Evolving the well-established

Decarbonisation Pathways for the Australian Lime Sector

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Lime and limestone: Solutions for significant societal benefits

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Lime has been used as a construction material for at least 3,000 years, and remains a critical input in multiple applications

Production of lime

Raw material deposit

Limestone, $CaCO_3$, is the raw material for lime production. $CaCO_3$ originated from geological carbonate deposits and from marine sediments which can be found in specific areas throughout the world. The limestone must be of high quality, with a carbonate content exceeding 95%. Limestone is extracted as hard rock from quarries or as shell sand or dune sand from coastal and sand-like deposits.

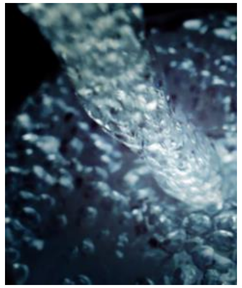
High temperature calcination

The limestone is processed through crushing, screening and sometimes washing before entering the kiln, where the calcination process begins at around 820°C. Full calcination occurs at around 900°C. During the calcination process, the $CaCO_3$ is split into CaO (quicklime) and CO_2. These ‘process emissions’ are the reason lime production is considered an emissions intensive process.

Product for dispatch

Quicklime (CaO) is produced in granulate, pebble or ultra-fine powdered form. Hydrated lime, also known as slaked lime, is produced by reacting quicklime with water. Both quicklime and hydrated lime are supplied in bulk or bagged forms.

Various fields of application

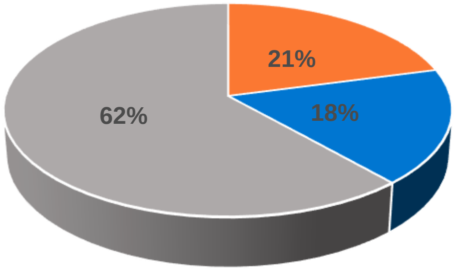


Lime is essential, life-sustaining and critical to many modern environmental, scientific and industrial applications. Quick-lime and hydrated lime are essential products for environ-mental and industrial applications. Due to its potential to absorb and to neutralize, it serves as a cleaning agent in different sectors, including the cleaning of water, flue gases or soils. It serves as a flux in metallurgy such as high quality steel making and is applied in aluminium and nickel processing, also being of importance for the mining industry. Lime products serve as a fertiliser, soil stabiliser and soil improver. Hydrated lime is often used as a critical constituent within modern building mortars and can also be carbonated to produce precipitated calcium carbonate, used in the pharma-ceutical sector and as a filler e.g. in paper products or paints.

The Australian lime sector

The lime plants are located in West and South Australia, New South Wales, Queensland, Victoria and Tasmania

Lime provenance [%]



Producers

Four companies produce lime in Australia:

AdBri Limited
Boral Cement Limited
Cement Australia Pty Ltd
Graymont

Consumption

Lime consumption in Australia is 1.9 million t/a of which around 400,000 t/a are imported. The per capita consumption amounts to around 75 kg/a.

Consumption peaked in 2011 at 2.6 million t/a during the mining boom and before dropping to 1.6 million t/a between 2013 and 2017. Today, consumption is around 1.9 million t/a.

Domestic Production

There are currently 13 lime plants operating in Australia, 12 of which produce quicklime, while 1 plant produces hydrated lime only.

Domestic production was almost 2.6 million t/a in 2011, before dropping significantly in 2013. Domestic lime production was 1.5 Mt in 2021-22, while imports have increased to 400 kt.

Imports

Imports of quicklime increased from 0.086 Mt in 2016-17 to 0.404 Mt in 2021-22.

Country of origin	Share of import
Thailand	50%
Malaysia	27%
Vietnam	14%
others	9%

The Australian lime industry today and tomorrow

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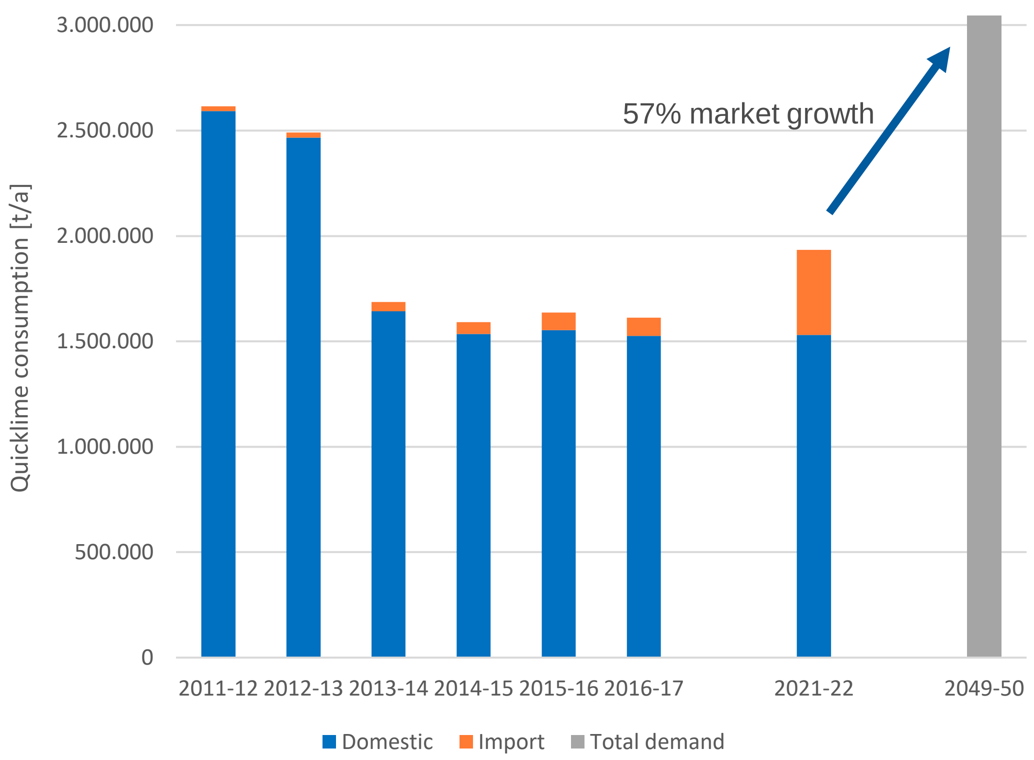
Domestic consumption has recovered since the 2013 downturn and is expected to grow by more than 50% by 2050



* Sources.

- Making Net Zero Steel Possible, Steel Transition Strategy, Mission Possible Partnership, 2022 Steel - Mission Possible Partnership
- ALUMINIUM SECTOR GREENHOUSE GAS PATHWAYS TO 2050, 2021
- The Role of Critical Minerals in Clean Energy Transition, IEA, 2022
- CIF and Australian Bureau of Statistics

Market segments for lime and its development by 2050*

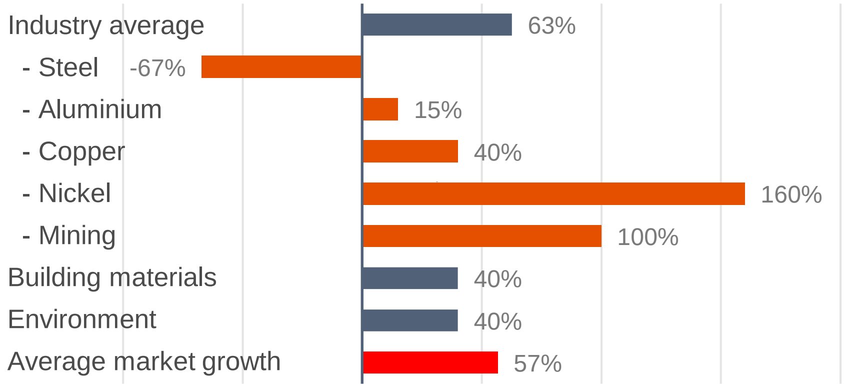
Industry

Steel will require less lime due to switching to direct reduction in the basic oxygen furnace (BOF). Aluminium, nickel and copper industries will grow according to world market expectations and will require correspondingly higher amounts of lime.
The mining industry will grow according to the global IEA outlook.
Weighted averages of these sectors results in an average growth in industry application of 63%.

Building materials, environmental application

The demand for lime in building and environmental applications including soil stabilization, waste water treatment etc. will follow the growth of the construction market i.e. +40% by 2050, which reflects the overall development of expected GDP in Australia.

Weighted average



Lime kilns: Types and installations in Australia today

Kiln technology is based on raw material conditions and product requirement

Kiln types and their energy demand*

Abbr.	Kiln type	Thermal energy demand GJ/t	Electrical energy demand kWh/t
LRK	Long rotary kiln	6.0 – 9.2	18 – 25
PRK	Rotary kiln with preheater	5.1 – 7.8	17 – 45
PFRK	Parallel flow regenerative kiln	3.2 – 4.2	20 – 40
ASK	Annular shaft kiln	3.3 – 4.9	18 – 35 (up to 50)
MFSK	Mixed-feed shaft kiln	3.4 – 4.7	5 – 15

Source: Best Available Techniques (BAT) Reference Document for the Production of Cement, Lime and Magnesium Oxide, 2013

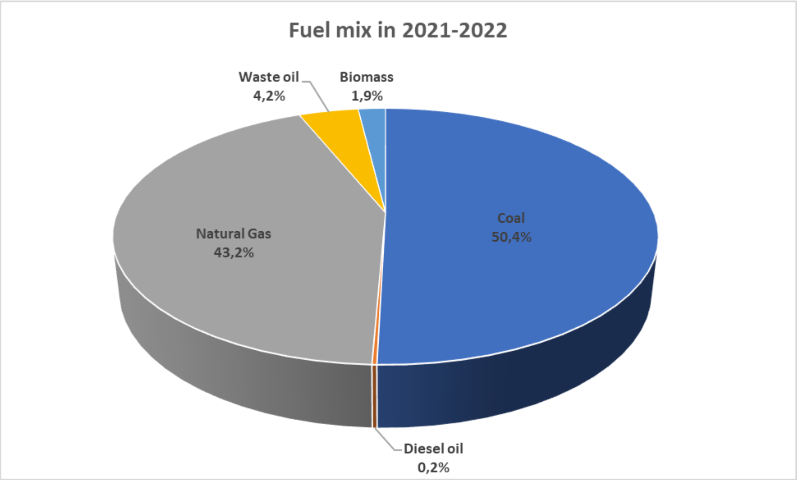
*** Ranges from literature are given since - due to competition and compliance reasons - specific kiln data can not be disclosed**

Lime kilns in Australia

- Preheater Rotary Kiln (PRK) is the dominant kiln technology (1.2 Mt; equivalent to 78% of total quicklime production)
- 85% of quicklime production in horizontal kilns (PRK and LRK)

Energy input

- Thermal energy demand (average) : 6,300 kJ/kg lime
- Predominantly coal and natural gas (>93%)
- Thermal substitution rate: 6.1%
- Biomass: 1.9%



CO_2 emissions of the Australian lime industry

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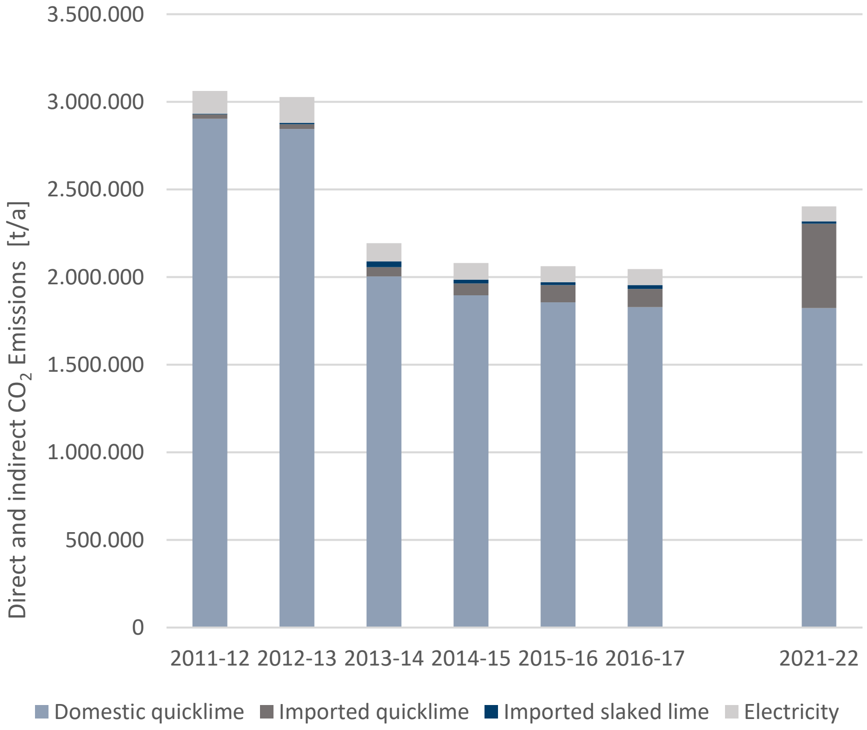
CO_2 emissions take into account direct and indirect emissions and include emissions from imports

CO_2 emissions



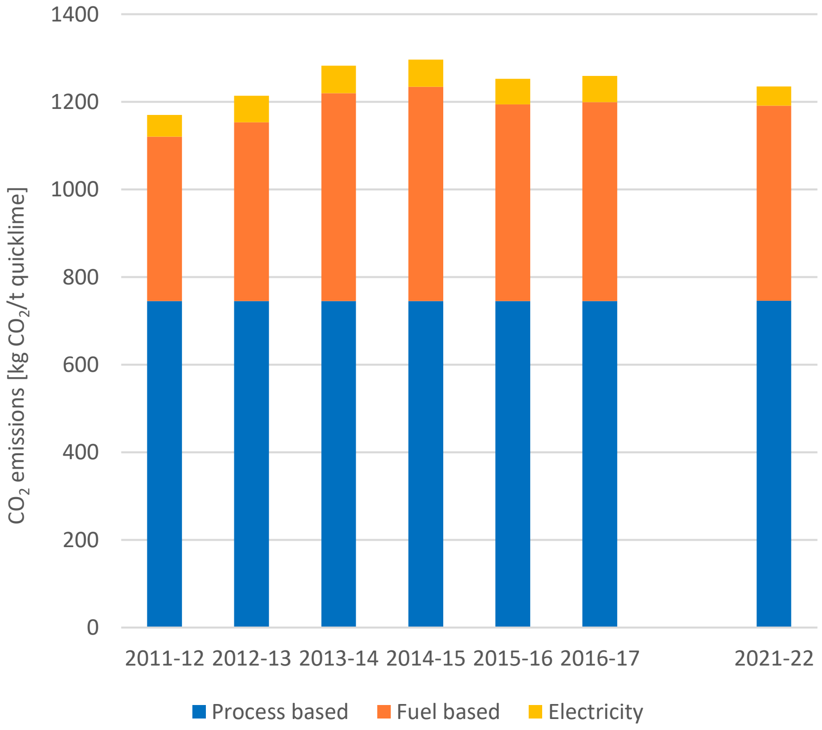
Total emissions 2021-2022

1.823 Mt CO_2 emissions – domestic lime
0.495 Mt CO_2 emissions – imported lime and slaked lime
0.086 Mt CO_2 indirect emissions from electricity

Total emissions 2011-2022

CO_2 emissions from imports based on same CO_2 emission factor as for domestic production

CO_2 emission factors (domestic quicklime)



Process Process emission factor of 746 kg CO_2/t lime, considering 95 % of CaO in quicklime and for calcination of $CaCO_3$: 785 kg CO_2/t CaO

Fuels Emissions based on emission factors for fuels, i.e. mainly coal and gas, specific heat consumption

Electricity Emission factor of 0.68 kg CO_2/kWh, power demand: 44 kWh/t quicklime,

Decarbonisation pathways for the Australian lime sector

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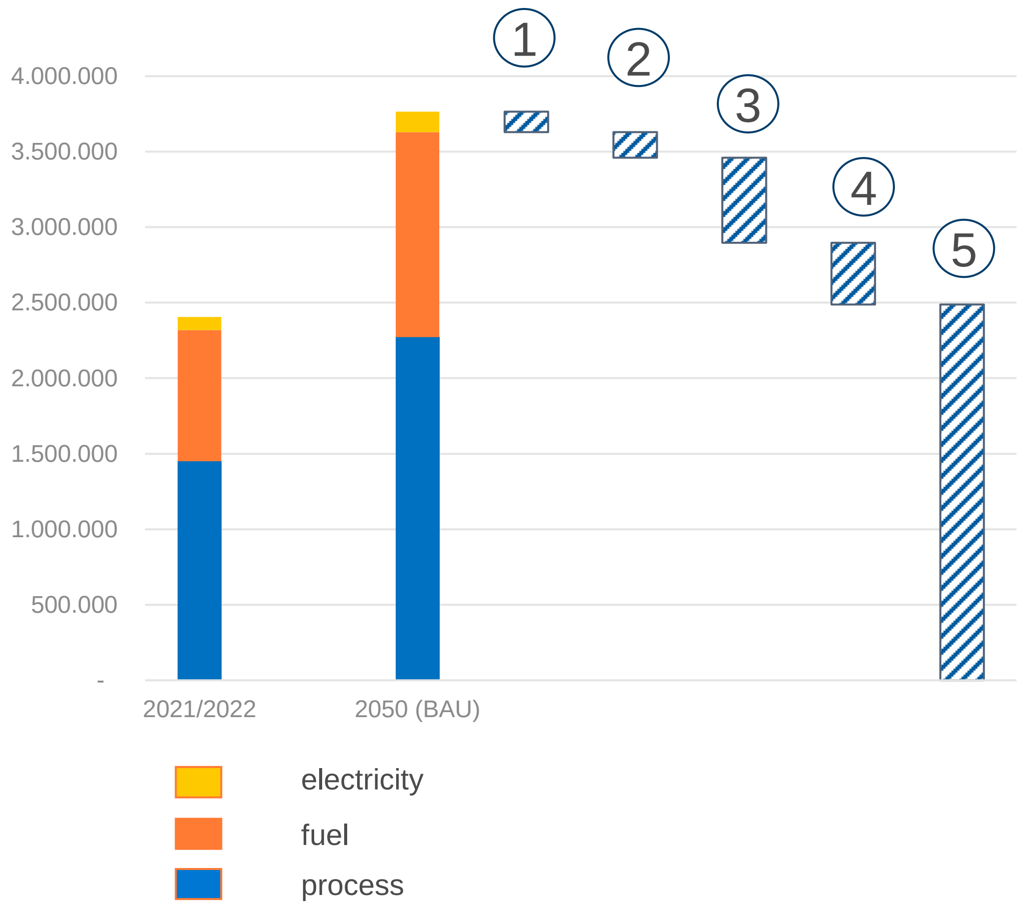
Different pathways add up to allow the sector to achieve net-zero CO_2 by 2050

Decarbonisation pathways



1	**Decarbonising electricity**	It is assumed that energy efficiency will be continuously improved and that the sector in Australia will be fully decarbonised by 2050.
2	**Thermal efficiency**	It is assumed that all kilns will be operated state of the art, which may include technologies such as modern preheater rotary kiln (PRK) and parallel flow regenerative kiln (PFRK).
3	**Fuel switch**	**Use of hydrogen** It is suggested that green hydrogen be used as a fuel, substituting 10 per cent of the conventional fossil fuels, as an average in the sector. Higher rates may be possible in the future and should be subject to further research. **Use of biomass** The thermal substitution rate of fossil fuels (TSR) is generally low in lime plants compared to cement kilns. However a TSR of 10% is suggested and should allow pure biomass such as wood chips to be utilised in lime production.
4	**Natural recarbonation**	Lime in use, depending on its application, takes up CO_2 to different degrees. Based on the market segments for lime in Australia, an equivalent of around 20% of the process emissions are recarbonated.
5	**Carbon capture**	Carbon capture will be needed to eliminate unavoidable emissions. Carbon capture technologies exist, but need to be further developed with respect to their Technology Readiness Level. Carbon capture technologies will require the implementation of a comprehensive policy framework.

Prerequisites for successfully decarbonising the lime sector

The lime sector can decarbonise its value chain - but needs support from all stakeholders

Stakeholders of the value chain

The lime producers

- Develop site-specific engagement plans which break down the sector pathway to each lime plant.
- Initiate feasibility studies for the different sites, in particular with respect to carbon capture.
- Start using biomass at a thermal substitution rate of 10% to lower the use of fossil fuels.
- Start using green hydrogen as fuel to lower the amount of fossil fuels, once available at a competitive price.
- Source price-competitive renewable purchase agreements.
- Continue to invest in available energy efficiency measures for existing technology, aligned with specific company emissions reduction goals.

Research network

- Define dedicated research areas, since not all of the technologies required have yet been developed to such an extent that immediate application is possible.
- Including in particular
  - the use of hydrogen as fuel with substitution rates greater than 10% will require further research.
  - The use of alternative fuels with high substitution rates
  - The application of carbon capture on demonstration scale and its scale-up to commercial sizes in the future.
  - Test indirect calcination (such as CALIX) to integrate domestic technology.

Policy makers

- Implement targeted federal and state government policies and funding programmes in order to maintain the international competitiveness of the industry, noting that the lime sector is already significantly trade exposed.
- Promote methods to decarbonise Australia’s electricity network, whilst ensuring it remains reliable and affordable.
- Create a functioning CO_2 infrastructure and ensure that CO_2 can be appropriately stored or utilised.
- Develop a national hydrogen market with competitive costs for industrial end users.
- Acknowledge recarbonation in the carbon accounting scheme.

Enabling the transition:

- Although new kilns will have lower operating costs for fuels, the overall cost will be considerably higher than today. Increasing capital and operating costs will be significant and require the support from governments to enable the transition of the sector.
- Without CBAM it will be difficult for industry to see an economic case for decarbonisation investment / domestic production on any scale. In this context the Federal Government has announced to undertake a review of policy options to reduce carbon leakage, including an Australian carbon border adjustment mechanism. The review is to begin in the second half of 2023.



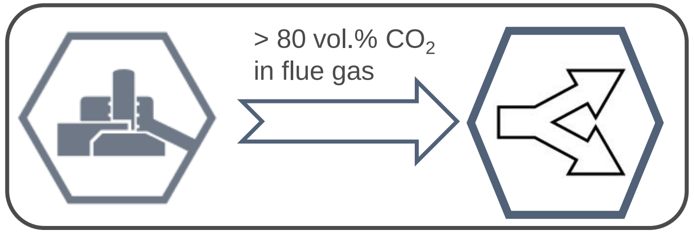


ANNEX to the report

Carbon capture technologies

Technologies are in the developing phase and the Technology Readiness Levels are expected to increase

Integrated Technologies



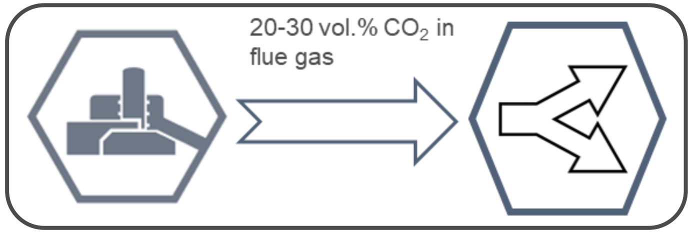
Main characteristics

- The concentration of CO_2 in the gas flow is integrated in the burning process and allows the purification of the CO_2 to be more efficient.
- The TRL is 6 to 7 and integrated combustion technologies have the potential for application in lime production

Technologies

- Oxyfuel technology
- Integrated Ca-Looping process
- Indirect calcination

Post-Combustion Technologies



Main characteristics

- The capture process is end-of-the-pipe and has therefore little impact on the lime production process. Concentrating CO_2 is an essential additional step following the capture part.
- The TRL is between X and Y and post-combustion technologies have the potential for application in lime production.

Technologies

- Absorption processes
  - Liquid solvents (e.g. by amines or hot potassium carbonate), solid sorbents (Ca-Looping)
- Adsorption processes
  - Temperature swing adsorption (TSA), Vacuum/Pressure swing adsorption (VPSA, PSA). Electro-swing adsorption
- Cryogenic capture
- Membranes

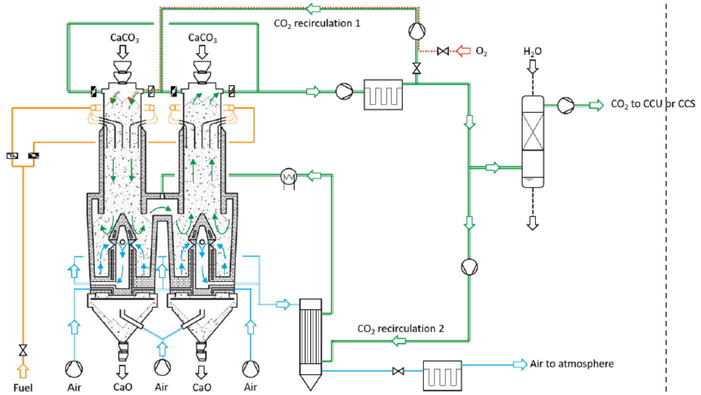
Most promising carbon capture technologies in the lime sector

Oxyfuel technology will be the preferred option – applicability also depends on the kiln type

Shaft kilns

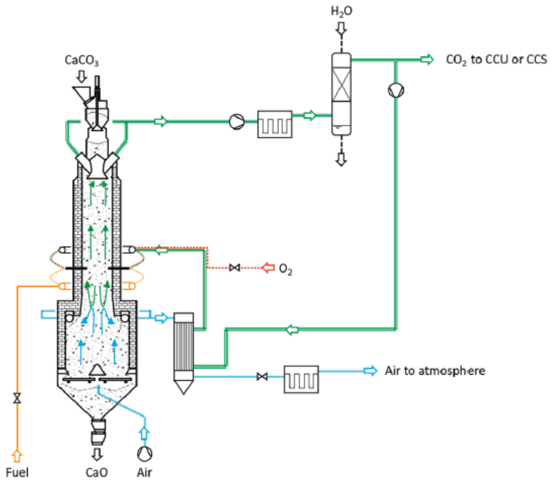
PFR

- In particular for high reactive lime
- Flexible operation in air or oxyfuel mode
- Capacities 500 – 800 t/d
- Enrichment of CO_2 up to 90 vol.%



ASK

- In particular for hard burnt lime
- Capacities of 50 to 250 t/d
- Modified shaft kiln design
- Enrichment of CO_2 up to 97 vol.%

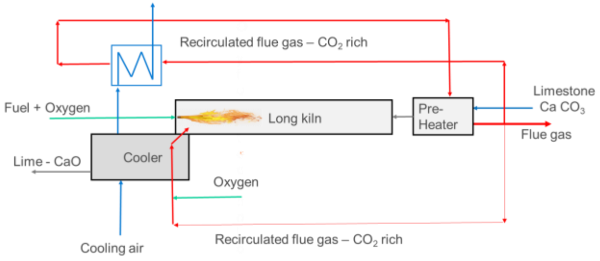


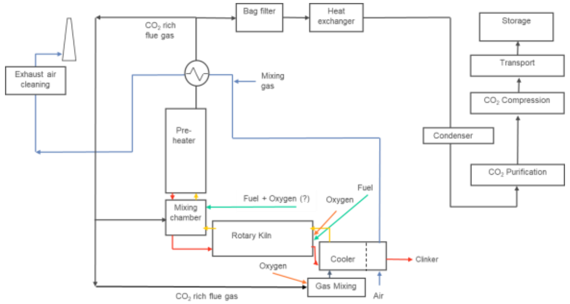
Both figures above: Maerz Ofenbau

Rotary kilns

LRK and PRK

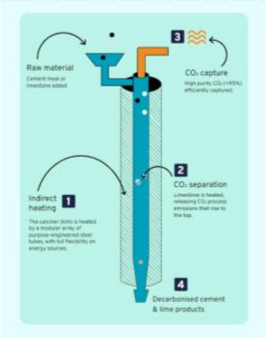
- For limes of different reactivities
- Wide range of limestone size can be used
- Typical capacities of around 1000 t/d
- Enrichment of CO_2 up to 90 vol.%





Indirect calcination

- Technical concept first developed in magnesium and cement production
- Feasibility study for application in lime sector underway, followed by a front-end engineering and design phase.
- Enrichment of CO_2 more than 95 vol.%



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