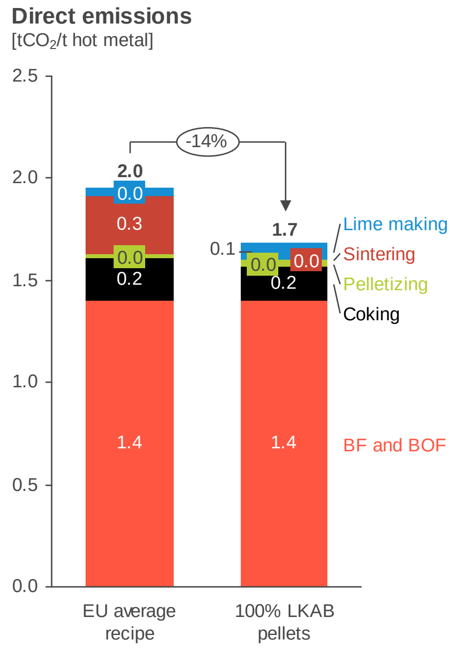
100% LKAB pellet steel vs. average European primary steel

Methodological appendix

Steel made with 100% LKAB pellets leads to a 14% reduction of CO_2 emissions compared to average European primary steel

Steel made with 100% magnetite-based LKAB pellets results in 14% less CO_2 emissions across the supply chain compared to the average European primary steel plant, which typically uses a blend of sinter and pellets. With LKAB's 2015 production of 22 Mt, this represents an emission reduction of 4.6 $MtCO_2$ in Europe; over 7 times LKAB's direct emissions from pelletizing.

This conclusion is based on a high-level calculation made by Ecofys in 2016. This document provides the details of the calculation underlying this statement.



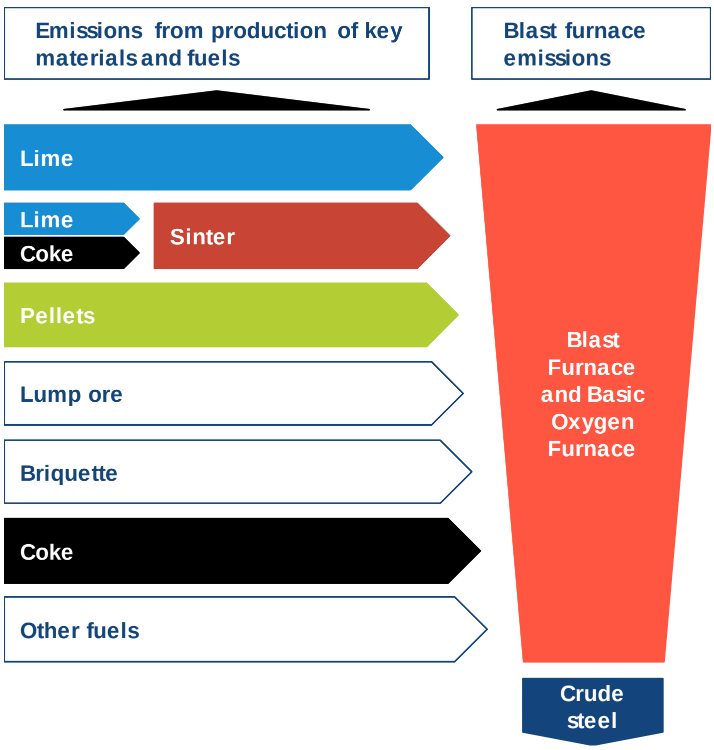
Source: Ecofys blast furnace model analysis

A blast furnace model was used to model the key inputs and outputs

We compared steel produced in blast furnaces (BF) with different mixes of inputs using our BF model.

The BF model calculates how different BF recipes result in different emissions per unit of output (i.e. hot metal, the intermediate product between the BF and the Basic Oxygen Furnace—BOF).

The key inputs (i.e. materials and fuels that are used in a BF) are indicated in the diagram. The lump ore, briquette, and other fuels are excluded since they are typically not produced on-site.



Two blast furnace recipes were modelled: the average EU recipe and a recipe with 100% LKAB pellets as the iron burden.

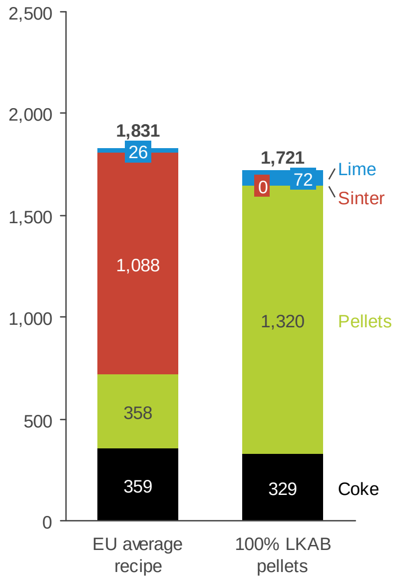
We compared two recipes to produce crude steel: the average EU recipe and a recipe with 100% LKAB pellets as the iron burden.

The BF recipes are displayed in the chart on the right.

The **EU average recipe** is based on the average values presented in the European Commission's Best Available Techniques (BAT) Reference Document for Iron and Steel Production[i] (or BREF document). Table 6.1 of this document gives input figures taken from many BFs, giving a representative picture of modern plants. The weighted average numbers were used in our EU average recipe.

The BF model takes into account the additional lime and coke needed for producing sinter. Table 3.2 in the BREF document provides the inputs needed for sinter production. The main carbon intensive inputs are lime and coke. The coke input was converted from MJ/t sinter to kg/t sinter by assuming 29 GJ/t coke based on the range of 28 to 31 GJ/t higher heating value found in literature.[ii] As a result, additional lime and coke is added to the EU average recipe.

Blast furnace recipe
[input in kg material per t hot metal output]



Source: EC BREF, Hooey et al. & Ecofys analysis

Source: EC BREF

The **100% magnetite-based pellets** recipe is based on the "Nordic pellets" scenario presented by Hooey et al.[iii] The pellet consumption in this recipe (i.e. 1,320 kg/t hot metal) was retrieved from Table 3 of Hooey et al. (2014). Additional lime input compared to the EU average was calculated by assuming a constant ratio of lime needed per tonne slag (i.e. 410 kg lime/t slag). This constant ratio is based on combining Table 3 and Table 4 of Hooey et al. (2014). The coke input was assumed to be 329 kg coke/t hot metal, based on an estimation by LKAB's blast furnace experts. Coal input is assumed to be the same as in the EU average recipe.

Emission factors per process were used to calculate the total value chain emissions from the total material requirements

Process	Unit	Value	Source
Lime making	kg CO_2/t lime	1,099	EC (2013b) Average of range for Parallel Flow Regenerative Kilns (which are typically used in the steel sector).[iv]
Coking	kg CO_2/t coke	510	EC (2013a) Average of range.
Sintering	kg CO_2/t sinter	265	EC (2013a) Average of range.
Pelletizing, EU average	kg CO_2/t pellets	57	JRC (2012)[v]
Pelletizing, LKAB average	kg CO_2/t pellets	28	LKAB (2016)[vi]
Blast furnace	kg CO_2/t hot metal	1,219	JRC (2012)

The enabling effect is calculated for LKAB's total production

The difference in emissions per tonne hot metal between the EU average recipe and the 100% LKAB pellets recipe is divided by the amount of pellets required per tonne hot metal to calculate the amount of emissions reduced per tonne pellets. Subsequently, this is multiplied with LKAB's 2015 production (i.e. 22 Mt)[VI] to calculate the total emission reduction from LKAB pellets of 4.6 MtCO_2—over 7 times larger than LKAB's direct emissions from pelletisation (i.e. 0.6 MtCO_2).[VI]

---

[i] EC (2013a) Rainer Remus, Miguel A. Aguado-Monsonet. Serge Roudier, Luis Delgado Sancho. Best Available Techniques (BAT) Reference Document for Iron and Steel Production. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control).

[ii] The Engineering Toolbox (2016) website, Available at: www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html

[iii] Hooey et al. (2014) Lawrence Hooey, Johan Riesbeck, Jan-Olov Wikström, Bo Björkman. Role of Ferrous Raw Materials in the Energy Efficiency of Integrated Steelmaking. ISIJ International, Vol. 54, No. 3, pp. 596–604.

[iv] EC (2013b) Frauke Schorcht, Ioanna Kourti,Bianca Maria Scalet, Serge Roudier,Luis Delgado Sancho. Best Available Techniques (BAT) Reference Document for the Production of Cement, Lime and Magnesium Oxide. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control).

[v] JRC (2012) N. Pardo, J.A. Moya, K. Vatopoulos. Prospective Scenarios on Energy Efficiency and CO2 Emissions in the EU Iron & Steel Industry.

[vi] LKAB (2016) Peter Kihlangi. Verification report of LKAB EU ETS reporting for 2015.