Courtesy of Mr. JIN Feng, Anhui Conch*
2. CCUS-Cement (Post combustion)

Demo Project: Anhui Conch (chemical adsorption)

* Courtesy of Mr. JIN Feng, Anhui Conch
3. CCUS-Cement (via mineralization)

Demo Project 1: Sinoma, CNBM (CCUS via mineralization)

Waste 1 + Waste 2 ➞ HVAD PCC (precipitated calcium carbonate)

Typical composition of the exhaust gas (Waste 1) from kiln

<table>
<thead>
<tr>
<th>Plant</th>
<th>CO₂</th>
<th>O₂</th>
<th>CO</th>
<th>N₂</th>
<th>Dust (g/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.1</td>
<td>3.8</td>
<td>0.26</td>
<td>64.8</td>
<td>53.7</td>
</tr>
<tr>
<td>2</td>
<td>32.24</td>
<td>4.29</td>
<td>0.01</td>
<td>63.46</td>
<td>18.4</td>
</tr>
</tbody>
</table>

Typical composition of carbide sludge (Waste 2)

<table>
<thead>
<tr>
<th>Plant</th>
<th>Loss</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>SO₃</th>
<th>Cl⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.96</td>
<td>4.30</td>
<td>2.59</td>
<td>0.34</td>
<td>68.36</td>
<td>0.34</td>
<td>0.03</td>
<td>0.03</td>
<td>0.07</td>
<td>0.009</td>
</tr>
<tr>
<td>2</td>
<td>31.22</td>
<td>3.48</td>
<td>1.21</td>
<td>0.30</td>
<td>62.74</td>
<td>0.30</td>
<td>0.01</td>
<td>0.05</td>
<td>0.26</td>
<td>0.064</td>
</tr>
</tbody>
</table>

- **PCC 50 kta industrial feasibility study**
- **PBC 50 kta industrial line in operation** (Barium carbonate)
3. **CCUS-Cement** (via mineralization)

Demo project 2: technical support by Zhejiang University*

—— Pavers made via CO2 curing

**72-hour trial**

- Use steel slag, bottom ash etc., 1700 t;
- Concrete pavers 1800 t, CO2 sequestered 50kg/t

*Prof. Tao Wang, Zhejiang University*
4. **CCUS-Cement** *(Oxy-fuel & CO2 enrichment)*

Developed by Sinoma, CNBM

<table>
<thead>
<tr>
<th>Position</th>
<th>CO₂ (%)</th>
<th>O₂ (%)</th>
<th>N₂ (%)</th>
<th>H₂O (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1</td>
<td>72.37</td>
<td>2.31</td>
<td>12.88</td>
<td>12.44</td>
</tr>
<tr>
<td>Calciner B</td>
<td>75.74</td>
<td>2.00</td>
<td>11.90</td>
<td>10.36</td>
</tr>
</tbody>
</table>

1. **CO₂ self-enrichment**: Increase CO₂ content above 75%
2. **CO₂ capture**: Adsorption-Distillation

CAPEX & OPEX cost is expected to reduce
4. CCUS-Cement (Oxy-fuel & CO2 enrichment)

Pilot project designed by Sinoma, CNBM

Pilot project with CO₂ capture capacity of 50,000 t/a has been designed.
Part II:  
Policy & Future Perspective
Demo CCUS projects in China: up to 2019
- 9 for CCS, 12 for Geo-sequestration and utilization;
- 2 million t of CO2 sequestered;
- Coal chemical & Power sector;
- Cement sector is taking action;
- Pilot ETS in cement sector has been implemented since 2011;
- ……

Challenge and Perspective of CCUS
- Further R&D to reduce the cost;
- Policy & regulation and standards enhancement;
- Financing and business model
- Cross-sector model & international collaboration;
- ……
Government policy on GHG Emission Control & CCUS since 2006

- 12th Five-Year Specialized Planning on National CCUS;
- 13th Five-Year National Plan on GHG Emission Control;
- Action Plan (2012—2020) to Cope with Climate Change in Industries;
- Technological Roadmap of China CCUS, eds. 2011 & 2019;
- National ETS Market Building Plan (Power Sector, Dec. 18, 2017)
- ETS Management Method launched on Dec. 25 2020 & to be enforced from Feb. 1, 2021

“China will scale up its Intended Nationally Determined Contribution by adopting vigorous policies and measures. We aim to have CO2 emission peak before 2030 and achieve carbon neutrality before 2060”.

—— President XI Jinping, Statement at the General Debate of the 75th Session of the United Nations General Assembly. Sept. 22, 2020
Collaboration & Mutual Success
For A community with A Shared Future for Mankind

suitongbo@sinoma.com.cn
Discussion and Q&A

Panel hosts:

Jamie GENTOSO
LafargeHolcim US

Rob van der MEER
Heidelberg Cement

Tongbo SUI
Sinoma – CNBM

Jarad DANIELS
US Department of Energy

Claude LOREA
Global Cement and Concrete Association