Cement precalcination with electricity and carbon dioxide sequestration

Oona Katajisto

25/05/2022 VTT – beyond the obvious
Content

- Rationale and the concept
- Industrial applications
- Decarbonate project
- Experimental kiln
- Results from pilot scale experiments
Rationale and present situation

- Limestone is one of the most used materials
  - 2.5 Gt of CO₂ from cement production
    → 8 % of global emissions
- Pressure and demand from market
- Increasing emission allowance price in the EU ETS
- Unstable fuel prices

\[ \text{CaCO}_3 + \text{heat} \leftrightarrow \text{CaO} + \text{CO}_2 \]

- Shifting from fossil fuels to electricity decreases the amount of CO₂ by roughly 50%
- Almost 100% concentration!

Picture: Finnsementti
Electrically-heated calciner with CO₂ capture and utilisation

Carbon neutral electricity

Electric heated calciner

CaCO₃ → CaO + CO₂

Electrolysis

H₂

CO₂ synthesis

CO₂ market

Cement kiln

Cement for concrete

Synthetic fuels and products
Rapid changes in operational environment

Emission allowance daily future price in the EU ETS [€/t CO₂]

- 11.5.2020: 18.98 €
- 6.5.2022: 91.10 €

Natural gas price, Dutch TTF benchmark [€/MWh]

- 11.5.2020: 5.71 €
- 6.5.2022: 96.36 €


Picture and data: [https://tradingeconomics.com/commodity/eu-natural-gas](https://tradingeconomics.com/commodity/eu-natural-gas)
Installed intermittent RES capacity in Finland

Solar power

Installed intermittent RES capacity in Finland

Wind power

Network-connected small-scale production capacity of solar electricity


Installed wind power capacity


25/05/2022 VTT – beyond the obvious
Power generation in Finland

CO₂ emissions of power generation

Electricity price, Nordpool spot


Electric heated kiln directly suitable for burnt lime production

World total: 424.6 Mt
- China: 300 Mt
- United States: 18 Mt
- India: 16 Mt
- Russia: 11 Mt
- Brazil: 8.4 Mt
- Japan: 7.6 Mt
- Germany: 7.1 Mt
- Korea: 5.2 Mt
- Turkey: 4.7 Mt
- Italy: 3.6 Mt
- Iran: 3.3 Mt
- Poland: 2.7 Mt
- France: 2.6 Mt
- Romania: 2.2 Mt
- Ukraine: 2.1 Mt
- Australia: 2.1 Mt
- Other countries: 28 Mt

Lime production [Mt]
Precalcination in cement plants

Cement (2020)
Global production: 4 281 Mt
Global CO₂ emissions: 2,5 Gt
CO₂ utilisation

CARBON DIOXIDE, CO₂

Mineralisation
- Concrete curing
- Aggregates
- Mineral carbonation
- Precipitated calcium carbonate (PCC)

Chemical conversion
+ H₂

Biological conversion
- Algae cultivation
- Greenhouses
- Gas fermentation (e.g. biological methanation)
+ H₂ + N₂

Direct use
- Food/beverages
- Industrial gas
- Refrigerant
- Working fluid
- Solvent
- pH control
- Enhanced oil recovery (EOR)
- Enhanced coal bed methane (ECBM)

Polymers
- Polycarbonates
- Polyols

Fuels & chemical intermediates

Commodity
- "Renewable urea"

Fischer-Tropsch (FT)

Polymers
- Methane (CH₄)
- Methanol (CH₃OH)
- Formic acid (HCOOH)
- Syngas (CO+H₂)

Fuels & chemical intermediates
- Gasoline
- Methanol, ethanol...
- Methanol, diesel, olefins...
- MTBE*, DME**
- Olefins

NOTE: The diagram presents only the most important options for the near-term. There are other routes such as electrochemical and photochemical routes and hundreds of other possible products.
Using indirect heating by electricity roughly 50% of CO$_2$ emissions can be directly avoided (by substituting fossil fuels)

Pure CO$_2$ stream can be used for utilization (CCU) or permanently stored (CCS)

The Decarbonate project will prove the concept using electrically heated rotary kiln integrated by CO$_2$ capture and upgrading

VTT’s budget: 1.2 MEUR
Schedule: Oct/2019 – Mar/2022
DECARBONATE partners and value chains

- KELIBER Spodumen
- UPM Lime mud
- FINNSEMENTTI Cement raw meal
- Nordkalk Lime stone

- KUMERA Indirectly heated rotary kiln 300 kW
- oxyCFB 100 kW
- In-Line PCC

- CaCO3
- CaO

- UPM Paper & cardboard
- FINNSEMENTTI Cement (incl. CaO)
- Nordkalk Lime products
- SSAB Steel

- ANDRITZ Industrial equipment supplier

- st1 Ethanol & biogas CO2
- s11 Low-carbon gases and liquids:
  - SNG (CH4)
  - FT liquids
  - CO2

- Water
- PEM electrolyser (21 kW)
- Mobile synthesis unit (MOBSU)
- H2
Drum length: 9 m
Drum diameter: 0.6 m
System height: 8 m
Power: > 300 kW
Capacity: > 100 kg/h
Mobile, built inside a 40 ft sea container
Schematic illustration

- Steel shell
- Framework
- Insulation
- Heating elements
- Rotary tube

Limestone → CaCO₃

CO₂ rich gases → Lime → CaO
Observations from the pilot scale rotary kiln first trials

| CO$_2$ content in kiln off gases up to 98 vol-% (dry) |
| Degree of calcination 88-98% |
| Continuous 3 x 4 day operation at ~1000 °C |
| No shutdowns or major availability issues |
Next steps

Decarbonate test runs – 2 materials, week/material
- Focus: degree of calcination, reactivity, CO₂ level in kiln-off gases
- Ring formation
- Performance and operability

Scale-up

More operation in future projects
- Public funded projects (e.g. EU)
- Customer projects (confidential)

Laboratory scale experiments:
- Scale
- ~100 kg/h 9 m
- ~1 kg/h 2 m

Scale-up
- ~1 kg/h 2 m
- 2020
- 2021
- 2022
- 2023
- 2024
Thank you for your attention!

Contact information:

Oona Katajisto
Research Scientist

oona.katajisto@vtt.fi
+358 50 476 1720

LinkedIn:
www.linkedin.com/in/oonakatajisto