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# Steel Industry: new technologies and associated risks

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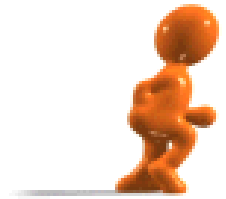
# Content

## Steel Industry: new technologies and associated risks



# 1. The steel industry today

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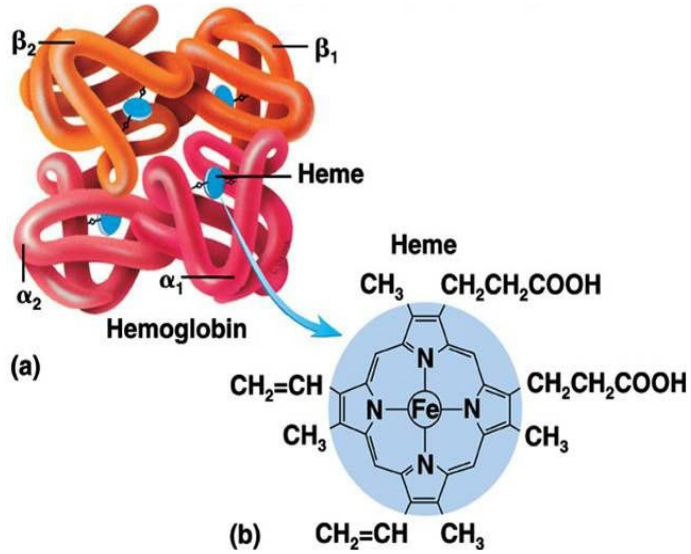
*Basic Chemistry*

Iron ore = Iron oxyde Fe0 + $Fe_2 0_3$

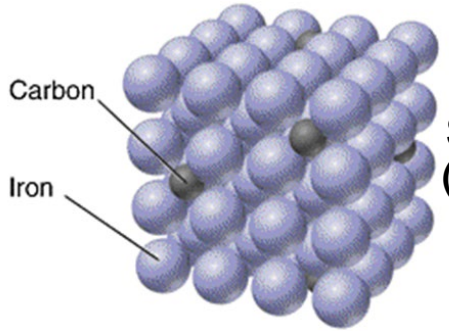
**2) Mineral (iron oxide)**


**1) Metal (element)**




**3) Essential mineral for human**

**5) "Iron" or iron alloy:**
**(2 to 5% Carbon)**




**Steel or iron alloy:**
**(up to 2% Carbon)**

**4) Alloy (Iron + Carbon)**

# 1. The steel industry today

*Basic Chemistry*

Iron ore = Iron oxyde Fe0 + $Fe_2 0_3$

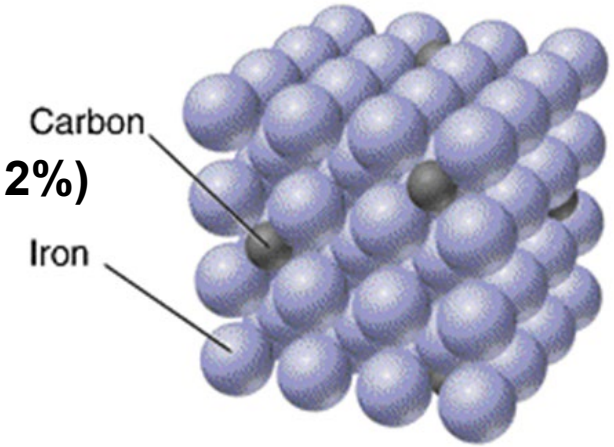

**= Mineral**

1) Iron Making

2) Steel Making

**"Iron"**

**90-95% Iron**
**(#4-5% Carbon)**
**= Alloy**




**Steel (Iron + Carbon) (up to 2%)**

**= Alloy**

# 1. The steel industry today

*Iron Making*

- Blast Furnace (BF)

**Mineral**

**Alloy (#4-5% Carbon)**

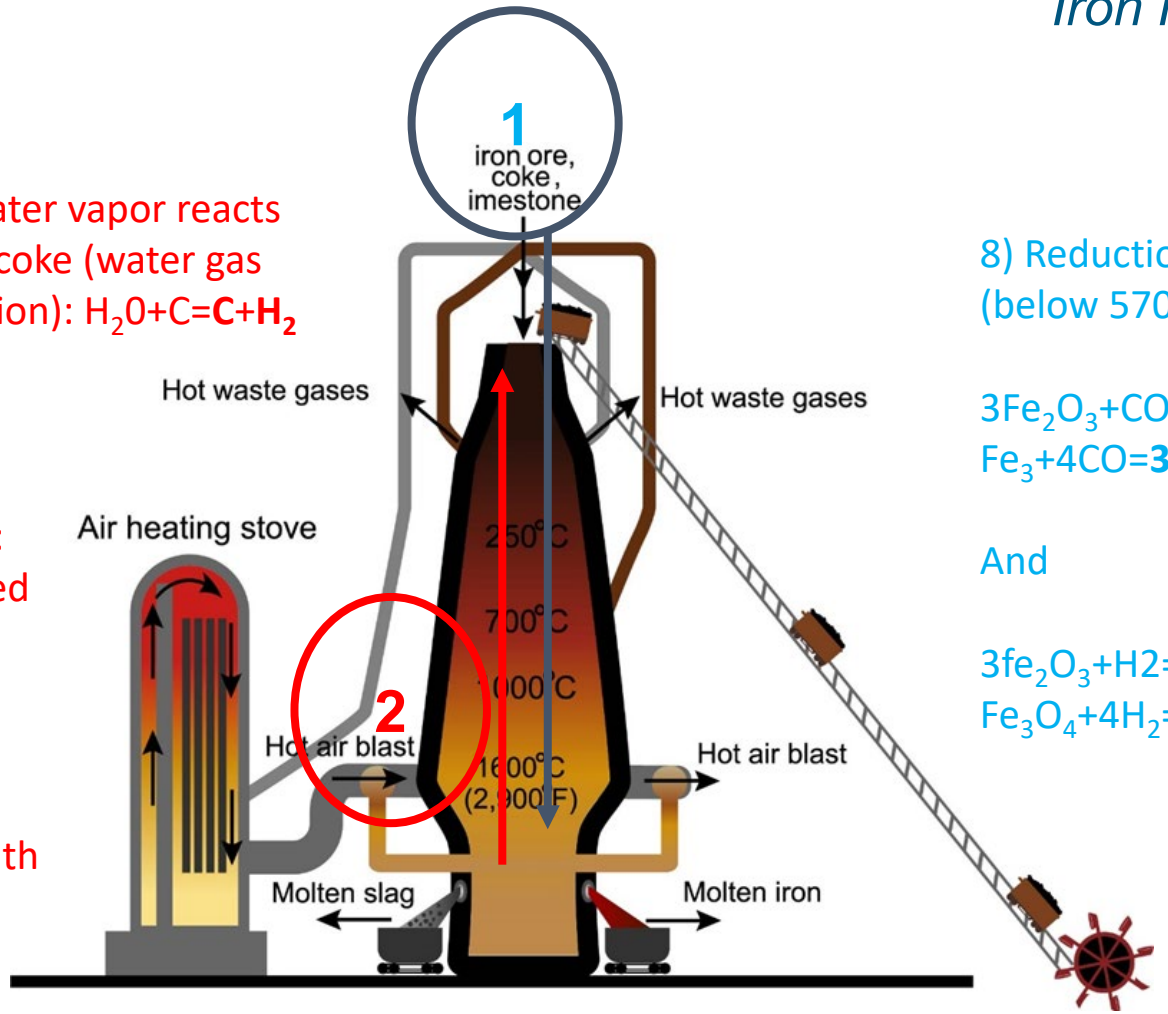
6) Boudourd reaction:
**$CO_2$**+C=2**CO**

5) Gas-solid reactions:
- CO+FeO=**Fe**+**$CO_2$**
- $H_2$+FeO=**Fe**+$H_2O$

4) Cohesive zone liquid phases:
- Iron and slag phase: unreduced iron oxide **FeO**
- Direct reduction:
**C+FeO=Fe+CO**

3) Oxygen in the blast reacts with coke and carbon:
C+$0_2$=$CO_2$
C+CO2=2**CO**
2C+$O_2$=2**CO**
C+$H_2O$=CO+**$H_2$**

7) Water vapor reacts with coke (water gas reaction): $H_20$+C=**C**+**$H_2$**




8) Reduction of iron oxides (below 570°C)

$3Fe_2O_3$+CO=$2Fe_3O4$+**$CO_2$**
$Fe_3$+4CO=**3Fe**+**$4CO_2$**

And

$3fe_2O_3$+H2=$2Fe_3O_4$+$H_2O$
$Fe_3O_4$+$4H_2$=**3Fe**+$4H_2O$



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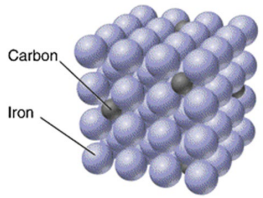
# 1.The steel industry today

*Steel Making*

- Molten iron is refined into steel by reducing the carbon content and adding oxygen, lime, scrap metal and alloys.

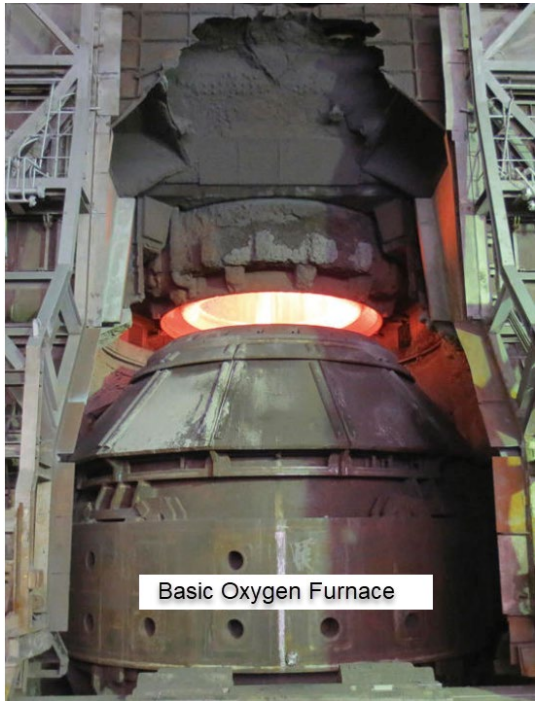
**Iron**

**90-95% Iron**
**(#4-5% Carbon)**
**= Alloy**

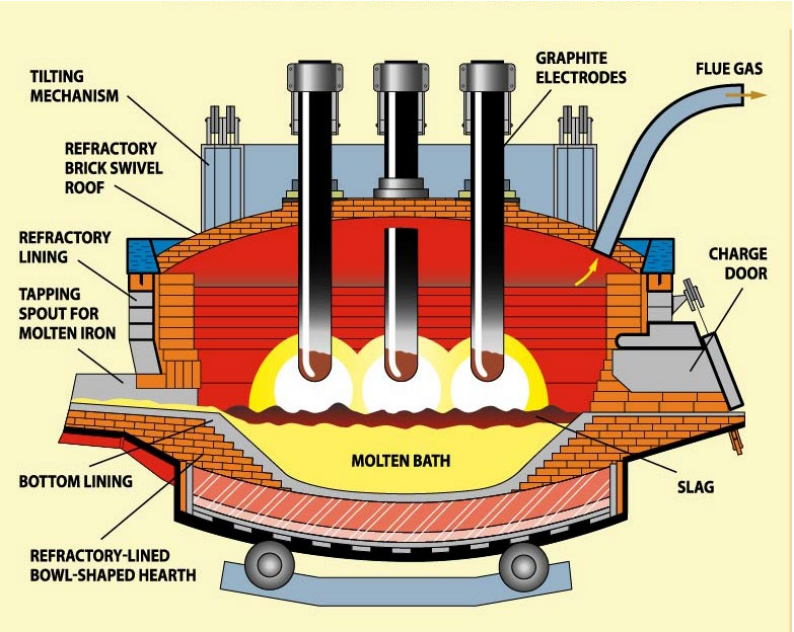



**(up to 2%)**
**Steel = Iron + Carbon**
**= Alloy**

## Basic Oxygen Furnace / Steelmaking (BOF/BOS)




## Electric Arc Furnaces (EAF)



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# 2. The current challenges

# 2. The current challenges

*Moving to « Green Steel »*

- Steel industry: reportedly accounting for an 7-8% of global $CO_2$ emissions (BF).

1. Need to achieve 55% reduction of $CO_2$ emissions by 2030 (vs. 1990 levels).
2. Need to adopt a new business strategy that aligns profit goals with a company's environmental policies.
3. This alignment should be efficient enough to sustain and grow a business while preserving the environment.

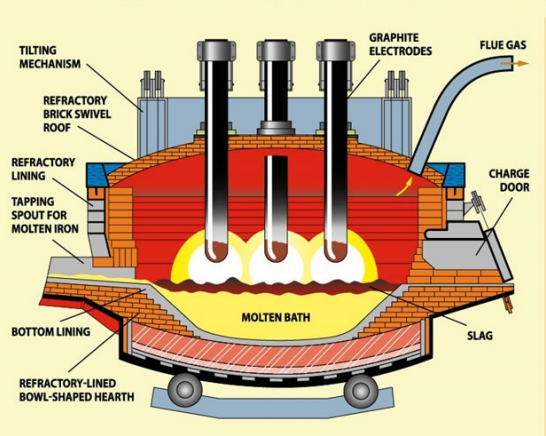
# 3. The strategies

# 3. The strategies

*Recycled Steel*

- Around 30% of the world's steel is reportedly made from recycled steel.

1. Steel recycling is mainly done in arc furnaces, driven by electricity.

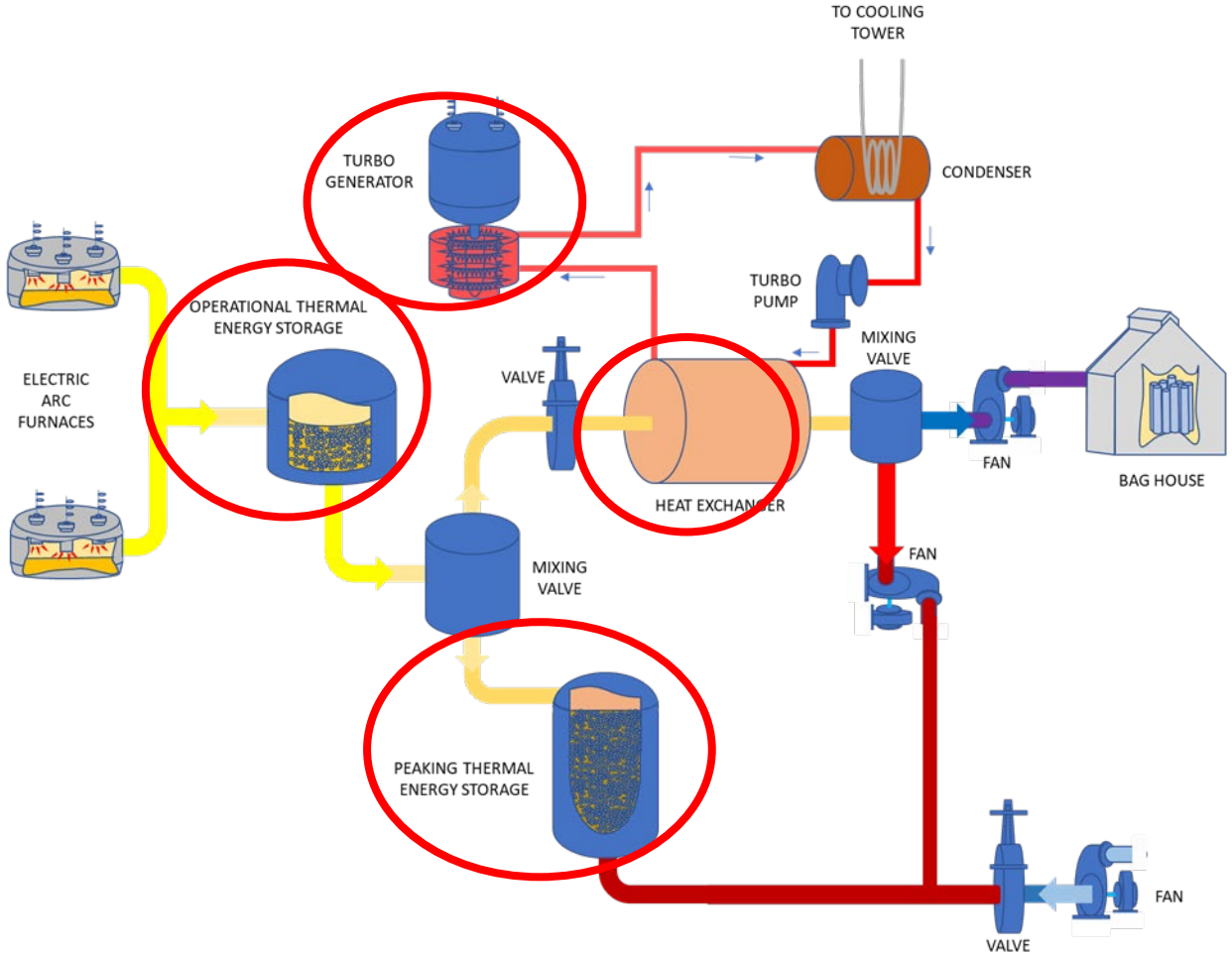



2. Each ton of steel produced using this method produces about 0.4 tons of $CO_2$ – mostly due to emissions produced by burning fossil fuels for electricity generation.

# 3.The strategies

*Energy recovery*

- Example of steel arc furnace energy recovery and storage system:



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# 3. The strategies

*Breakthrough Technologies*

- Goal: 55% reduction of CO2 emissions by 2030 (vs. 1990 levels).

1. New emerging path: making “green steel”, made using hydrogen rather than coal.

2. Using hydrogen for the  Blast Furnace (BF):
   a) The BF needs more externally added heat to keep the temperature high.
   b) Solid coal in the main body of the furnace cannot be replaced with hydrogen.
   c) Biomass alternative blended with coal being developed:
      i. Sustainable sourcing issue
      ii. Fossil-fuel derived emissions to be captured and stored


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# 3. The strategies

*Breakthrough Technologies*

- Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR):

1. Less than 5% of production
2. Two dominant gas-based process: MIDREX and HyL III
3. Use of massive amount of natural gas enriched with hydrogen
4. The reaction takes place in a reactor
5. The result is almost pure iron to be used in EAF for making steel
6. Overall emissions are lower than BF (more electricity. No coal!)

# 3. The strategies

*Breakthrough Technologies*

- Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR): MIDREX process

**3) Reactions in the reactor:**

**With H2 (Reduction):**

$3Fe_2O_3 + H_2 \rightarrow 2Fe_3O_4 + H_2O$

$Fe_3O_4 + H_2 \rightarrow 3\,FeO + H_2O$

$FeO + H_2 \rightarrow Fe + H_2O$

**With CO (Carburization):**

$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO$

$Fe_3O_4 + CO \rightarrow 3\,FeO + CO_2$

$FeO + CO \rightarrow Fe + CO_2$

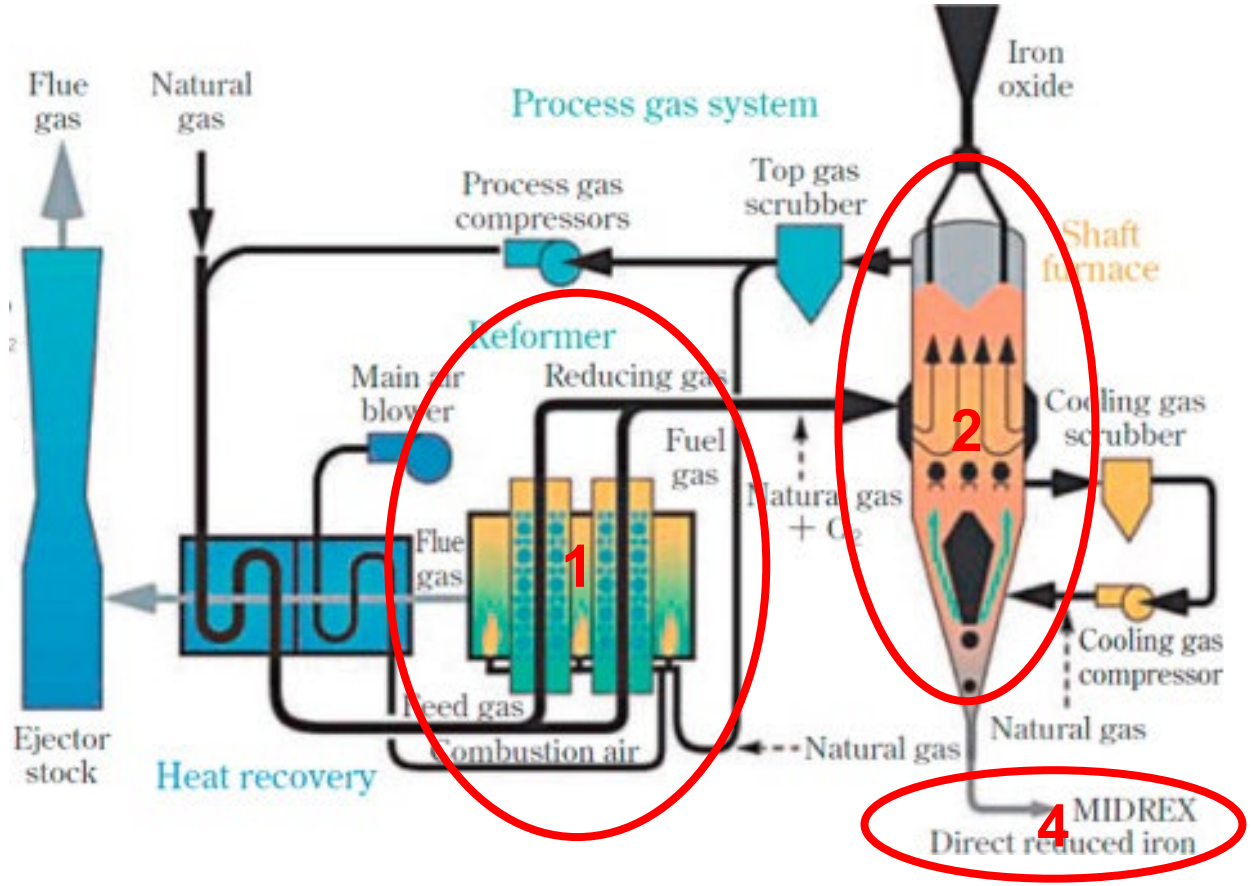
**With Solid Carbon:**

$CO_2 + C \rightarrow 2CO$

**With CH3 (Reforming):**

$CH_2 + CO_2 \rightarrow 2CO + 2H_2$

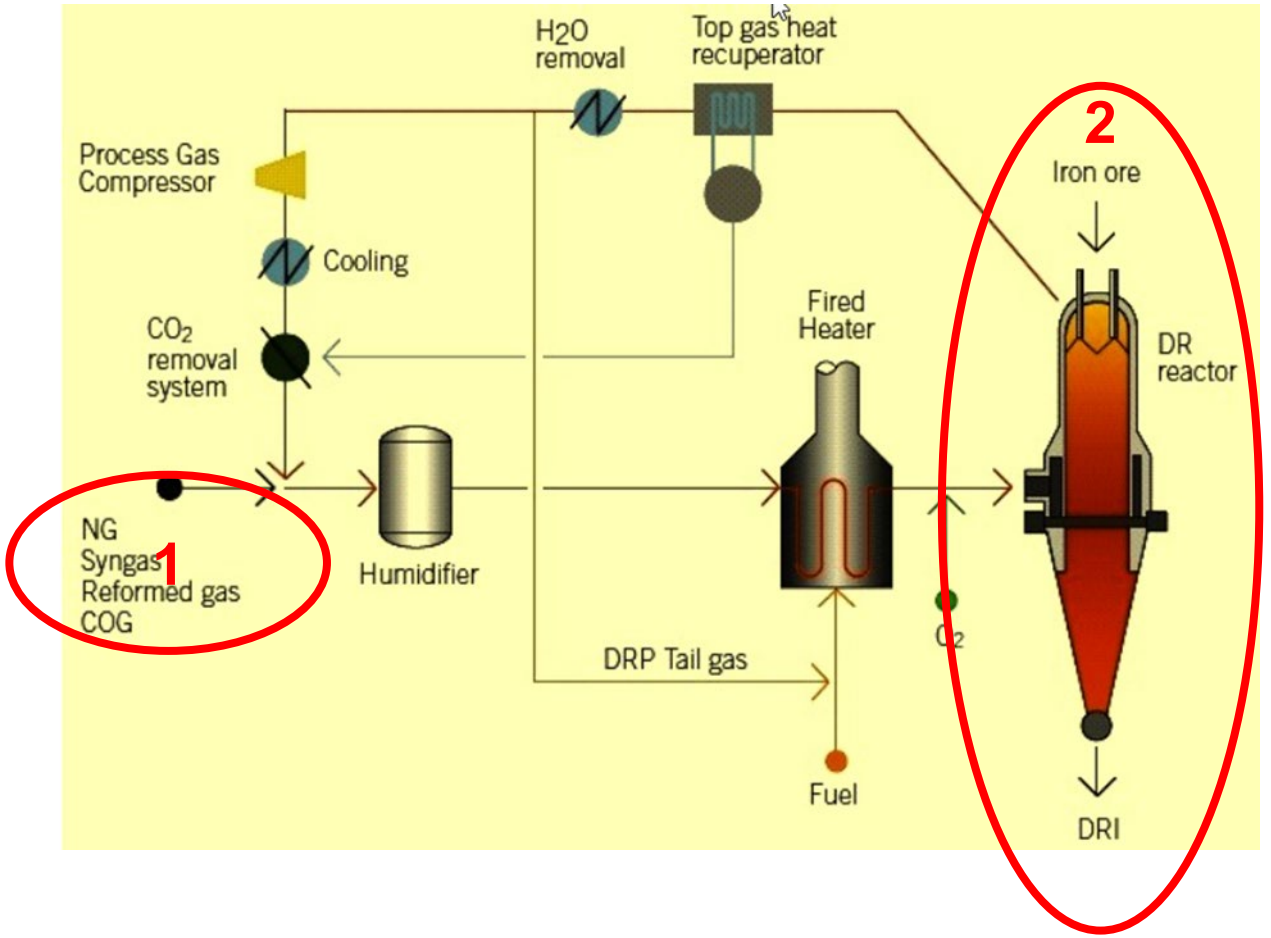
$CH_3 + H_20 \rightarrow 2CO + 3H_2$



# 3.The strategies

*Breakthrough Technologies*

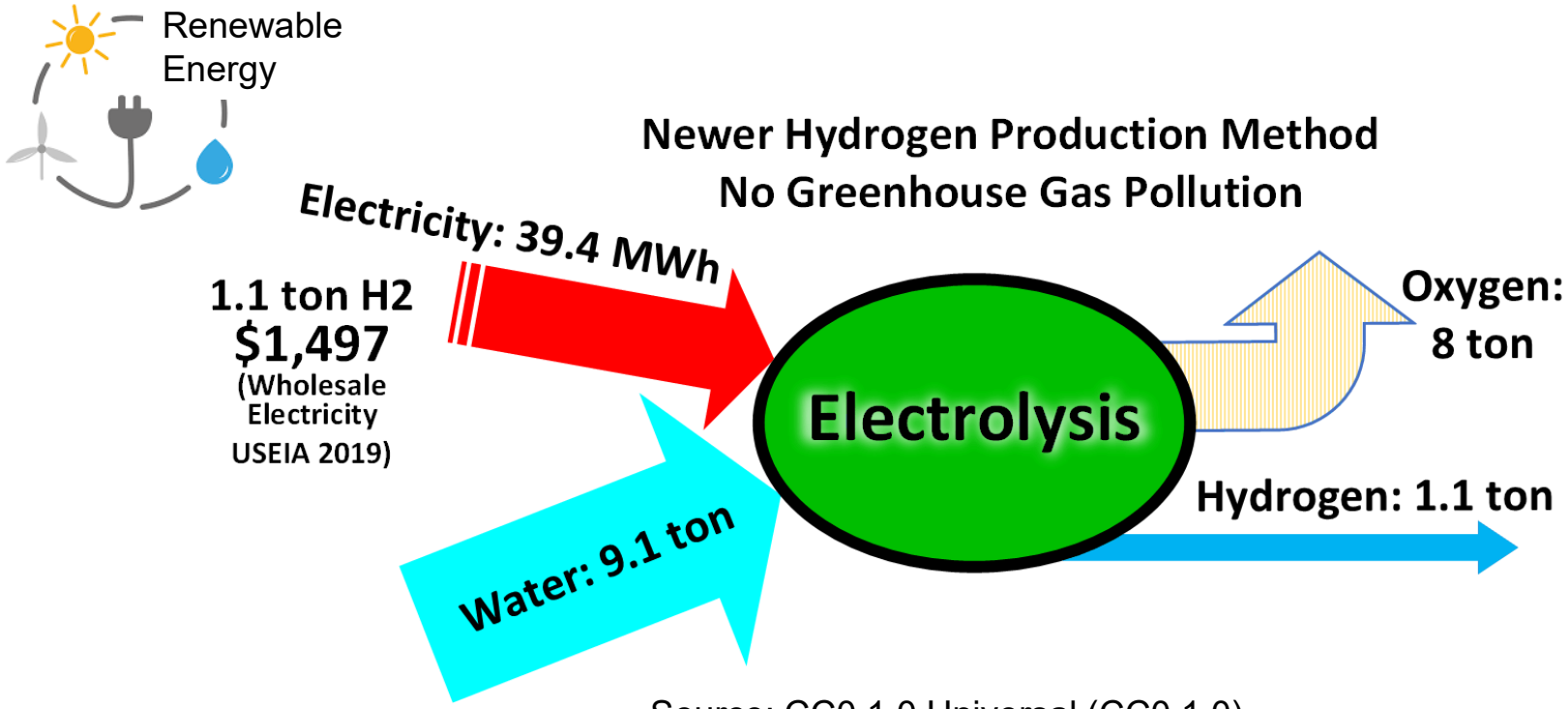
- Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR):  HYL process



# 3.The strategies

*Breakthrough Technologies*

- Hydrogen-based direct reduction (H-DRI):

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# 3. The strategies

*Breakthrough Technologies*

- High-temperature iron electrolysis:

1. Electrometallurgy = electrochemical process
2. Iron electrolysis is estimated to use 15-30% less electricity per ton of steel produced, relative to the hydrogen-based DRI route
3. Use of an inert anode is critical
4. Difficulties in finding a suitable non-consumable anode material capable of weathering the challenging conditions of the process.
5. Could come to the market by 2035

# 4. Introduction of New Hazards

# 4. Introduction of New Hazards

- Main issues:
  1. Supply chain
  2. Hazmat
  3. Moisture content
  4. Steel quality

*Use of Recycled Steel*

# 4. Introduction of New Hazards

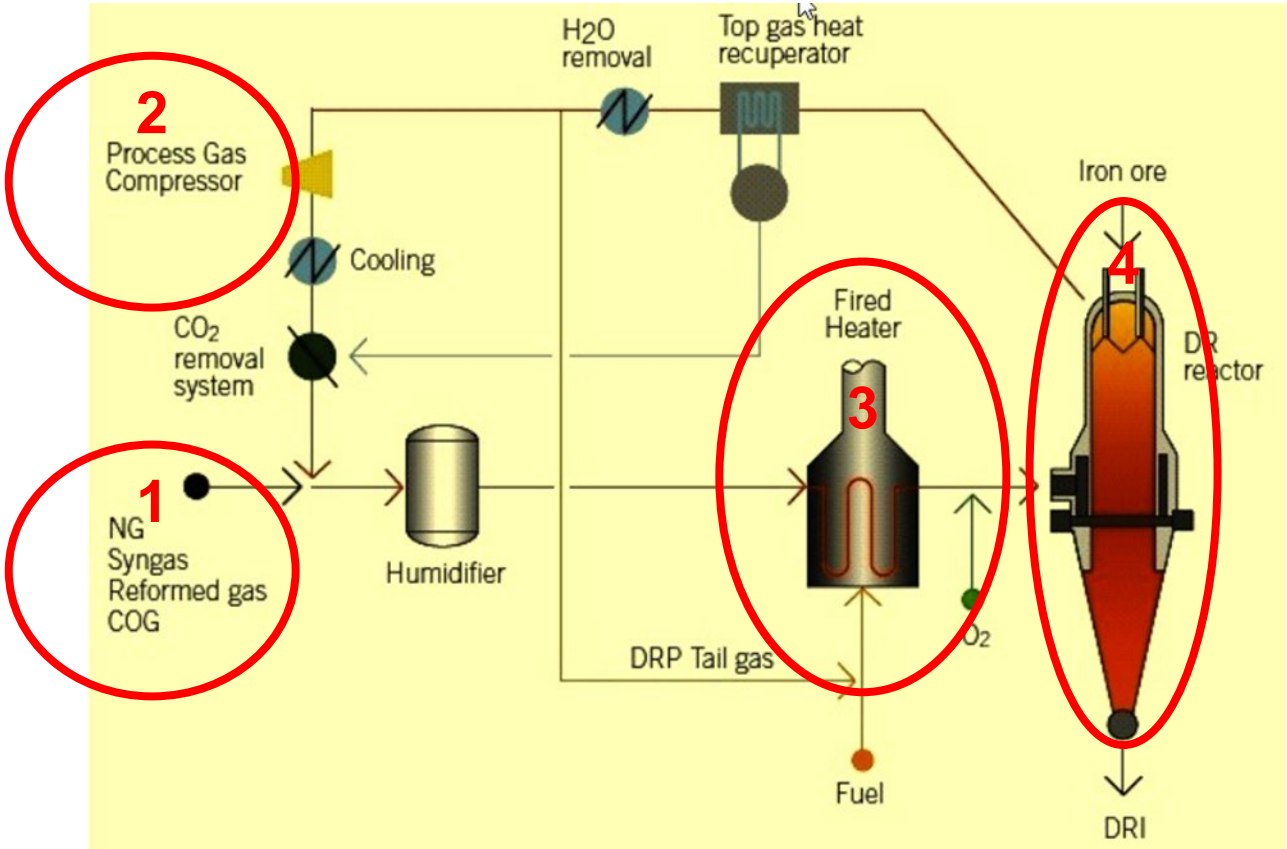
*Electric Power Co-Generation*

- Becoming a Power Plant Operator in addition to steel maker:

# 4. Introduction of New Hazards

*Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR)*

- HYL process:




**Reforming of natural gas**

**High Temperature**
&
**Pressurized**
Reduction Process

**Further methane reforming in-situ**

# 4. Introduction of New Hazards

*Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR)*

- Reformer:

  - Steam-methane reforming (mature production process)
    - high-temperature steam - 700°C–1,000°C
    - methane reacts with steam under 3–25 bar pressure
    - endothermic reaction

**Explosion potential**

- Steam-methane reforming reaction

  $CH_4 + H_2O$ (+ heat) → $CO + 3H_2$

- Water-gas shift reaction

  $CO + H_2O \rightarrow CO_2 + H_2$

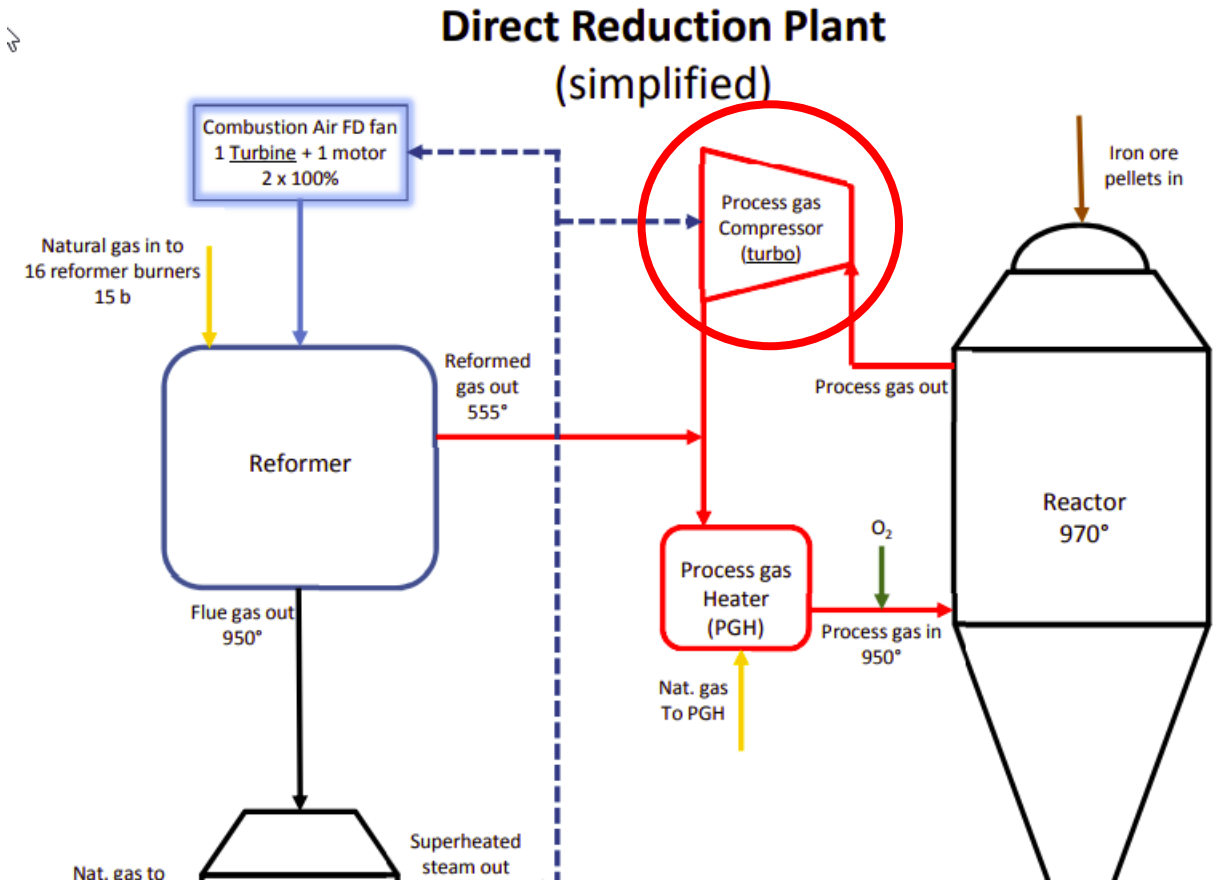
  (+ small amount of heat)

Courtesy of Emirates Steel (ES) Abu Dhabi UAE

# 4. Introduction of New Hazards

*Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR)*

- Reducing compressor and Process Gas Compressor:




**Fire**

**Explosion**

**Disintegration**

**BI for DRI unit**

# 4. Introduction of New Hazards

*Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR)*

- DRI-Reactor:

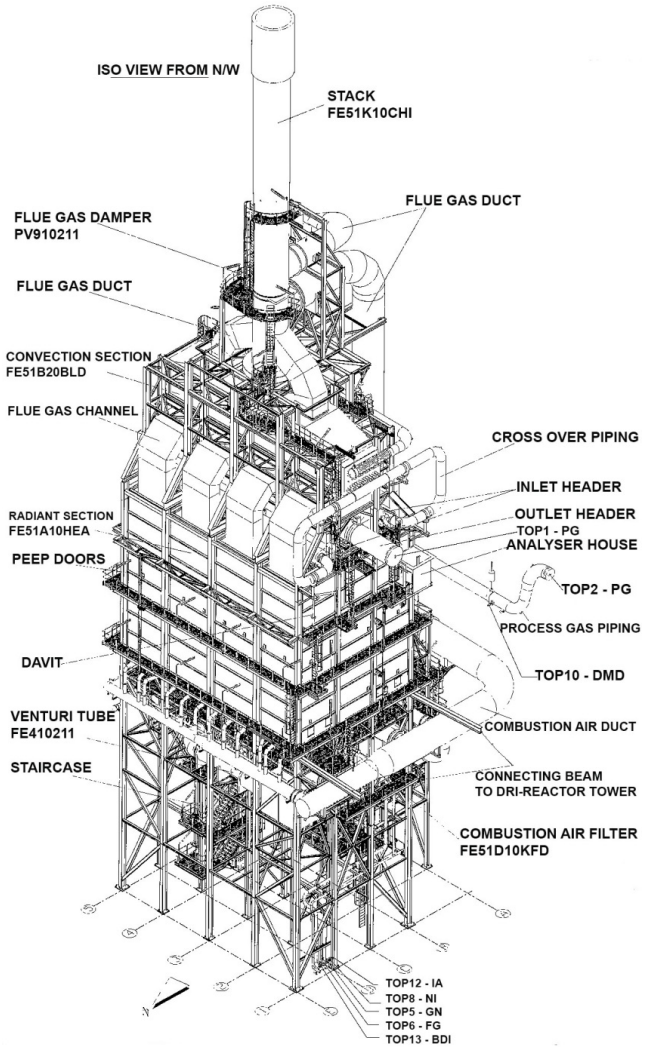
Process Gas Heater (left) DR Reactor (right)
Courtesy of Emirates Steel (ES) Abu Dhabi UAE

**High Pressure Rupture potential**

# 4. Introduction of New Hazards

*Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR)*

- Process Gas Heater (PGH):




Process Gas Heater (left) DR Reactor (right)
Courtesy of Emirates Steel (ES) Abu Dhabi UAE

**Integral to the production of Direct Reduction Iron (DRI)**

**DRP cannot work without a PGH**



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# 4. Introduction of New Hazards

*Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR)*

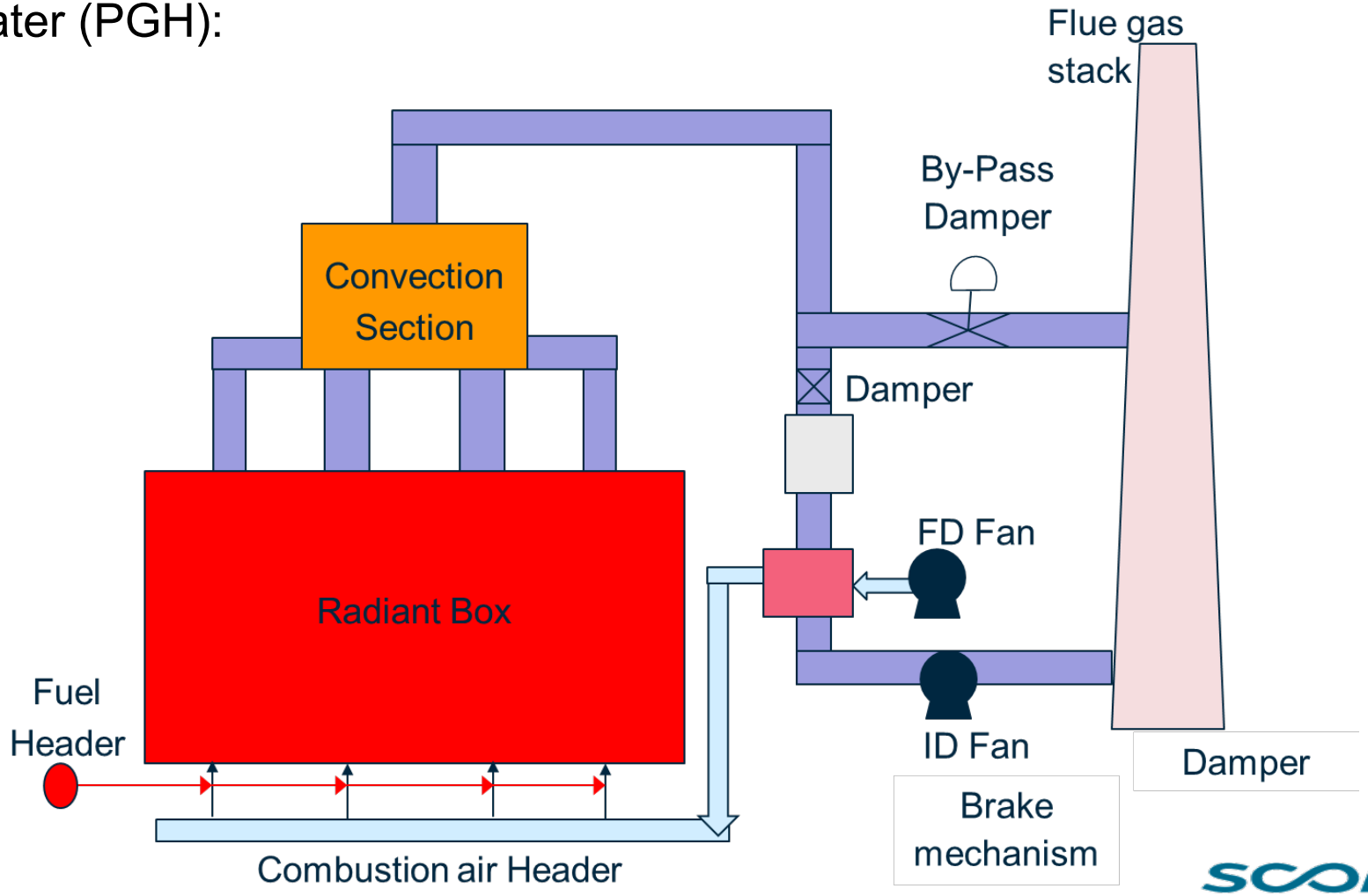
- Process Gas Heater (PGH):

Initially known as "intrinsically unsafe pieces of equipment"

heating combustible gases

in a gas-fired furnace

at temperatures very close to the admissible metallurgical limits of the heater tubes



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# 4. Introduction of New Hazards

*Direct reduced iron (DRI) or (Natural Gas-NG)-based direct reduction (DR)*

- Process Gas Heater (PGH):

Process Gas Heater (left) DR Reactor (right)
Courtesy of Emirates Steel (ES) Abu Dhabi UAE

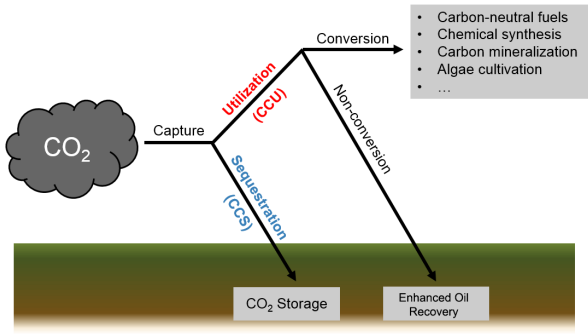
**Monitoring systems adequate process controls and alarms installed.**

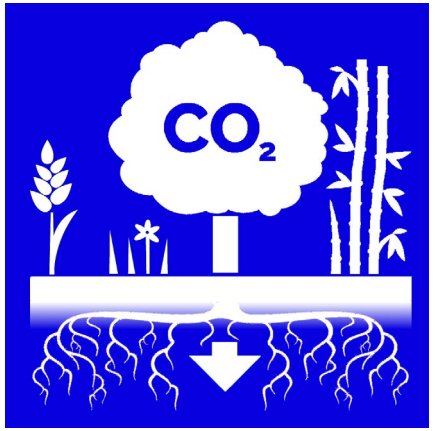
# 4. Introduction of New Hazards

*Carbon Recovery*

- Carbon Capture:

1. Usually, third party owned and operated facility
2. On site / off site
3. Fed from the Direct Reduction Plant
4. Usually for free
5. CO2 is recovered and compressed
6. For further injection in oil field



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# 4. Introduction of New Hazards

*Renewable Energy*

- Roof mounted Photovoltaic Solar Panels

**Risk Aggravating factor**

**Electric fire**

**Structural and weather hazards**



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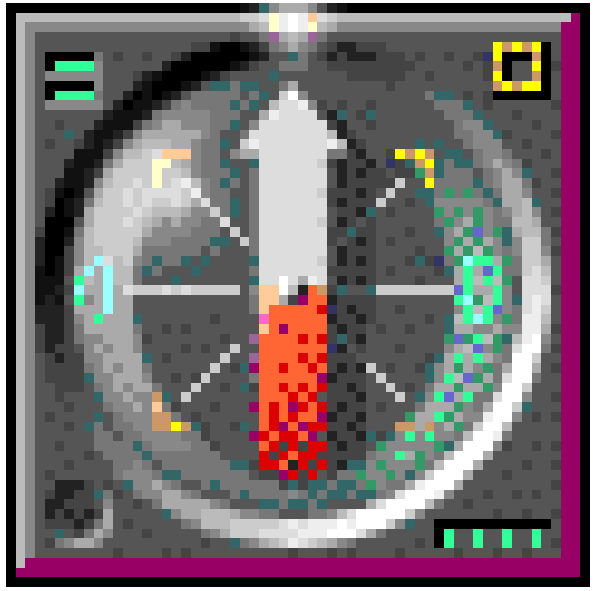
# Open discussion – Q&A



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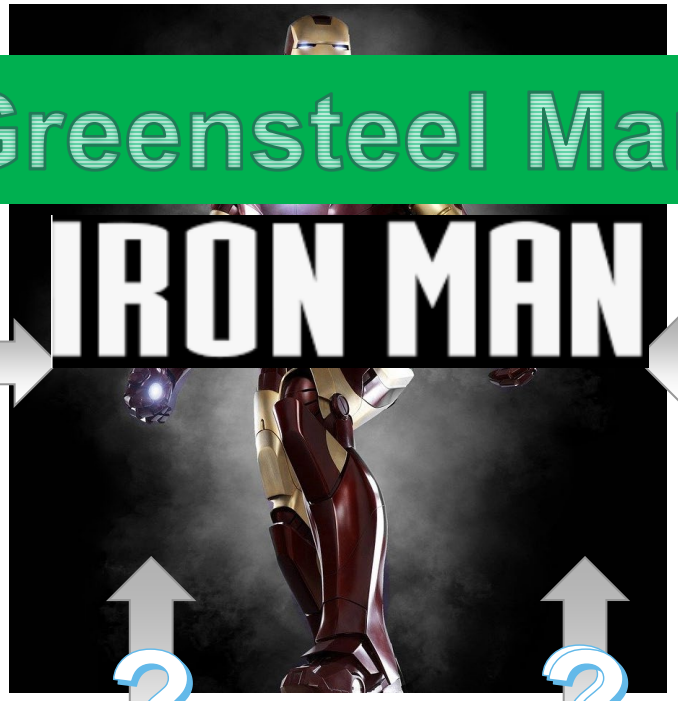
# Open discussion – Q&A

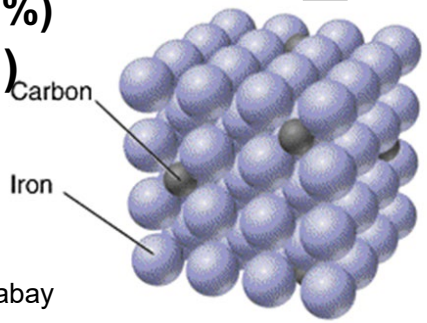
*Basic Chemistry*

**= Mineral**
**(Iron oxide)**




**“Iron” (Iron + Carbon)**
**(2 to 5%)**
**= Alloy**

**(up to 2%)**
**Steel (Iron + Carbon)**
**= Alloy**





**= Metal (element)**



Iron Man Superhero Edit - Free photo on Pixabay

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**Na Som** (Douala)
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**Dankie** (Afrikaner)

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