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The Case for BECCS in the Hard-To-Abate Lime Industry

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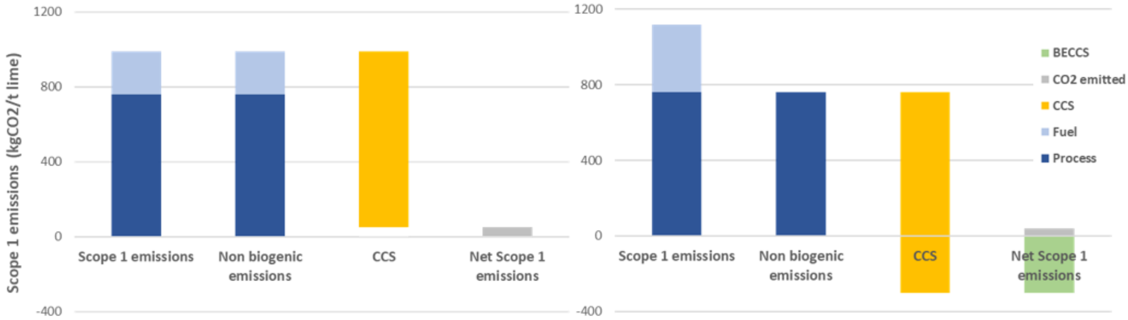
Abstract

Lime is an essential product used in a wide range of key environmental processes and primary industries. The production of lime is highly carbon intensive, with typical emissions of ~1.0 tCO2/tlime, which vary depending on the type of product (e.g. soft burnt, slaked, etc.), choice of fuel, and type of kiln. It is estimated that the direct emissions associated with lime production accounted for a total of 430 MtCO2 worldwide in 2021, representing ~1.6% of global direct industrial emissions [1].

There are two approaches that lime producers can use to reduce their direct emissions. With roughly 1/3rd of emissions linked to the combustion of fuel, one solution is to replace fossil fuels (e.g. natural gas, lignite) with biomass. The remaining 2/3rds of process emissions, linked to the calcination of the limestone, can then be addressed through carbon capture, utilization, and storage. The combination of these two approaches results in a negative carbon intensity (see Figure 1), the magnitude of which increases if we consider that roughly 1/3 of the of the lime recarbonates in downstream applications [2].

Figure 1: Scope 1 emissions on a Parallel-Flow-Regenerative Kiln, in the NG+CCS case (left), and a BECCS configuration (right)



A BECCS approach on lime would thus allow for additional CO2 removal from the atmosphere. Such an approach entails extra costs, however, owing to various considerations:
- the purity specifications for the lime products are stringent, notably for their use in environmental processes (e.g. drinking water and waste water treatment, flue gas treatment, etc.), with the consequence that high-quality, homogeneous biomass is required
- the lime industry is shifting away from energy-intensive rotary kilns to efficient vertical shaft kilns. Various technical limitations on these new kilns require extra investment for biomass pre-treatment, and adaptation of the kilns
- the carbon intensity of biomass is higher than that of Natural Gas, thereby generating extra costs on the entire CO2 value chain (capture, transport, and storage), which is more notable in regions such as Europe, where the high costs of offshore transport and storage are compounded
- the impurities will increase with the use of biomass, raising the prospect of costly flue gas treatment processes (e.g. SCR, SNCR for NOx abatement), in order to satisfy emissions limits in the treated flue gas, meet stringent CO2 specifications, and protect the integrity of the carbon capture unit

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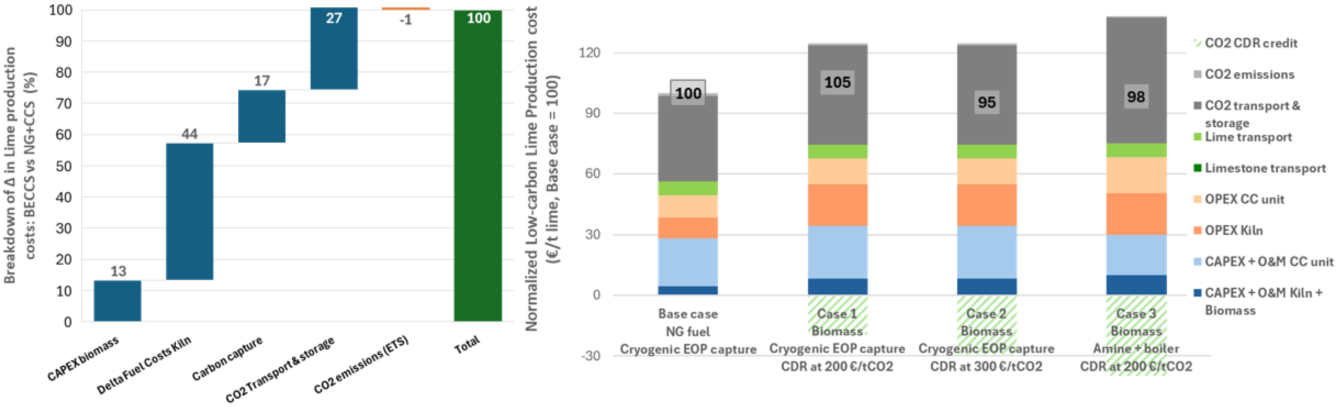
A BECCS setup in lime thus meets the criteria of additionality, with a higher carbon intensity and higher costs than the NG base case. As Figure 2 (left) indicates, these higher costs are largely driven by the spread between biomass and NG, and the corresponding impact on the kiln fuel costs. These higher expenses require a financing mechanism, such as the sale of Carbon Dioxide Removals (CDRs). In Figure 2 (right), we consider the example of a 600 ktpa lime plant in France based on Rety CalCC, the most advanced large-scale CCS project for lime worldwide, with a targeted capacity of 650 ktpa CO2. The impact of various BECCS setups and CDR prices is then evaluated against a base case consisting of NG fuel and a cryogenic capture unit.

Figure 2: breakdown of Δ BECCS vs NG+CCS (left), low-carbon lime production costs for various setups and CDR prices (right)



In Cases 1 and 2 with a cryogenic capture unit, an affordable BECCS proposition on this project requires a CDR value well in excess of the current price of CO2 on the EU Emissions Trading Scheme. Conversely at lower CDR prices the economics of a BECCS approach can be improved by combining an amine wash and a biomass-fed boiler to generate the required heat (Case 3), thus generating more CDRs. The caveat of such a concept is that the biomass consumption increases significantly, in this case by 89% relative to the cryogenic capture solution.

In order to assess the practicality of the BECCS setups on such a project, we can estimate the required biomass quantities, and associated land footprint, which depend on biomass type, lower heating value, density, yield, and growth time. In Table 1, three scenarios are considered: an energy crop (miscanthus), waste from agriculture (wheat straw), and a dedicated tree farm (eucalyptus).

Table 1: biomass and land requirements for a 600 ktpa lime plant

	Miscanthus crop		Wheat straw		Eucalyptus	
Capture technology	Cryogenic	Amine	Cryogenic	Amine	Cryogenic	Amine
Biomass (ktpy)	137	259	147	278	134	253
Total land req'd (1000 ha)	26	50	70	133	34	63

These biomass consumption requirements can be compared with the residual biomass available. In France the amount of unused residual biomass is estimated at 105 Mt of dry material [3], and carbon sinks are ranked 3rd in terms of merit order for its use, after human and animal feed. Extending this analysis to the entire lime production in France (~2.2 Mtpa lime), a total of ~0.7 Mtpy of biomass would be sufficient to supply this whole industry, or 0.7% of the available residual biomass in the country.

A BECCS approach on lime would be advantageous for various reasons. Lime is a hard-to-abate industry with high process-related emissions from stone decarbonation, resulting in a high CO2 concentration in the flue gas. This CO2 content opens possibilities for the use of technologies that require higher CO2 partial pressures (e.g. cryogenic, desublimation), and yields efficiency gains on the capture of the CO2, both from the process and from the biogenic fuel. The negative emissions from BECCS further complement the role of lime as a partial carbon sink in its end uses. To make this setup viable, however, the lime industry needs access to sustainable biomass, regulatory support for CO2 infrastructure, and a market price for CDRs that reflects both the benefits of carbon removals and the associated costs.

[1] IEA-EDGAR CO2, a component of the EDGAR (Emissions Database for Global Atmospheric Research) Community GHG database version EDGAR_2024_GHG (2024) including or based on data from IEA (2023) Greenhouse Gas Emissions from Energy
[2] M. Grosso et al, Literature Review On The Assessment Of The Carbonation Potential Of Lime In Different Markets And Beyond
[3] Secrétariat général à la planification écologique, Bouclage biomasse : enjeux et orientations, Juillet 2024
Keywords: BECCS; hard-to-abate; low carbon lime; negative carbon intensity; Carbon Dioxide Removals; biomass; land-use