Decarbonization Journey for Mini Steel Mills with Linde's established technologies

Making our world

Presentation Contents

- Mini Steel Mill: Current carbon footprint status
- Decarbonization journey
- Immediate or Short-term measures (Linde's oxyfuel solutions)
- REBOX for reheating furnace, OXYGON for Ladle preheating & COJET in EAF
- Long term measures (Hydrogen base combustion)

Flat Steel Mills : Current CO_2 emissions status

BF route Steel Plants

Only Scope-1 emissions included

CO_2 for Electric Energy consumption is not included

200 Kg of CO_2 /ton of

EAF

140

Kg of CO_2/ton of steel

Ladle preheating

10-15

Kg of CO_2/ton of steel

Reheating Furnace

40-60

Kg of CO_2/ton of steel

Mini Steel Mills : Current CO_2 emissions status

It is less when seen as specific emissions per ton of Steel produced

It is very tiny when compared with BF-BOF route steel making

However, the absolute number for mini mill producing 2 Million tons of steel per annum is very large

For environment the pertinent thing matters is absolute emissions of CO_2

Decarbonization Journey

Linde

Car | Carbon Free

Immediate

Increased Energy-efficiency

If energy consumption in the level of top 15% is achieved by every steel mill there will be [illegible] 19% [illegible]

Short & Mid-Term

Use of oxyfuel technologies

Carbon Capture

Low-carbon fuels

Oxyfuel technologies can bring down CO_2 [illegible]

Long-Term

Full use of hydrogen as a fuel

The transition to a low-carbon world requires a transformation in the way we manufacture iron and steel. There is no single solution to CO_2-free steelmaking, and a broad portfolio of technological options is required, to be deployed alone, or in combination as local circumstances permit. – World Steel Org

Linde's best technologies in Mini-Steel Mills

- Coherent Jet
- Higher Productivity
- Higher Yields
- Savings in Power, Electrode and carbon
- More efficient chemical Energy injecti
- Elimin lance
- Cost in Electri Arc Furnace

CO2 reduction potential 3-10%

- Flameless Oxyfuel technology
- Fuel Savings greater than 50%
- Faster heating & higher lining temperature
- Ul
- S

CO2 reduction potential 5-10%

- HLL –Semi flameless technology
- Fuel Savings greater than 20%
- Add on system , no change in existing combustion syst
- Lo
- In eff nd productivity

CO2 reduction potential 20-30%

Already established

Lead time of 4-7 months

Economically viable for operating cost

Other benefits can Pay for CAPEX

Melt Shop

Rolling Mill

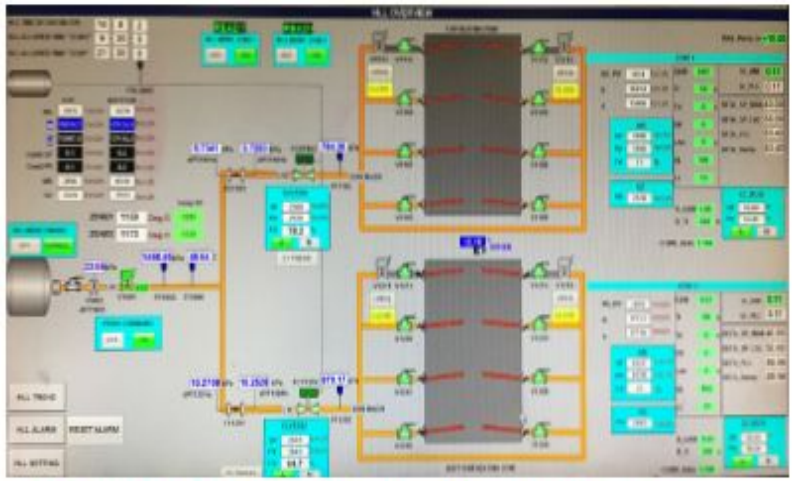
REBOX HLL: Benefits

Applicability: Continuous reheating furnace

Add –on Installation

Operation s Benefits

- Reduced flue gas volume
- Quick responsive system
- Lower CO_2 and NO_x emissions
- Improved [illegible]



Process Benefits

- Increased productivity + 10-20%
- Lower fuel consumption -20%
- Lower scale

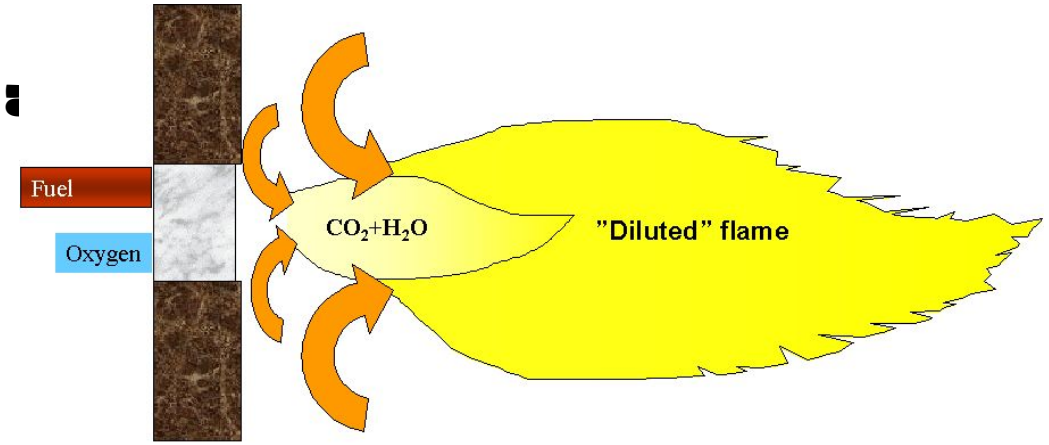
User Friendly Safe Automatic

REBOX Flameless oxyfuel

Applicability: Batch type reheating furnace

Dilution by recirculation of flue gases

Separation of fuel : oxidant

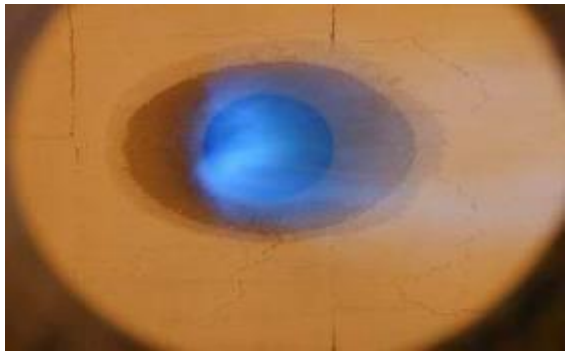


$$CH_4 + 2O_2 + \text{Hot Flue gas} \Rightarrow CO_2 + 2H_2O + \text{Heat}$$

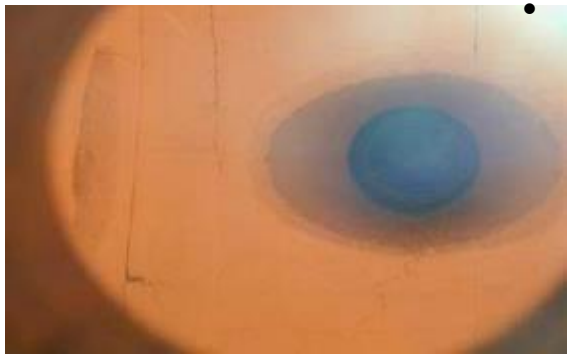
Benefits

- **Fuel consumption lowered by 30-50%**
- **Capacity increase by 20-50%**
- **Lower CO_2 and NO_x emissions**

Conventional oxyfuel



Transition stages



Flameless Oxyfuel

OXYCOR® Flameless Oxyfuel Ladle Preheating

- Faster heating providing shorter heating cycles for less ladles in circulation
- 75-80% reduced flue gases due to less fuel and no nitrogen in combustion
- Up to 60% lower fuel consumption and CO_2 emissions
- More homogeneous heat distribution and improved temperature uniformity in the ladle
- Possibility to reach very high pre-heating temperatures when wanted (e.g., 1300°C)
- Ultra low NO_x emissions
- Very safe as designed with flame supervision, pilot burner and ROC-OXYCOR® unit
- PLC installations reliable and

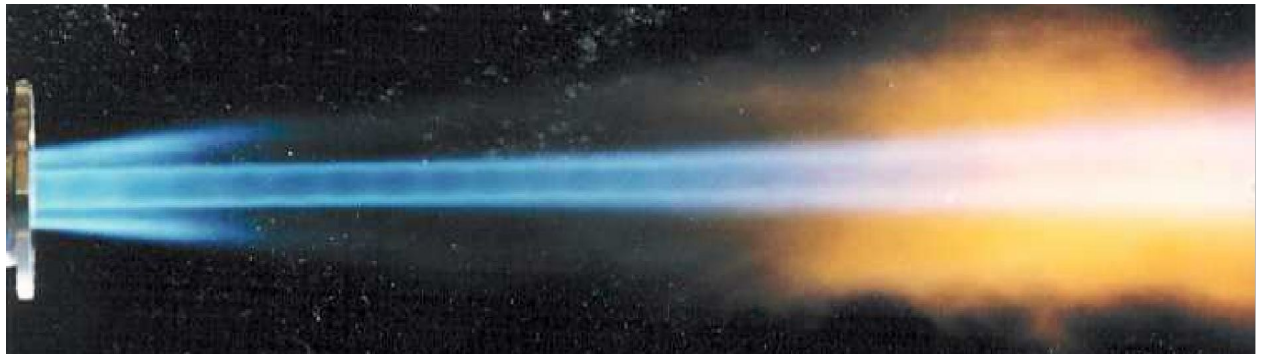
Technology

Revolutionized Electric Arc Furnace Steelmaking since 1996

Industry standard for chemical energy input into EAFs

Multi-point injection around the furnace

175+ installations



- Efficient use of oxygen up to 55 Nm^3/t
- Flexibility of charge materials and scrap melting/flat bath operation
  - Scrap
  - Hot metal
  - DRI
- Higher productivity (up to 50%)
- Power savings (up to 20% or

Widely Adopted, Step Change Technology for Mini-mills

Economics
Oxyfuel is a Prerequisite for Hydrogen Combustion

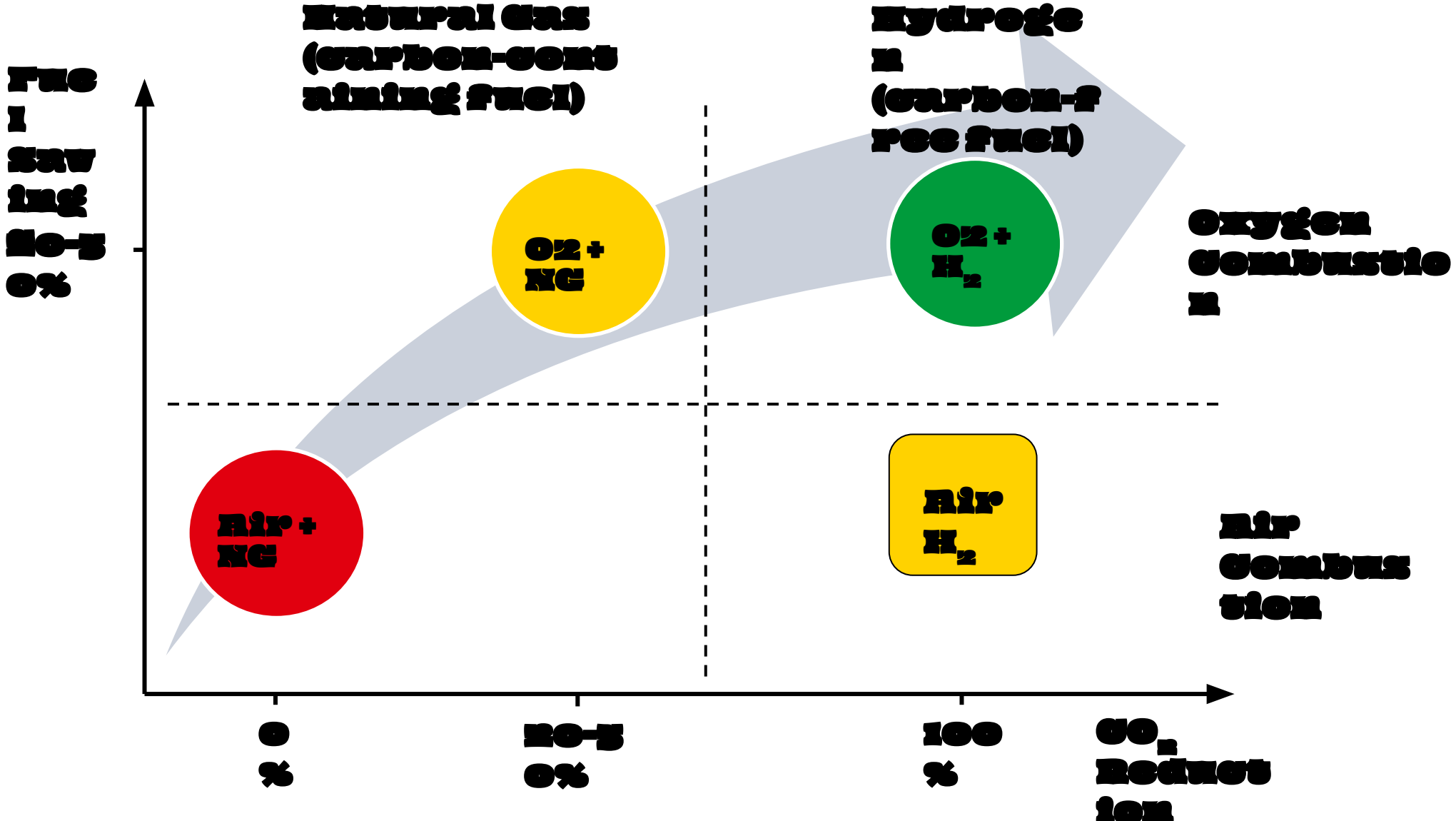
Hydrogen will be an expensive fuel

- **Lowest anticipated cost of H_2 = $2/kg**
- **Equivalent to ~$15/GJ ($15/MM BTU)**

Oxyfuel combustion will be economically necessary with H_2 fuel

Air-fuel ⇨ **Oxy-fuel w/ CO2 Savings** ⇨ **Oxyfuel w/ H_2 Decarbonization**

Route to Decarbonize Industrial Heating Operations

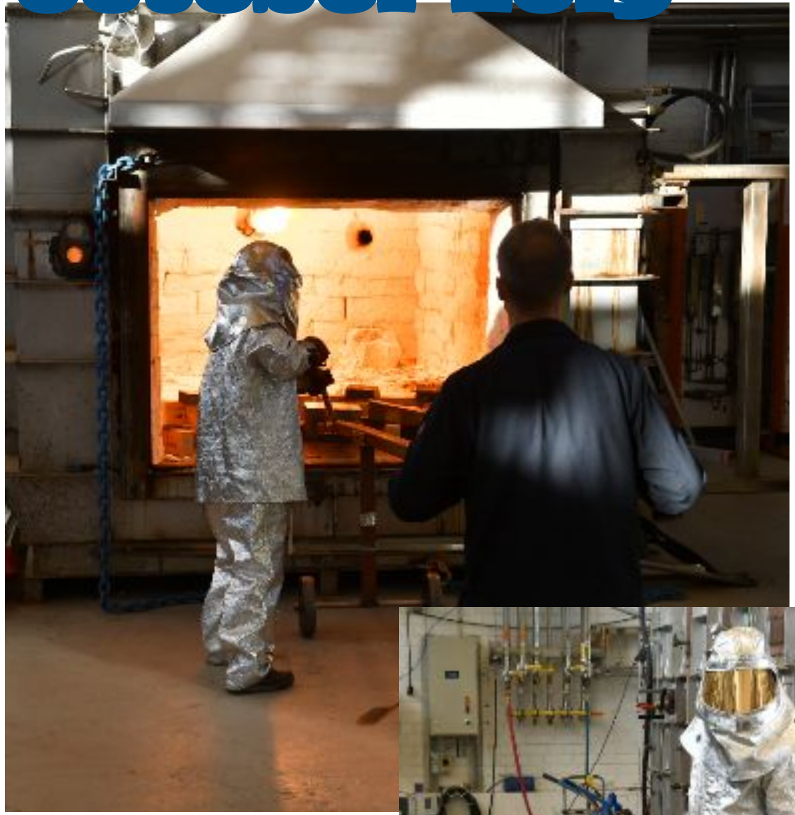


Trials in Spring 2019
Linde Technology Centre Munich

Open air firing of 300 kW oxyfuel burner

High concentration of water vapour creates infrared radiation

Steel Reheating Tests with REBOX® Hyox
Linde Technology Centre Stockholm, October 2019



Material tested from four steel companies, including engineering steel and

World's First Fossil Free Heated Steel

Ovako Steel, Hofors, Sweden
18th of March 2020

25 tons of ball bearing steel heated with Flameless Oxyfuel using 100% Hydrogen as fuel

Both Hydrogen and Oxygen produced with Electricity from Renewable Energy sources

Full-scale permanent installation planned for 2025 in Soaking Pit Furnaces

Saving 80,000 t CO_2 annually

Decarbonization Journey Map

Hydrogen Steelmaking

Long Term

CO_2 Capture

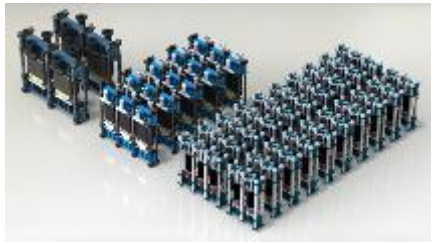
Low Carbon Fuels

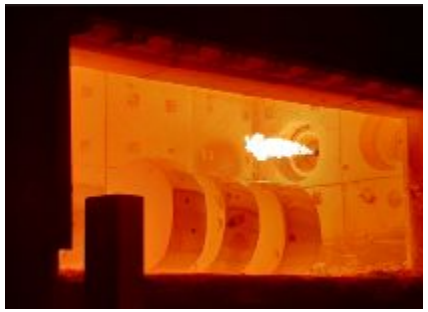
Oxyfuel Combustion

Lowering of NOx+ 30-50%

Efficiency Improvement

Term





Thank you for your attention

Gajanan Doijad

Sr. Technology Expert (Metals & Glass)

Application Technologies

Linde Plc

Please contact for any further questions, information or enquiry

gajanan.doijad@linde.com

+6[illegible]4747