# Enhanced Energy Efficient Steel Production – **E³-SteP**

October 2019

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**E³-SteP**

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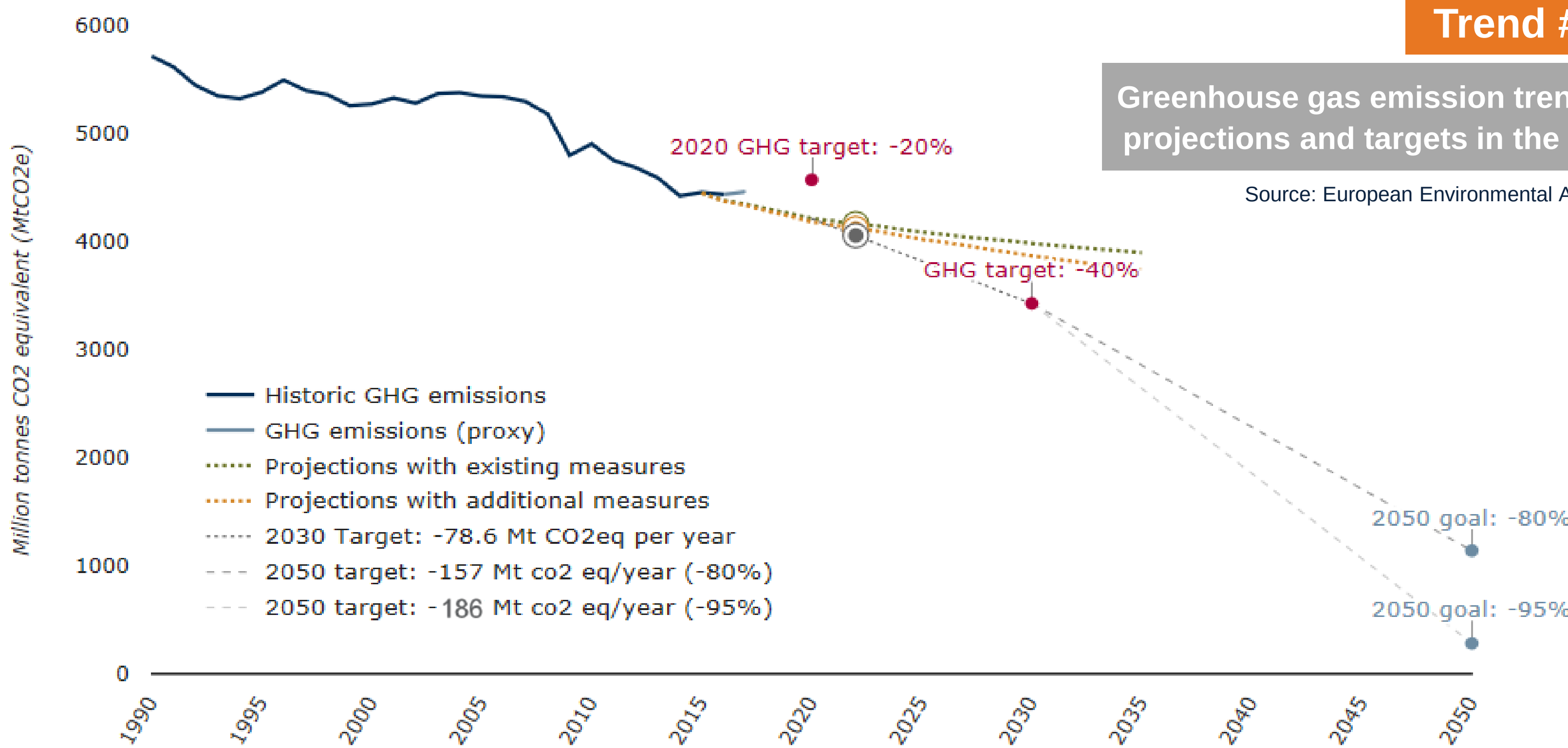
# E³-SteP

## 1 - Main industrial trends (1/2)




**Trend #1**

**Greenhouse gas emission trends, projections and targets in the EU**

Source: European Environmental Agency

**!**

**Challenge:**

Global trend to **reduce $CO_2$ emissions** in steelmaking processes

**Solution:**

Direct reduction route **using natural gas or hydrogen**

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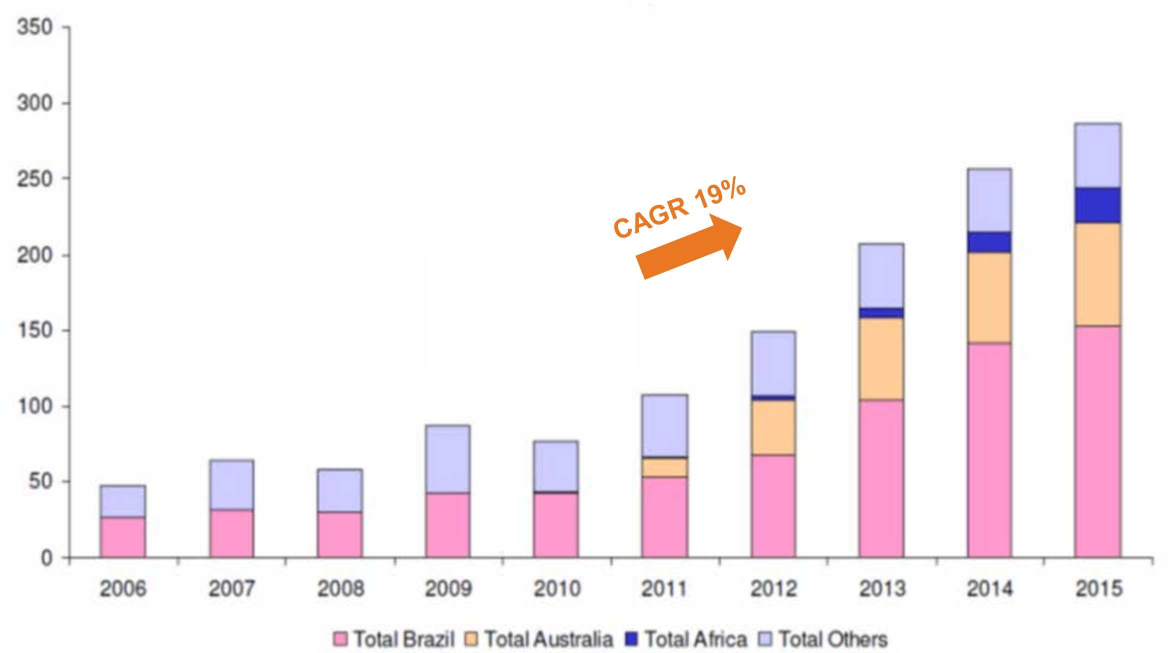
# 1 - Main industrial trends (2/2)




**Trend #2**

**Global Ultrafine Supply (Mt/a)**

Source: Hatch Beddows

!

## Challenge:

Increased demand for iron ore pellets by Blast Furnaces/Direct Reduction plants lead to an **increased price for iron ore** and **especially pellet premium**

✓

## Solution:

Direct use of pellet feed fine ore material → **Enhanced Energy Efficient Steel Production – E³-SteP**

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## $CO_2$ Emissions for Steel Making based on different Reductants (kg $CO_2$ / t liquid steel)

**1,765 *)** kg $CO_2$ / t liquid steel

**940** kg $CO_2$ / t liquid steel — **- 47%** $CO_2$ emissions

**437** kg $CO_2$ / t liquid steel — **- 75%** $CO_2$ emissions

| Reductant | Route |
|---|---|
| Coke/coal based | **BF and BOF route** (80% hot metal and 20% scrap in BOF) |
| Natural gas based | **DR and EAF route** (80% hot DRI and 20% scrap in EAF) |
| Hydrogen based | **DR and EAF route** (80% hot DRI and 20% scrap in EAF) |

***Note:***
**) based on a calculation model for an average modern blast furnace with 2.5 MTPY capacity and PCI injection; Location - OECD Europe*
*$CO_2$ emission factor for grid/calculation model: 0.452 kg $CO_2$ / kWh*

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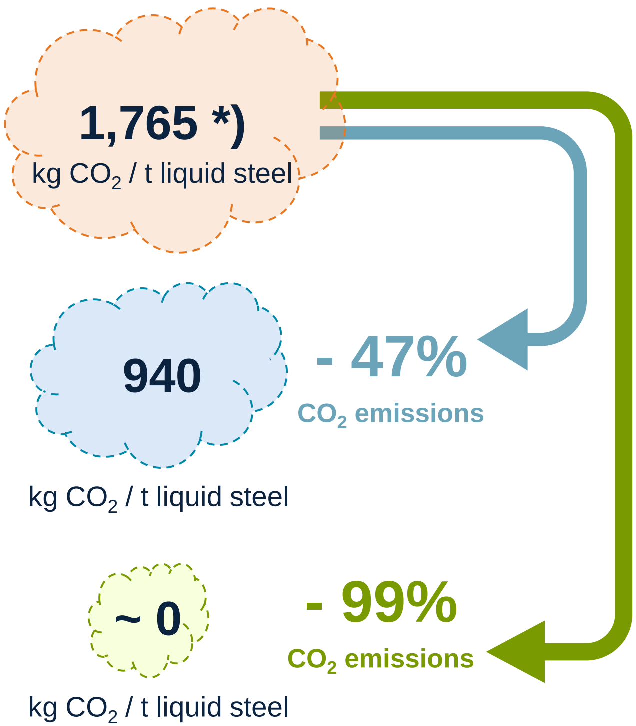
# $CO_2$ Emissions for Steel Making based on different Reductants (kg $CO_2$ / t liquid steel)




| Reductant | Route |
|---|---|
| Coke/coal based | **BF and BOF route** (80% hot metal and 20% scrap in BOF) |
| Natural gas based | **DR and EAF route** (80% hot DRI and 20% scrap in EAF) |
| Hydrogen based | **DR and EAF route** (Hydrogen, Electricity, Carbon & Heating Source incl. transport without CO2 load) |

***Note:***
**) based on a calculation model for an average modern blast furnace with 2.5 MTPY capacity and PCI injection Location - OECD Europe*

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## 2 - $CO_2$ Emissions (3/3)

**Raw steel production - $CO_2$ emissions**

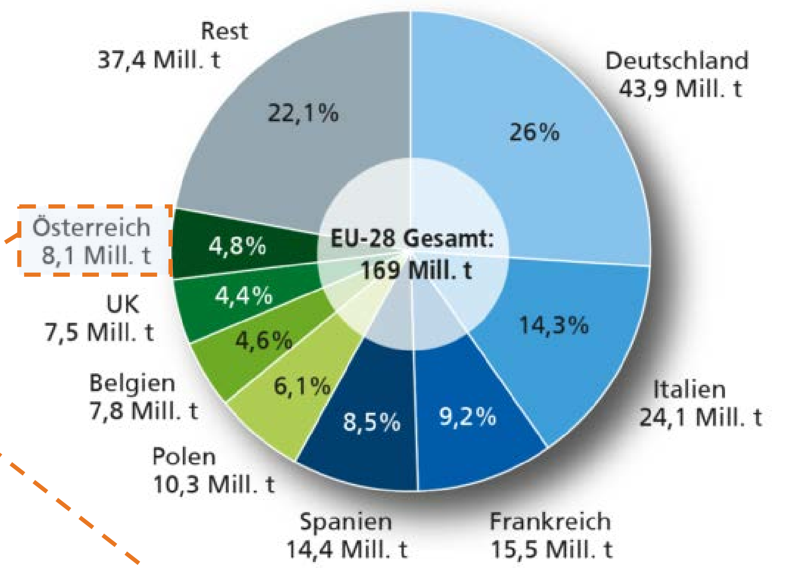
**2500**

**Mio. t $CO_2$/a worldwide**

**12**

**Mio. t $CO_2$/a in Austria**

**EU28: Raw steel production 2018**




Quelle: Eurofer, European Steel in Figures 2018

**Linz/Donawitz raw steel production**

**100**

**% BF / BOF**

| Standort | Menge $10^6$ $t_{RS}$ | spez. $CO_2$-Emissionen kg $t_{RS}$ |
|---|---|---|
| Linz | 5,260 | 1.654 |
| Donawitz | 1,610 | 1.824 |
| EAF (gesamt) | 0,708 | 126 |
| Österreich | 7,578 | 1.557 |

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# E³-SteP
## 3 – Future scenarios (1/2)

**2018**

**12**

**Mio. t $CO_2$/a in Austria**

**8,1 Mio. t raw steel/a**

**Natural Gas Based DR/EAF Route**

**20xx**

**6,25**

**Mio. t $CO_2$/a in Austria**

$CO_2$ emission factor for grid/calculation model: 0.177 kg $CO_2$ / kWh (Austria)

**Add. Electric Power**
**510 MW for EAF&DR !**

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**8,1 Mio. t raw steel/a**

**Green Hydrogen Based DR/EAF Route**

**20xx**

**< 1**

**Mio. t $CO_2$/a in Austria**

CO2 emission factor for grid/calculation model: <0,03 kg CO2 / kWh

**Add. Electric Power**
**2.9 GW for $H_2$**
**510 MW for EAF&DR !**

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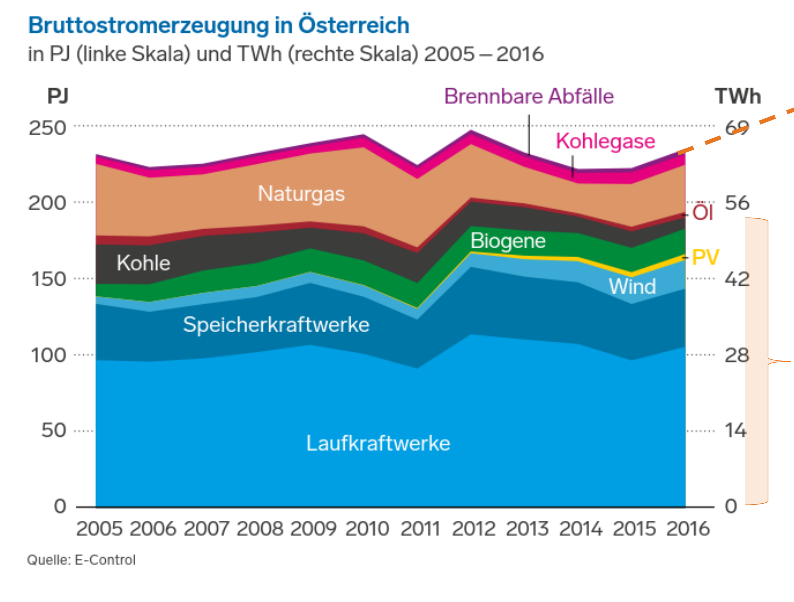
# 3 - Future scenarios (2/2)




**Actual situation in Austria**

**67 TWh**
**Electricity production**

**~ 8 GW @ 8640h**
**Electricity production**

**~ 78 %**
**Renewable energy**

**21,3 GW**
**Installed Electrical Power**

**Green Hydrogen Based DR/EAF Route Additional Electric Power:**
2.9 GW for $H_2$
510 MW for EAF&DR

**Future situation for this scenario:**

**~30 TWh** !
Additional renewable energy demand

$CO_2$ emission factor for grid/calculation model: <0,03 kg $CO_2$ / kWh

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# E³-SteP
## 4 – Challenges for the Future

! Development and implementation of **technologies and infrastructure** for **production and distribution of additional renewable energy**

! Innovation and development of **industrial scale hydrogen production technologies** from renewable energy (e.g. PEM, SoC)

! **Sufficient and secure supply of hydrogen** for steel works

! Initiative to develop **innovative, disruptive technologies** for steelmaking with hydrogen

**E³-SteP**

***From lab scale** via* → ***pilot plant** to* → ***industrial scale***

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Vast experience and know-how in fluidized bed processes by Primetals Technologies as well as usage of hydrogen, enabled the **development of the next generation DR process**.

### FINORED (FINMET)

- Fluidized bed reduction technology
- **Hematite sinter fines** (0.06 – 8 mm) with a high Fe-content
- **Utilizes hydrogen rich reducing gas** ($H_2$/CO ration of > 6)
- 2 reference plants: Orinoco Iron and BHP (each 2.0 MTPY)

### FINEX

- Fluidized bed reduction technology
- **Hematite sinter fines** (0.06 – 8 mm) with a high Fe content
- **Magnetite concentrate addition** (up to 30%) is possible
- Utilizes CO-rich reducing gas from coal gasification
- 3 reference plants: POSCO FINEX # 1-3 (0.6 / 1.5 / 2.0 MTPY)

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### Breakthrough Technology

- Applying **in-house know-how for fluidization, DRI handling** etc.
- Direct use of any iron ore **pellet feed concentrate (< 0.15 mm; hematite or magnetite)**
- Utilizes **hydrogen as reducing gas** (optionally generated from natural gas)

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### "The next Generation of Direct Reduction Processes"

**BREAKTHROUGH TECHNOLOGY**

Is a new developed direct reduction process **for any type of iron ore concentrate** (hematite and magnetite)

**E³-SteP**

**MAIN INPUT**

- **Iron ore concentrate** – direct use of pellet feed concentrate

  Typical grain size: 100% < 150 µm
  Max. grain size: < 500 µm

- **Reducing gas** – hydrogen (pure or generated from natural gas)

**MAIN BENEFITS**

- **No pelletizing required** – enables low operation cost
- **High oxide yield** due to dry dedusting and recycling of oxide dust
- **$CO_2$ free ironmaking** by use of hydrogen based on renewable energies
- **High reduction rate** at **low temperatures and pressures** due to high particle surface

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# **Output** of the new developed Direct Reduction Process

## Hot Direct Reduced Iron

- **Hot Direct Reduced Iron (HDRI)** is discharged from the reactor in hot condition and is transported to the EAF for melting.
- HDRI provides the **optimum way of DRI-charging of an EAF** to increase productivity and reduce cost.

| | |
|---|---|
| Metallization | 92 - 96% |
| Fe total | 90 - 94% |
| Carbon | minor |
| P, S, gangue | depends on iron ore source |
| Physical form | fines |
| Temperature | 600° C |

## Hot Briquetted Iron

- **Hot Briquetted Iron (HBI)** is the **premium form of DRI** and the preferred method of preparing DRI for transport and long term storage by the industry as well as public authorities.
- HBI is **normally used in EAFs** as well as in the foundry industry and can **also be added to the BF and BOF.**

| | |
|---|---|
| Metallization | 92 - 96% |
| Fe total | 90 - 94% |
| Carbon | minor |
| P, S, gangue | depends on iron ore source |
| Physical form | briquettes |

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## 5 - Breakthrough Technology (4/6) – Consumption figures

1,4

### Iron oxide (pellet feed concentrate)

Due to the direct processing of pellet feed concentrate, the use of a dry dedusting system as well as the recycling of dust direct into the reduction system, **an oxide yield of ~1.4 $t_{concentrate}$ / $t_{DRI}$** can be achieved, depending on the type of concentrate.

550

### Reduction gas (pure hydrogen or produced by natural gas)

**Approx. 550 Nm³ hydrogen per $t_{DRI}$** are required for the reduction process. Additional energy is needed to heat the hydrogen and the oxide to the required reduction temperature (electric or gaseous heating). Alternatively approx. 300 Nm³ natural gas per $t_{DRI}$ are required if natural gas is used. This amount includes the energy for heating of the reducing gas.

0,1

### Electrical energy

The **power consumption per $t_{DRI}$ is about 0.1 MWh**.

↘

### Water

Due to the usage of a waste heat recovery and a dry dedusting system, **less process water is required**. The reduction with hydrogen even generates water as a by-product, which lowers the amount of water treatment for process water and machinery cooling systems.

5

### Others

Cost of plant operators, maintenance and other cost **can be assumed to be less than 5% of the overall operation expenses.**

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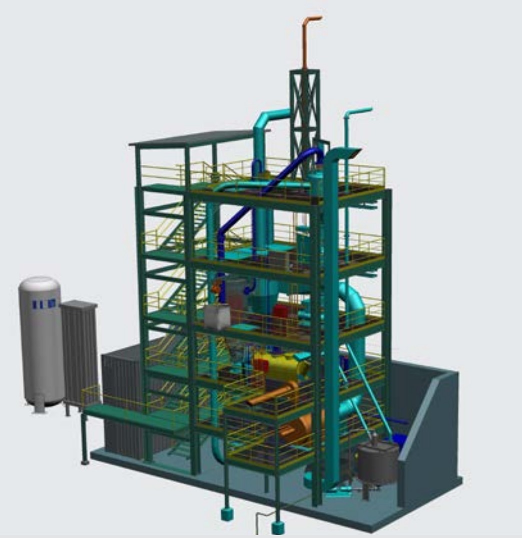
**E³-SteP – NEXT STEP**

***From lab scale** via* → ***pilot plant** to* → ***industrial scale***

**Hot Bench Scale Plant**



**Commissioning mid of 2020**

As next step **a hot bench scale plant will be set up in partnership with voestalpine Stahl Donawitz GmbH**, at the steel plant at Donawitz, Austria.

The **hot bench scale plant will consist of**

- Preheating and oxidation unit
- Reduction unit
- Gas supply and off-gas treatment

Hydrogen will be supplied by a gas supplier.

**GOAL**

**Verification of the break-through process** and to serve as a testing facility to provide the **data basis for a following industrial scale size plant**

Application for KPC funding submitted in **June 2019**

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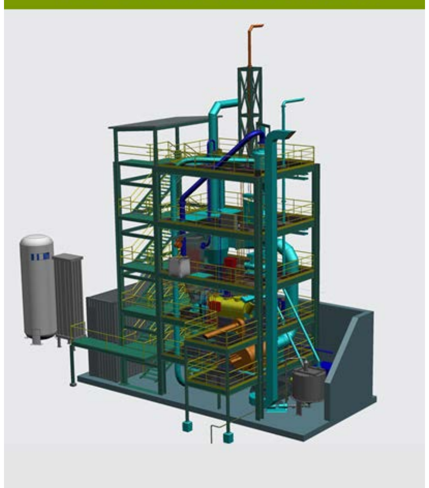
## 5 - Breakthrough Technology (6/6)

**Timeline** for installation of industrial production plants:

**E$^3$-SteP – NEXT STEP**

***From lab scale*** *via* → ***pilot plant*** *to* → ***industrial scale***

**Hot Bench Scale Plant**



**Pilot plant in Austria**
Start up: Mid of 2020

**Testing phase:**
- Test of different iron ore fines.
- Material tests of concentrates of customers interested in this new technology for iron ore reduction.

**After successful testing**, industrial plants will be built for lead customers.

**Industrial plant**


Module size by 250,000 t/a

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