Comparing the CO_2 Emissions of Different Ironmaking Routes

7th European Coke and Ironmaking Congress – ECIC 2016

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Introduction
2015 Paris Agreement

The **climate change** represents an **urgent and potentially irreversible threat** to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions.

Deep reductions in global emissions will be required in order to achieve the ultimate objective of the Convention and emphasizing the need for urgency in addressing climate change.

The conference of the parties notes with concern that the estimated aggregate greenhouse gas emission levels in 2025 and 2030 resulting from the intended nationally determined contributions do not fall within least-cost 2˚C scenarios but rather lead to a projected level of 55 gigatonnes in 2030, and also notes that

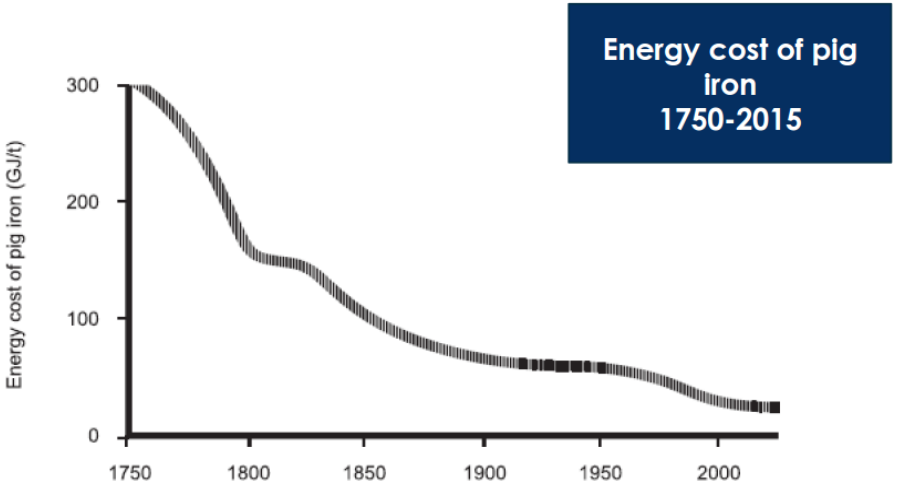
much greater emission reduction efforts will be required than those associated with the intended nationally determined contributions in order to hold the increase in the global average temperature to below 2˚C above pre-industrial levels by reducing emissions to 40 gigatonnes or to 1.5˚C above pre-industrial levels by reducing to a level to be identified in the special report referred to in paragraph 21 below.

ADOPTION OF THE PARIS AGREEMENT

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Diminishing Returns from Efficiency

- Steel industry's **long-term record of improved efficiency** (reduced emissions) is excellent, matching or surpassing that of other key industrial conversions
- **Further efficiency gains** are possible but are relatively **limited**, and the greatest reward should come from changes in the use of steel products
- Global nature of GHG effects requires a **system-wide approach** to solutions and **other sectors offer far greater and less expensive reductions**



GHG Source	Global CO_2 Share	Potential for reductions
Iron and steel industry	8%	< 10%
Agriculture	14%	> 20%
Transportation	20%	> 30%
Electricity generation	30%	> 30%

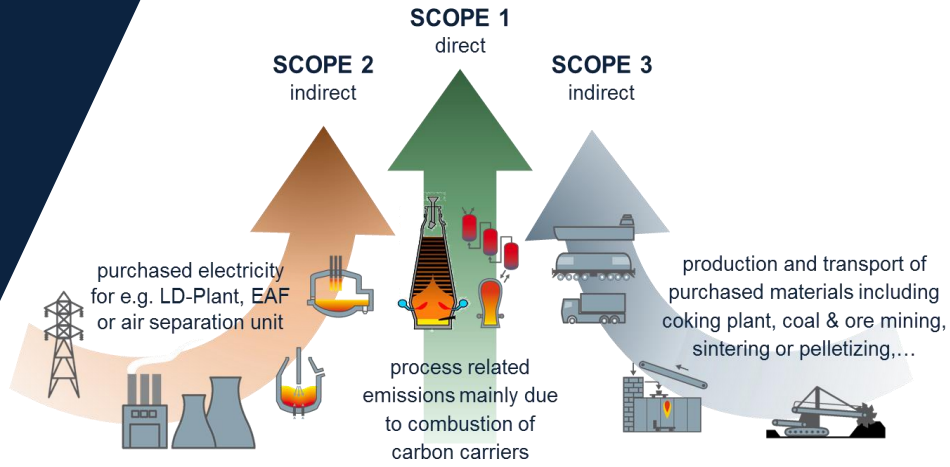
V. Smil, ICEF Forum 2015

Definition of Emission Scopes according to Greenhouse Gas Protocol

Scope 1: All **direct GHG emissions**

Scope 2: **Indirect GHG emissions** from consumption of purchased electricity, heat or steam.

Scope 3: **Other indirect emissions**, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. T&D losses) not covered in Scope 2, outsourced activities, waste disposal, etc.



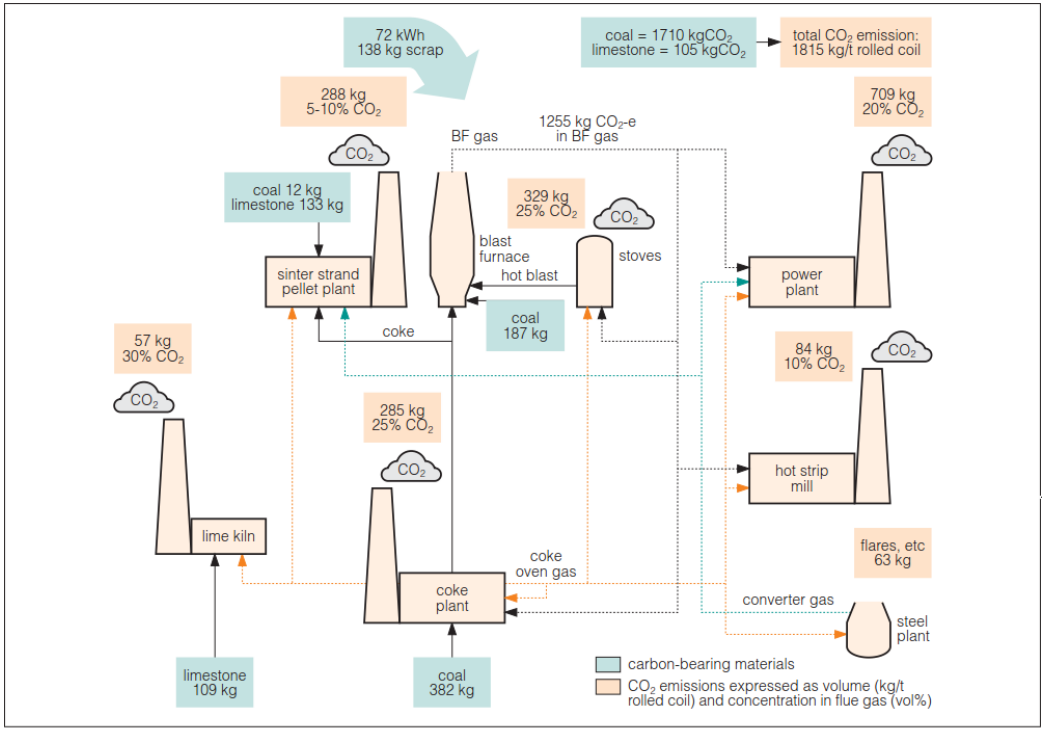
Emission Values for Grid Electricity

country	kg CO_2 / kWh	country	kg CO_2 / kWh	country	kg CO_2 / kWh
Norway	0.002	Argentina	0.392	World	0.624
Sweden	0.023	Italy	0.411	Iran	0.631
France	0.071	Japan	0.443	Germany	0.672
Brazil	0.093	OECD Europe	0.452	Indonesia	0.685
Austria	0.177	South Korea	0.504	China	0.973
Canada	0.180	United Kingdom	0.509	South Africa	1.069
Venezuela	0.208	Russia	0.513	Bulgaria	1.166
Spain	0.343	USA	0.547	India	1.333

Specific emission values for grid electricity, excluding heat generation (M. Brandner, A. Sood, C. Wylie, A. Haughton, J. Lovell, “Electricity-specific emission factors for grid electricity”, ecometrica (2011))

For many countries there is a significant difference between the composite electricity/heat factors published by the IEA and electricity-specific factors. It is important to use electricity-specific factors so that the emissions from electricity are not over or under-estimated within corporate GHG accounts.

CO_2 Calculations – Definition of Borders



CO_2 emissions from a typical steel mill

fair comparison of different ironmaking routes can only be achieved if the same basis is used for all calculations:

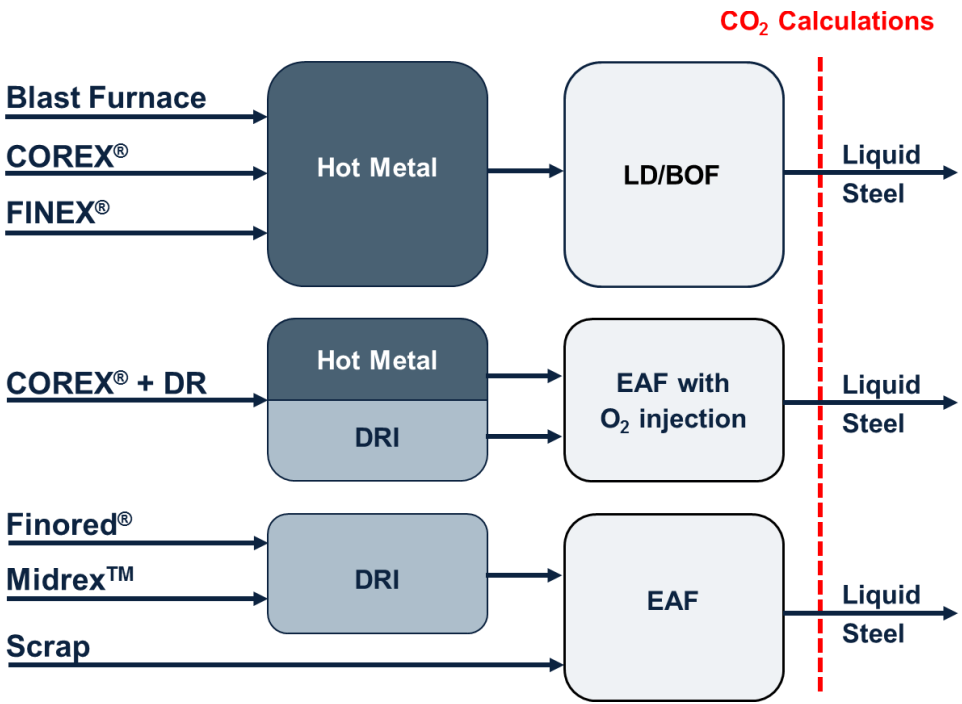
defined inclusion of scope 1, 2 and or 3 in the calculations

use of accurate emission values for grid electricity

comparable
- Raw materials (ore, coal, additives)
- Products (liquid steel, top gas)

Image Source:
CO_2 abatement in the iron and steel industry
IEA Clean Coal Center No. 12/1 (2012)

CO_2 Calculations – Definition of Routes



BF, Smelting Reduction:

- Blast Furnace
- COREX®
- FINEX®

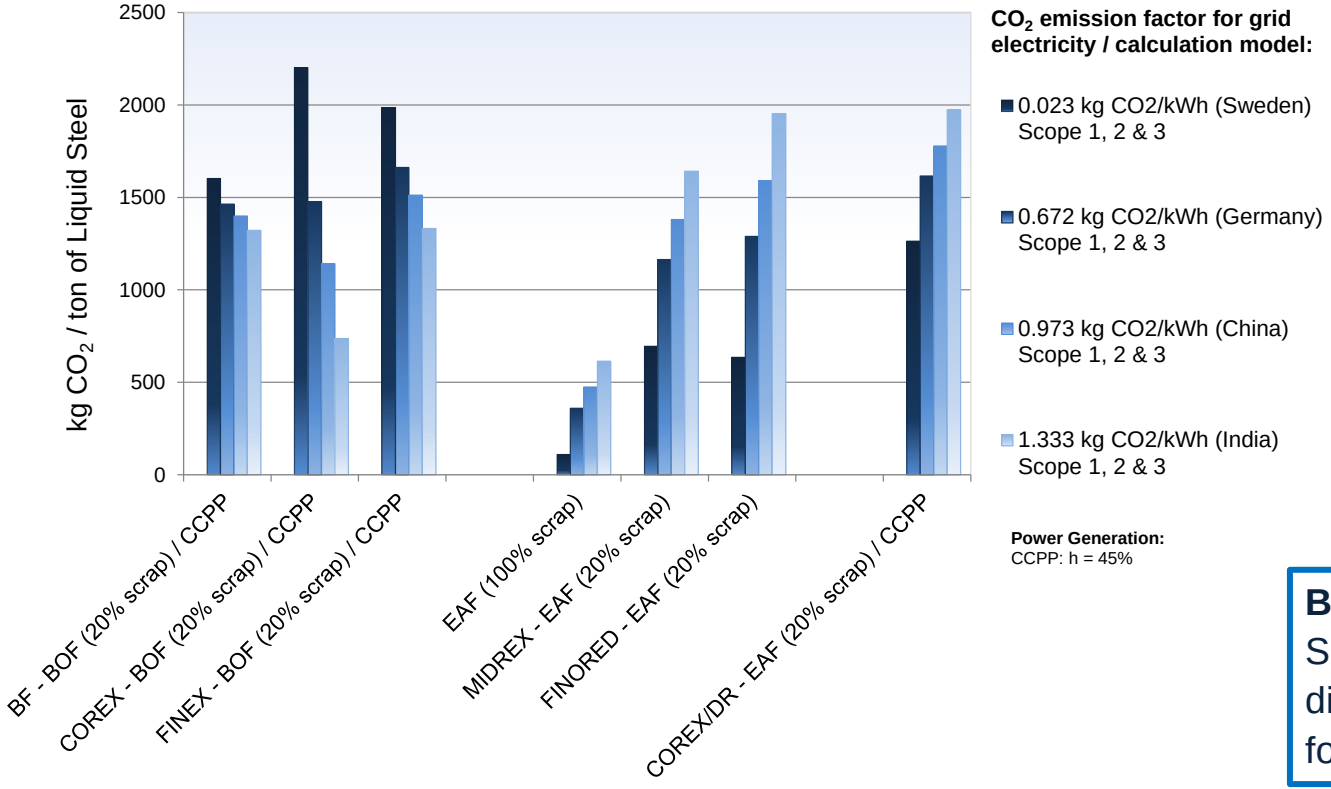
Direct Reduction

- COREX® gas based Midrex™ plant
- Finored®
- Midrex™

Electric Steel

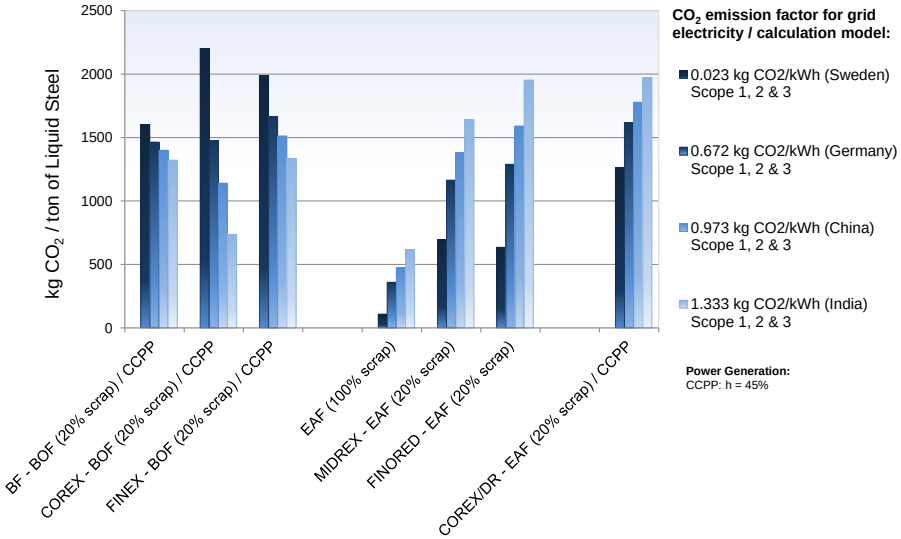
- 100% Scrap in EAF

CO_2 Calculations – Results



Base Cases:
Scope 1, 2 and 3 included different emission factors for different countries

CO_2 Calculations – Results

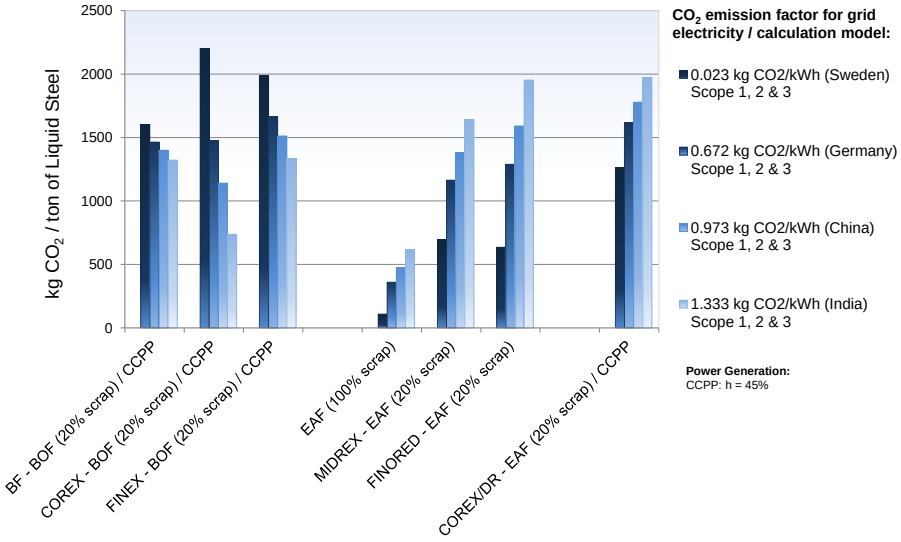


- **Smelting reduction processes** (blast furnace, COREX® and FINEX®) utilize coke and coal. Carbon is the primary energy source and reductant, leading to **CO and CO_2 as the main gas emission**

- Production routes based on the use of **natural gas** (with carbon and hydrogen as reductants) are **advantageous** compared to production routes based on coal

- The **most favourable conditions** when it comes to CO_2 emission are achieved by the **scrap + EAF** route, but this is limited due to the availability of high-quality scrap necessary for high-quality steel (+ less reduction work compared to iron ore as raw material)

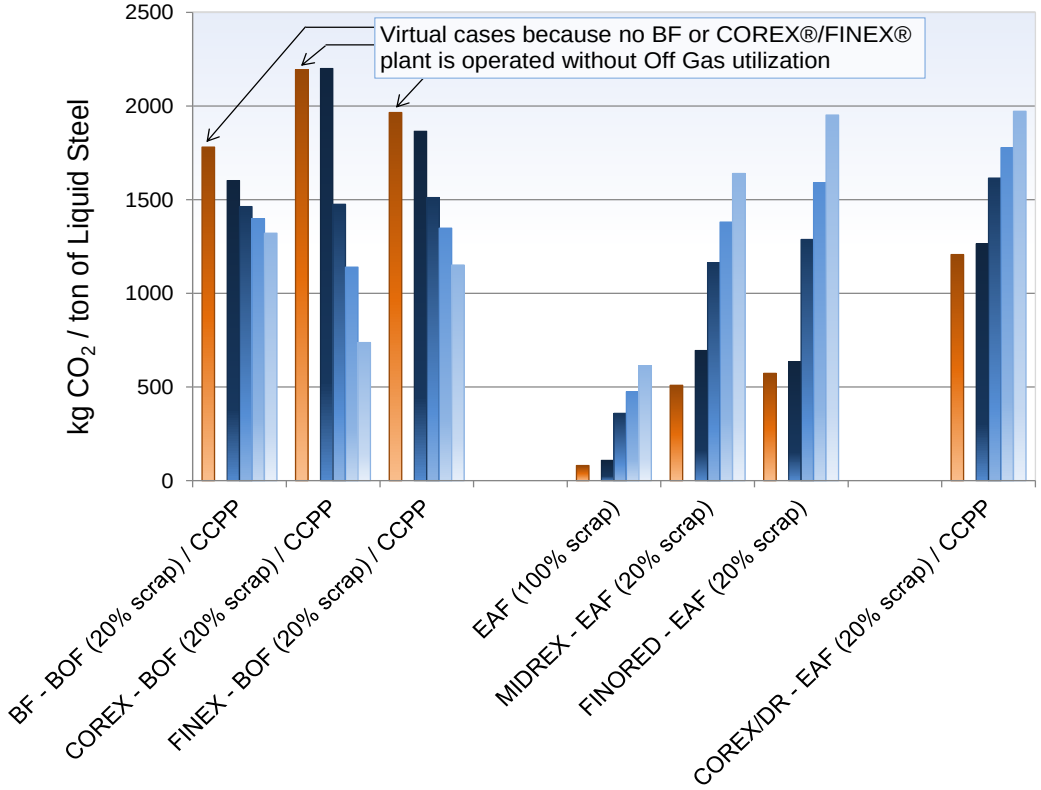
CO_2 Calculations – Results



- Strong dependency of the results on the nation-wide specific CO_2 emission value for the generation of electric power.
- Countries with **high CO_2 emission values**: **smelting reduction** technologies advantageous (no EAF required)
- Countries with **low CO_2 emission values**: **direct reduction routes** with EAF advantageous
- **combined Corex®+DR plant** (utilization of Corex® Export gas for DRI production, low CO_2 emission for electric steelmaking) if natural gas is limited

  Corex®+Midrex™ combination plants successfully implemented at ArcelorMittal South Africa, Saldanha Steel Works, South Africa and Jindal South West Steel, India

CO_2 Calculations – Results



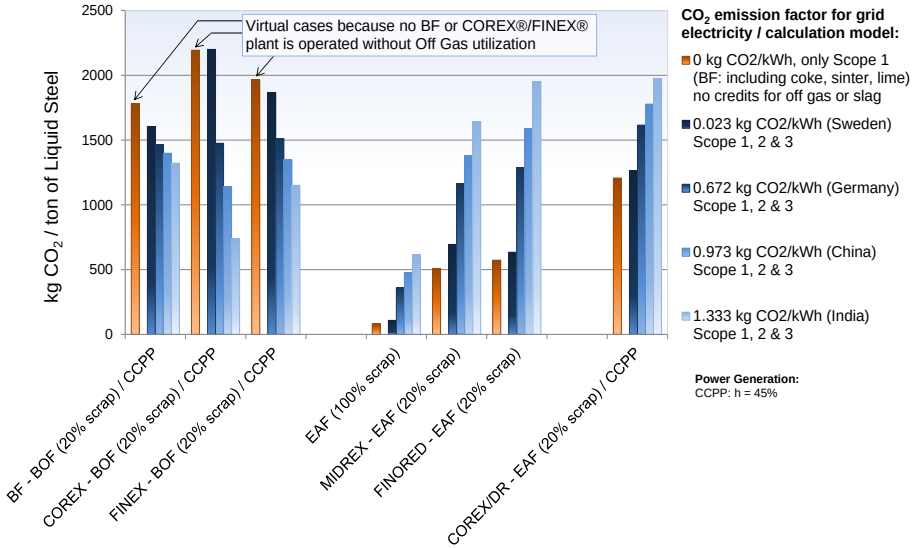
CO_2 emission factor for grid electricity / calculation model:

- 0 kg CO2/kWh, only Scope 1 (BF: including coke, sinter, lime) no credits for off gas or slag
- 0.023 kg CO2/kWh (Sweden) Scope 1, 2 & 3
- 0.672 kg CO2/kWh (Germany) Scope 1, 2 & 3
- 0.973 kg CO2/kWh (China) Scope 1, 2 & 3
- 1.333 kg CO2/kWh (India) Scope 1, 2 & 3

Power Generation:
CCPP: h = 45%

operator specific model:
only Scope 1
(BF: including coke, sinter, lime)
No credits for off gas or slag

CO_2 Calculations – Results



- Omitting Scope 2 and 3 in the calculations gives results rather similar to those of Sweden (country with low CO_2 emission value for grid electricity)
- In this case of very low CO_2 emissions caused by electricity production, the **blast furnace is the most advantageous** route in smelting reduction processes (virtual case – no BF or Corex® or Finex® plant is operated without off gas utilization!)
- **Direct reduction routes benefit** from low CO_2 emission values (but only feasible if natural gas is available at low cost)
- if natural gas is limited: combined Corex®+DR plant excellent alternative to blast furnace for producing steel at low CO_2 emissions

Conclusions

- Depending on the local site conditions and especially the specific CO_2 emission value for the generation of electric power, the **COREX® and FINEX® Process offer significant potential for achieving low greenhouse gas emission figures**.

- Although the **direct reduction + EAF routes benefit most from low emission values**, they are only economically feasible if sufficient amounts of low-cost natural gas are available at a reasonable cost.

- If the latter is not the case, the **combined COREX®+DR plant is an excellent alternative for producing steel at much lower CO_2 emissions** than the blast furnace or other smelting reduction technologies.

Outlook

Calculations have been carried out for different systems under comparable conditions

Alternative process routes in Ironmaking:

- Usage of HBI in blast furnace
- H_2 injection
- COG injection

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THANK YOU