



Reducing CO2 emissions from iron and steel making

By Stephen B. Harrison on Jul 16, 2024 | [R20](#)

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Stephen Harrison from sbh4 Consulting analyses the key role oxygen and ASUs are playing in tackling emissions in heavy industry

Scope 3 emissions take place in the supply chain to an iron or steel making facility. They are not directly emitted from the iron or steel making plant (scope 1) and neither do they account for emissions from power generation for the plant (scope 2). Production of green steel will require reduction in all categories of greenhouse gas emissions.

One contributor to scope 3 emissions is over-the-fence oxygen supply for basic oxygen furnaces and reheating burners. Oxygen is produced on power-hungry air separation units.

The emissions from off-site oxygen production with pipeline supply are related to electricity generation. But when the power is used by a third party, the emissions are categorised as scope 3.

Green air gases

The core process for making oxygen is cryogenic air separation. Ambient air is drawn into the process and pressurised using a large air compressor.

To serve an iron making plant equipped with a blast furnace and multiple basic oxygen furnaces, the air separation unit (ASU) may require an air compressor that continuously draws 20MW of power.



Air Separation Unit

Within the ASU, warm incoming air is cooled against cold air leaving the cryogenic core of the ASU. This cold air is fed to the base of a distillation column where it rises up through refluxed liquid air. The progressive contact between the rising air and the falling liquid separates oxygen and nitrogen due to vapour liquid equilibrium differences of these two gases.

Within the ASU, a stream of high pressure air is expanded across a high speed rotating turbine to cool it. Electrical power is recovered from the turbine to maximise the energy efficiency of the ASU. However, this amount power is not sufficient to drive the main air compressor.

To ensure that the oxygen and nitrogen separation takes place effectively, argon must be removed from the system with an additional distillation step. Argon is present in air at less than 1%, but it accumulates in the distillation columns and inhibits the separation of oxygen from nitrogen.

The recovered argon has many commercial applications, including stainless steel making. Sale of argon is important in the air separation business model to offset the cost of the power that is consumed to make oxygen and nitrogen.

Once the air is separated to yield oxygen, argon and nitrogen 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 drive the oxygen into the furnaces. An oxygen compressor with an additional power draw of around 10MW may be required.

To supply the air and oxygen compressors, renewable power generation from wind, solar any hydro-power is a clear alternative to using electricity generated from combustion of fossil fuels. Low-carbon nuclear power or biomass as a feedstock to thermal power generation can also be used.

With so many options open to produce green electricity, decarbonising the air separation unit may appear to be simple from a technological perspective. However, the challenge is related to assigning the green power production to the ASU, since the biomass-fired power plant or wind farm is unlikely to be adjacent to the gas compressors.

Power transmission over the grid will generally be required and a power-purchase-agreement (PPA) must be put in place to assign the appropriate quantity of green power to the ASU operator so that their oxygen and other air gases produced from the process can be certified as 'green'.

Green lime

Lime is used for slagging in the blast furnace to remove impurities in the ore. When lime is made offsite and sourced through the supply chain, carbon dioxide (CO2) emissions from the lime kiln are categorised as scope 3.

Other feedstocks procured for use at iron and making steel plants will also contribute to the overall scope 3 emissions.

Lime making results in geogenic CO2 emissions which are generated through baking calcium carbonate in the limestone ore (CaCO_3) to generate lime (CaO). The heat required to bake the limestone rock is also a source of CO2 emissions.

Heat for the lime kiln can be theoretically be decarbonised using biogas, biomass or biocarbon as a fuel source.

Alternatively, electrical heating could be used and a PPA put in place to ensure the consumed power is green. However, whilst these options may look good on paper, the reality is that a huge amount of heat is required.

The geogenic CO2 emissions from the lime baking chemistry are unavoidable. To mitigate these, CO2 capture equipment must be used. There is no alternative. This feeds back into the decision-making process for decarbonising the heat to the lime kiln.

The lime kiln burner flue gases are generally produced with the geogenic CO2

emission from the process. This offers the potential to capture CO₂ from the fuel combustion and heat generation alongside the unavoidable geogenic CO₂ emissions.

A similar situation arises in the cement industry, where CO₂ capture is being adopted as a decarbonisation solution on several plants.

The CO₂ concentration in the flue gas from the kiln is elevated beyond that of a typical combustion process since it also contains geogenic CO₂ from the lime making. This influences the technology selection for the CO₂ capture process.

Other factors that are key when considering the most appropriate CO₂ capture technology include the presence of moisture, oxygen and sulphur compounds in the flue gas and the pressure of the flue gas stream.

Liquid solvent-based CO₂ capture systems are being deployed for cement and lime making decarbonisation. The solvent is often an amine-type solution.

Liquid absorbents are sprayed onto a rising plume of flue gas and absorb CO₂ from the flue gas as the gas and liquid come into contact with each other. This process takes place in an absorber tower.

The CO₂-rich solvent is then pumped to a second tower called a stripper. At the base of the stripper heat is introduced to boil CO₂ out of the solvent. The regenerated CO₂-lean solvent is pumped back to the absorber tower and re-used to capture more CO₂.

The CO₂ from the top of the stripper is yielded as a high purity stream which is dried using cooling and condensation. The dry CO₂ can either be compressed to transmit it by pipeline to a sequestration scheme or liquefied for transportation by rail or ship to a CO₂ storage location.

Solid adsorbents are also penetrating this CO₂ capture application. These may be molecular sieves, solid amines or metal-organic-frameworks (MOFs). In this technique, CO₂ from the flue gas is chemically or physically adsorbed onto a bed of solid material at an elevated pressure.

The bed of adsorbent material is contained within a simple pressure vessel. A number of vessels containing adsorbents are connected in parallel with a manifold and change over valves to control the direction of gas flow. When the adsorbent material is saturated with CO₂, the flue gas is diverted to another bed of adsorbent.

The bed of adsorbent that is saturated with CO₂ is then depressurised. This pressure reduction, or pressure swing, causes the CO₂ to be desorbed. The adsorbent is regenerated through this process and the beds can then be switched again. The pressure swing (PSA), or vacuum swing (VSA) process alternates between adsorption and desorption over cycles that may last several minutes.

PSA and VSA systems are well known to the industrial gases sector for small- to mid-scale oxygen production. The adsorbent material used for oxygen production is different to that which is used for CO₂ capture, but the process and equipment are similar. Analogous to this CO₂ capture application, they generate oxygen at a lower purity than the oxygen produced on an ASU.

The CO₂ released from the PSA or VSA system is typically less pure than that from a liquid solvent process. However, it can generally be recovered at 95% purity or more and will be suitable for compression and pipeline transmission or can be fed to a CO₂ liquefier.
