Decarbonising Scope 3 emissions

SCOPE 3 emissions occur in the supply chain. They are neither directly emitted from the iron and steel plant (Scope 1) nor do they account for emissions from power generation for the iron and steel plant (Scope 2).

Purchased materials such as coke, oxygen, and lime are high CO_2-intensity inputs that contribute to Scope 3 emissions.

Coke substitution with biocarbon

Pulverised coal injection (PCI) is used in some blast furnaces to reduce the iron ore while others rely on coke derived from coal. Biocarbon, produced from torrefaction or pyrolysis of wood, is gaining attention as a substitute for blast furnace coal or coke.

While switching to biocarbon does not reduce the total CO_2 produced during iron ore reduction, it shifts emissions from fossil-based to biogenic, which is considered carbon-neutral over the lifecycle of the biomass.

Outokumpu is using biocarbon produced from waste-wood to reduce its carbon footprint in Tornio, Finland. Biocarbon replaces fossil coke in Outokumpu's ferrochrome stainless steel production. The company has invested €40 million in a biocarbon plant at Mukran on the island of Rügen in Germany. Additionally, Outokumpu has invested in Envigas AB, a Swedish biocarbon producer, to develop a long-term biocarbon supply.

Switching from coke to biocoke reduces Scope 1 emissions at the iron and steel plant. If the biocarbon is sourced from a third-party supplier, its use also reduces Scope 3 emissions, as the CO_2 emissions from offsite biocarbon production are biogenic.

Renewable power for over-the-fence green oxygen supply

Over-the-fence oxygen supply can significantly contribute to Scope 3 emissions. Oxygen is used for basic oxygen furnaces and reheating burners. It is produced on power-hungry air separation units (ASUs). The emissions from off-site oxygen production with over-the-fence pipeline supply are related to electricity generation. But when the power is used by a third-party oxygen supplier, the emissions are categorised as Scope 3 at the iron and steel factory.

The core process for making oxygen is cryogenic air separation. Ambient air is drawn into the process using a large air compressor. To serve an iron making plant equipped with a blast furnace and multiple basic oxygen furnaces, the ASU may require an air compressor that continuously draws 20MW of power.

After the air is separated, the oxygen gas must be compressed to around 20 to 40 bar and supplied by pipeline to the iron processing facility. High pressure is required to blow the oxygen through the pipeline and ensure there is sufficient pressure to force the oxygen into the furnaces. In addition to the ASU air compressor, an oxygen compressor with a power draw of around 10MW may be required.

To decarbonise the electricity supply to the air and oxygen compressor motors, renewable electricity can be purchased by the ASU operator from wind, solar, or hydro sources. Use of low-carbon nuclear power generation for the ASU would also decarbonise oxygen production and supply.

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Green pig iron and steel are the way forward. However, there are many inputs to these processes and finding cost-effective solutions to reduce Scope 3 emissions can be challenging says Stephen Harrison*

Power transmission to the ASU via the grid will generally be required. A power-purchase-agreement (PPA) with a suitable guarantee of origin must be put in place to assign the appropriate quantity of renewable or nuclear power to the ASU operator so that the oxygen can be certified as 'green'.

Low-carbon lime

Lime production is another significant source of Scope 3 emissions. Lime, used for slagging in blast furnaces to remove impurities, is often produced offsite. The CO_2 emissions from offsite lime kilns are categorised as Scope 3 emissions for the steelmaker.

Lime making results in geogenic CO_2 emissions which are generated when calcium carbonate ($CaCO_3$) is baked out of limestone rock to generate lime (CaO). The thermal energy that is required to heat the rock during this process is also a source of CO_2 emissions.

Heat for the lime kiln can theoretically be decarbonised using biogas or biomass as a fuel source to supplement a natural gas burner or powdered coal burner. While these options may sound good in theory, the reality is that a huge amount of heat energy is required. This stretches each of these decarbonisation options to, or beyond their practical limits.

The geogenic CO_2 emissions from limestone baking are unavoidable. To mitigate these, CO_2 capture equipment must be used. This feeds back into the decision-making process for decarbonisation of the high temperature heat input to the lime kiln.

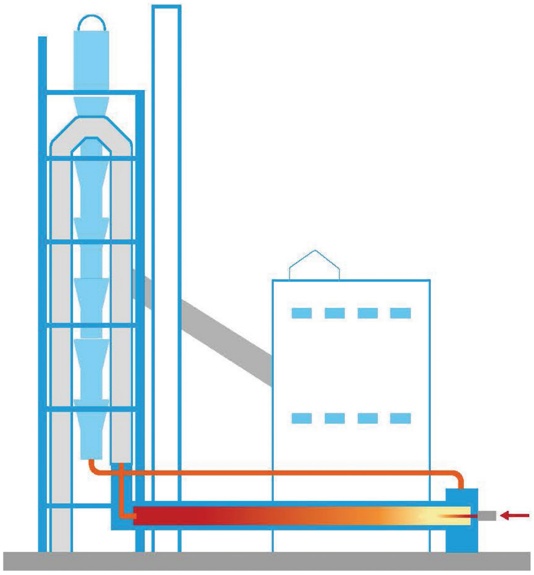
The lime kiln burner flue gases are generally produced in the same gas stream as the geogenic CO_2 emissions from the calcination process. This offers the potential to capture CO_2 from heat generation alongside the unavoidable geogenic process CO_2 emissions. A similar situation arises in the cement industry, where CO_2 capture is being implemented on several plants. There are transferrable lessons between these sectors.

Notes:

Unavoidable CO_2 emissions occur from the lime stone calcination process and are also associated with the energy and power requirements.

Heat for calcination can be decarbonised with renewable power for electrical heating, or biofuels.

CO_2 capture from the process is essential for decarbonised lime production.



Calciner tower & rotary lime kiln

	Lime making
Main CO_2 source	Reduction of limestone to calcium oxide
Chemical reaction producing CO_2	$CaCO_3 \rightarrow CaO + CO_2$
Other industries with similar applications	– Cement making – Refractory materials, $MgCO_3 \rightarrow MgO + CO_2$

Liquid solvents to capture CO_2 from lime making

The CO_2 concentration in the flue gas from the kiln is elevated beyond that of a typical combustion process because it also contains geogenic CO_2 from the calcination process. This CO_2 enrichment influences the technology selection for the CO_2 capture process.

Liquid solvent-based CO_2 capture systems are being deployed for cement and lime making decarbonisation. In recent deployments, the selected solvent has often been an amine-based solution. This liquid is sprayed onto a rising plume of flue gas in an absorber tower. The amines chemically bond with CO_2 to remove it from the decarbonised flue gas, which is vented to atmosphere.

The CO_2-rich amine solvent is then pumped to a second tower called a stripper. At the base of the stripper, heat is introduced to boil CO_2 out of the solvent. The regenerated CO_2-lean solvent is pumped back to the absorber tower and re-used to capture more CO_2.

CO_2 leaves the top of the stripper at a dry purity of around 99.5%. It is cooled to condense residual water vapour. The dry CO_2 can either be compressed to transmit it by pipeline to an underground geological storage scheme or liquefied for transportation by rail or ship to a CO_2 storage or utilisation location.

As an alternative to an amine-based solvent, hot potassium carbonate (HPC) solution can be used. Selection of an amine type solvent or HPC is driven by many factors, including the CO_2 concentration in the flue gas and the pressure at which this stream is available. Higher concentrations and pressures tend to favour use of HPC, whereas the amine can be more cost-effective in low-pressure flue gas streams where CO_2 is present at a very diluted concentration.

Other factors which are key when considering the most appropriate CO_2 capture technology include the presence of moisture, oxygen and sulphur compounds in the flue gas. Furthermore, if there is limited fuel supply available to provide heat for regeneration of the liquid solvent, an electrified process using solid sorbents (a substance which has the property of collecting molecules of another substance by sorption) may be preferred.

PSA for electrified CO_2 capture

Solid sorbents can also be used for CO_2 capture in lime making on pressure swing adsorption (PSA) systems. These sorbents may be molecular sieves, solid amines or metal-organic-frameworks (MOFs). In this technique, CO_2 from the flue gas is chemically or physically adsorbed onto a bed of the sorbent at an elevated pressure.

The sorbent beads are contained within a pressure vessel. Several vessels are connected in parallel with a manifold and change over valves to switch the gas flow between the sorbent beds. When a sorbent bed is saturated with CO_2, the flue gas is diverted to another bed.

The sorbent bed which is saturated with CO_2 is then depressurised. This pressure reduction, or pressure swing, causes the CO_2 to be released. The sorbent is regenerated through this process. The process cycles between adsorption and desorption approximately every minute.

The CO_2 released from the PSA system is typically less pure than that from a liquid solvent process. Several percent of nitrogen from the combustion air are generally captured with the CO_2. A PSA system can generally recover CO_2 at 95% purity. This gas may be suitable for compression and pipeline transmission, or it can be liquefied and purified for transportation by rail, barge or ship.

CO_2 capture for Scope 1 and Scope 3 emissions

CO_2 capture techniques can also be used at the iron and steel making site to decarbonise blast furnace gas, basic oxygen furnace gas and other emissions. In these cases, Scope 1 emissions would be reduced.

CO_2 capture at the offsite lime-making facility is the responsibility of the third-party lime producer. However, the iron and steel maker must ensure that the 'green' lime is appropriately certified with a suitable life cycle analysis to genuinely claim a reduction in Scope 3 emissions.

When it comes to Scope 3 emissions, trust, certification and collaboration throughout the supply chain are essential.