



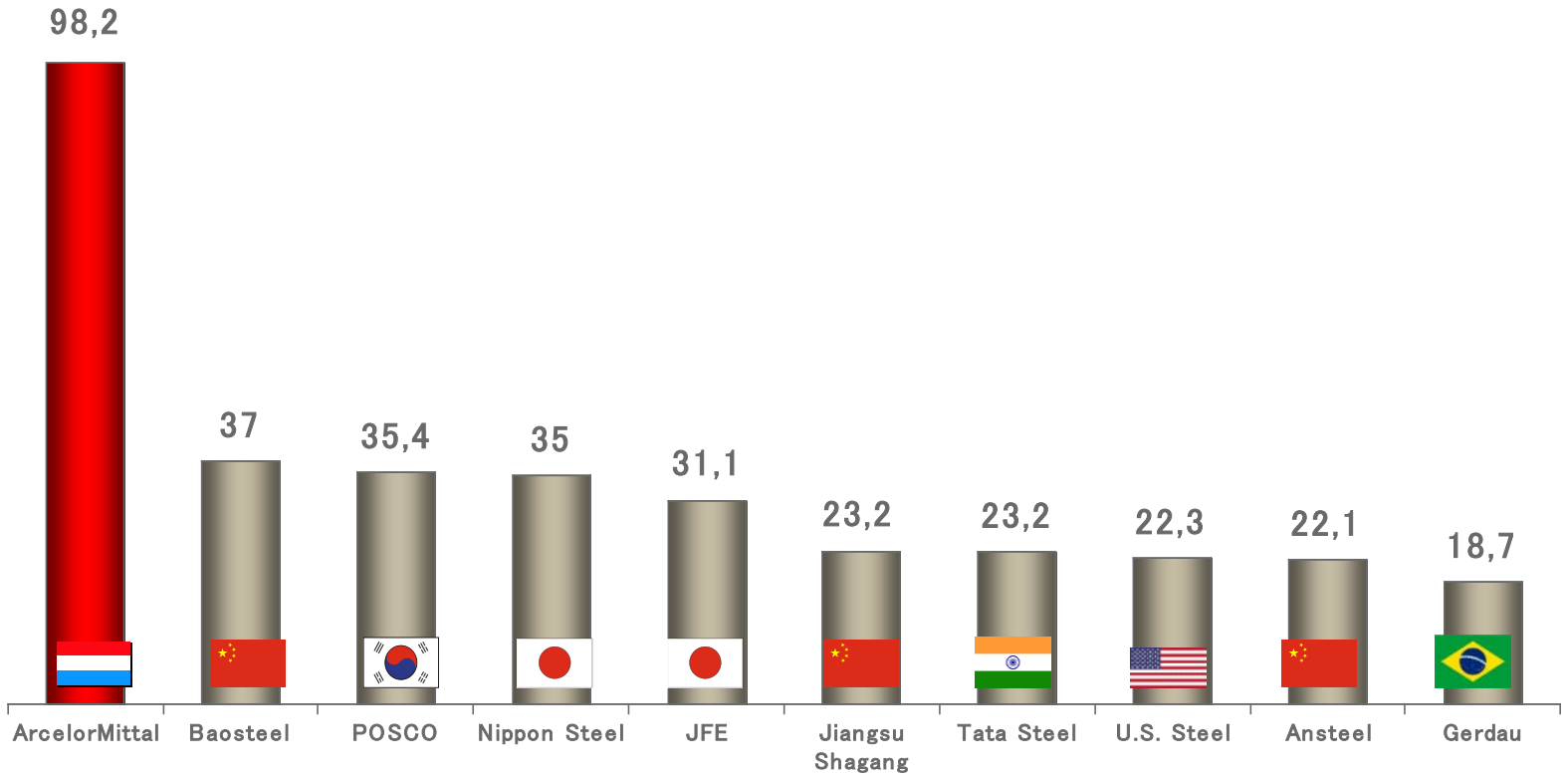
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ArcelorMittal : a steelmakers view on

THE ZERO EMISSION PLANT

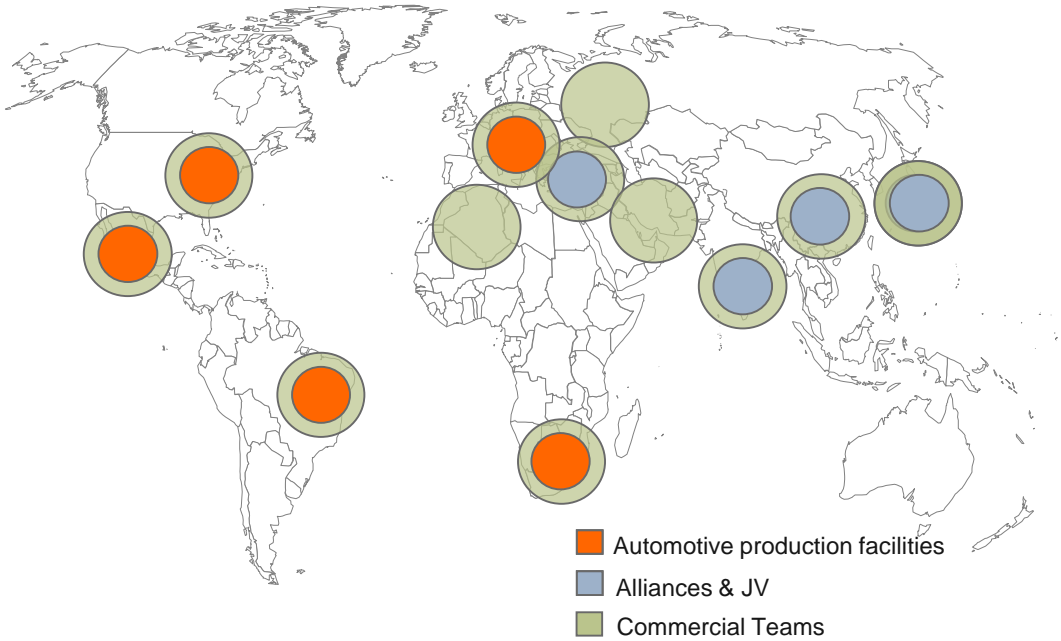
May 2017

Largest steel producers in 2016 (in mt crude steel)

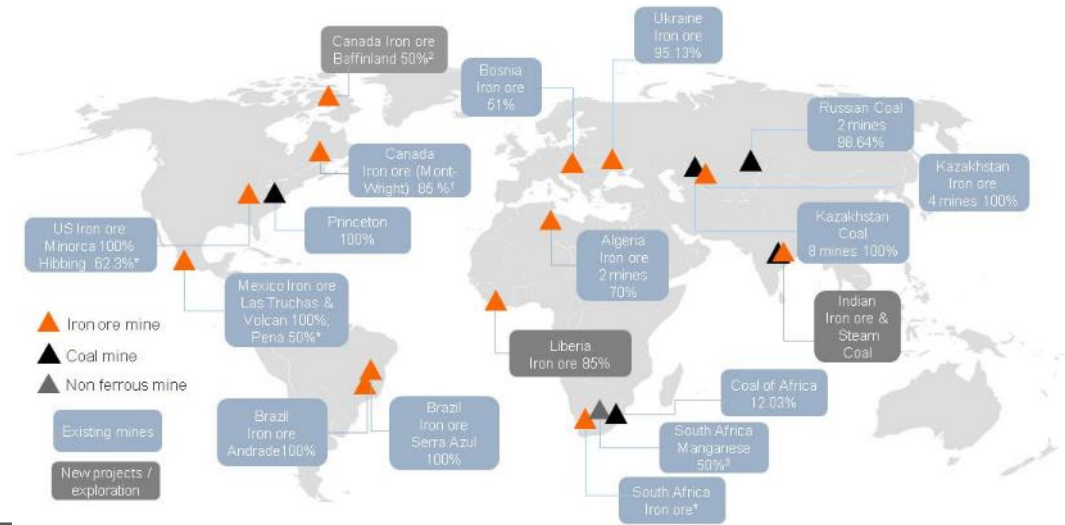


* Source: Worldsteel

ArcelorMittal's industrial and commercial network



Mining business portfolio



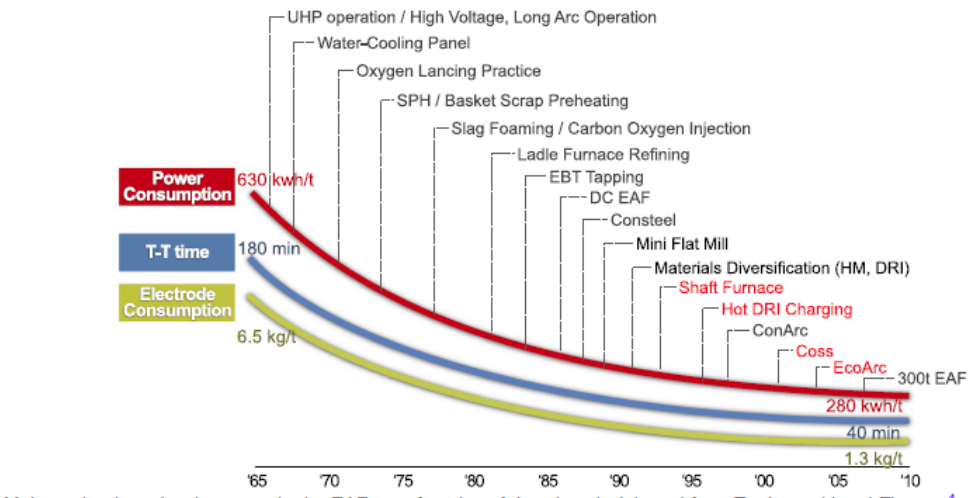
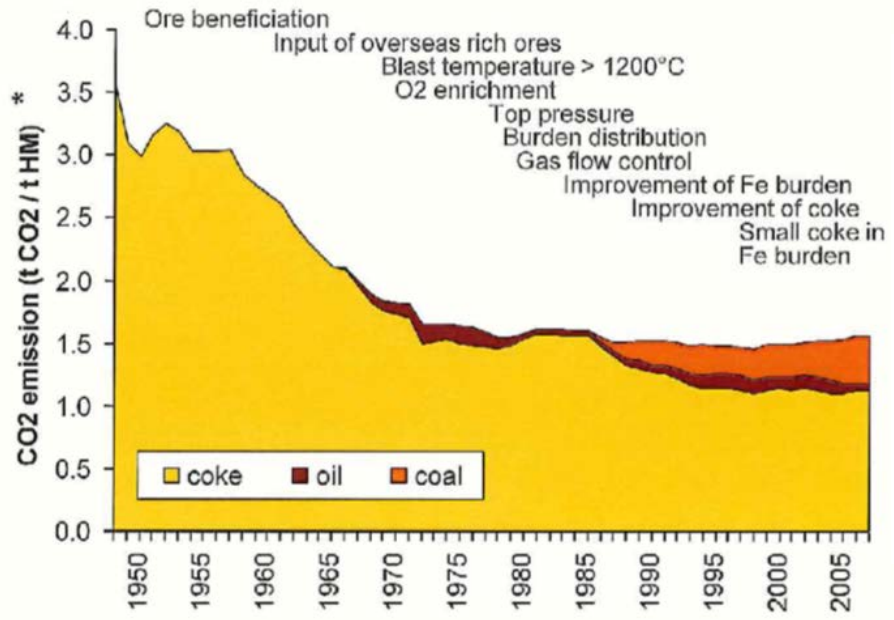


Agenda :

1. European history of steelmaking
2. Others are still at the very beginning of this history
3. What can Europe afford ?
4. ArcelorMittal zero emission concept
 - a) Gas separation
 - b) CO re-use by chemical industry
 - c) CO₂-H₂-chemistry : new technologies
 - d) CO₂ sale
 - e) CO₂ storage

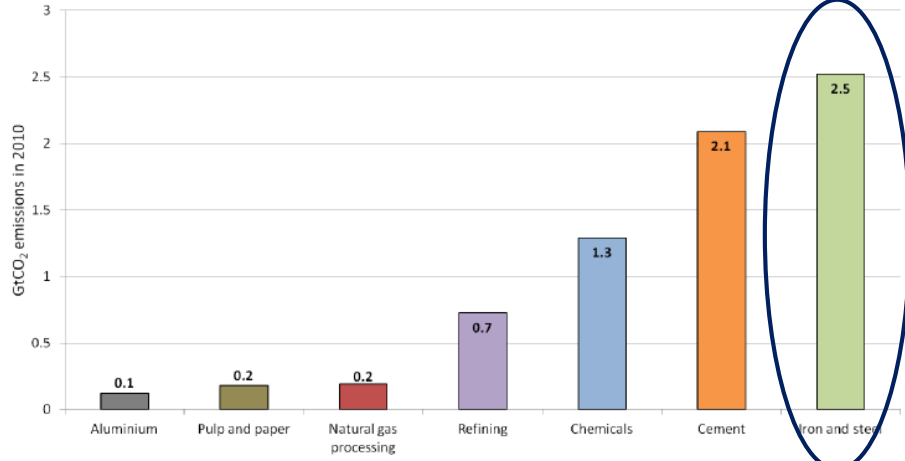
The challenge of the steel industry = C-footprint reduction

Conventional steel making = blast furnaces (BF) Electrical steel making = electric arc furnaces (EAF)



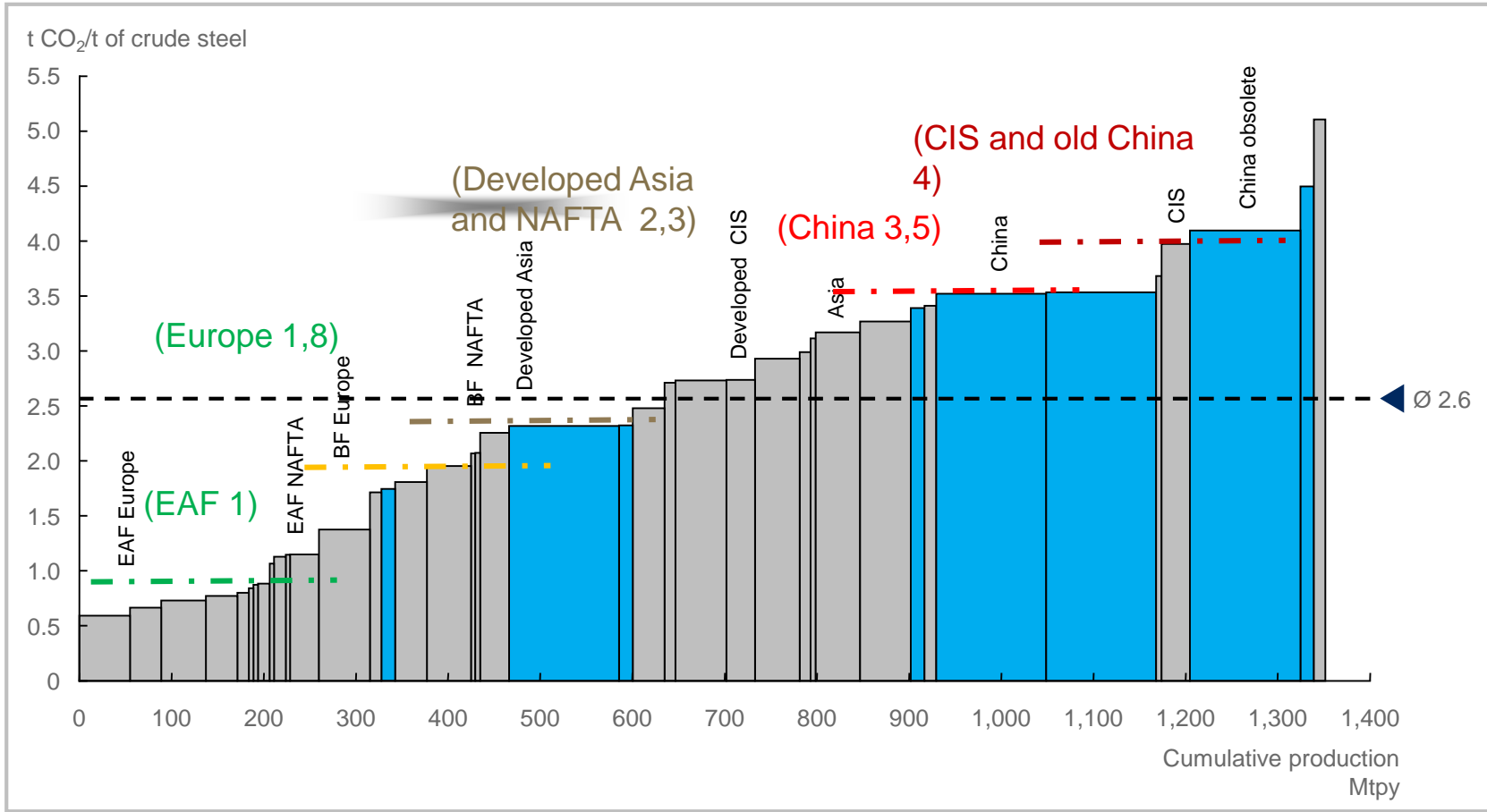
1,6 billion tons of steel in 2014
 30% of industrial CO₂-emissions.
 6,7% of anthropogenic CO₂-emissions
 They are amongst the highest of industries....

Figure 1. Global emissions from the seven most CO₂-intense industrial sectors in the IEA Energy Technology Perspectives (ETP) analysis



C-footprint reduction : the main emitters are not located in Europe !!!

■ China/India
■ Other

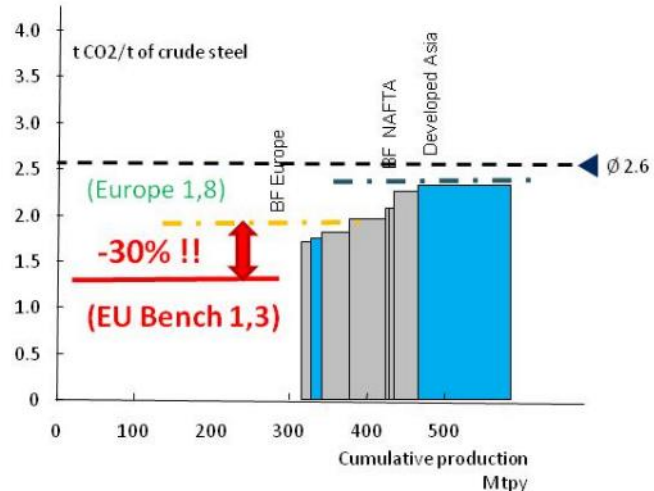
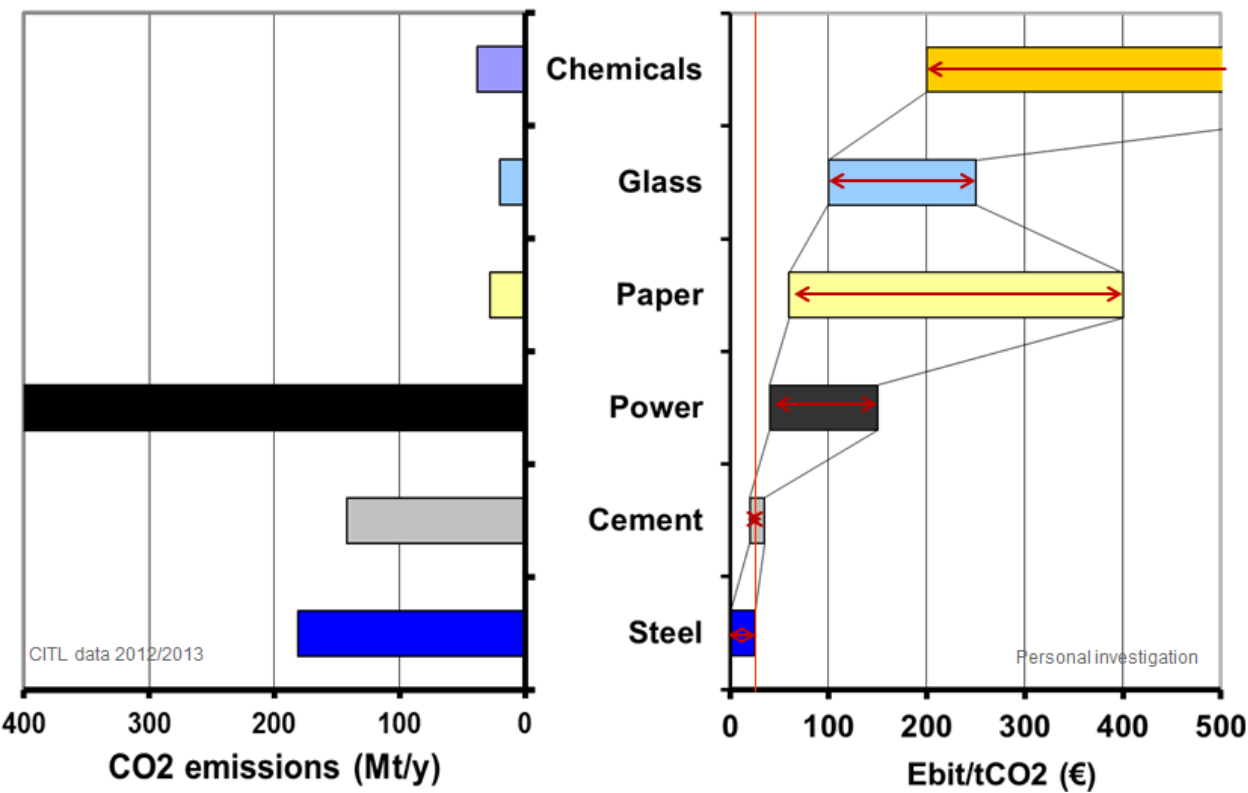


global CO₂ curve



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How much can Europe afford ???



Carbon is a reactant agent for steel production, not an energy source !



You can not lower the CO₂ emission from the steel industry by installing one more windmill...

ETS is made for power generation, not for chemical processes.

EU 27 figures
EU benchmark is 30% below the technical limits

The Zero Emission Plant concept of ArcelorMittal

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Principles :

- CO₂ is not a waste, but a raw material
Value can be created with that.

e.g. German FONA-program =
25,6 Mt/y CO₂-re-use on 912 Mt/y

- CCU is the way to go, to create value and employment.
CCU will change the game and will lead to social acceptance of CCS, and will allow us to pay for it.

- Technologies must be easily integratable in the existing equipment, preferably be modular, and must be robust not to impact the furnaces.
Experienced industrial partners are invited to work with us.

- Synergies with the steel making must be exploited (recovery of valuable byproducts of CCU, use of waste heat of steel making)

- CCS is not our responsibility, the authorities have to explore and operate this technology.

Too many unknowns still exist
in this domain.

08/04/2017

Confidential



recent Risk Management position paper (DNV, 2011) states that using a variety of carbon utilisation technologies can potentially reduce annual CO₂ emissions by 3.7 Gt. This equates to approximately 10% of current annual CO₂ emissions. A 10% replacement of building materials by CO₂ captured in stable minerals would reduce CO₂ emissions by 1.6 Gt

CCS is the only option to decarbonise many industrial sectors. CCS is currently the only large-scale mitigation option available to cut the emissions intensity of production by over 50% in these sectors.

The steel mill of the future will still produce gasses



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Steel mill gases contain
CO/CO₂/H₂/N₂



→ BF Gas : 60%

			dry gas	
parameter		unit	average	stdev
H ₂	hydrogen	mol%	3,80	0,52
N ₂	nitrogen	mol%	48,46	1,59
Ar (+O ₂)	argon (+ oxygen)	mol%	0,62	0,03
CO	carbonmonoxide	mol%	24,43	0,69
CO ₂	carbondioxide	mol%	22,50	0,80
som		mol%	99,81	0,45



→ BOF Gas :
10%

component	%vol	% mol	% mol
	dry	dry	wet
H2	3,34	3,34	2,93
CO	56,42	56,34	49,43
N2	18,83	18,80	16,50
CO2	20,76	20,87	18,31
Ar	0,63	0,63	0,55
O2	0,02	0,02	0,02
H2O	0,00	0,00	12,27
sum	100,000	100,000	100,000

→ CO Gas : 30%



Power plant : 50%

			dry gas	
parameter		uniteenheid	average	stdev
H ₂	hydrogen	mol%	62,99	0,70
N ₂	nitrogen	mol%	6,07	0,74
Ar (+O ₂)	argon (+ oxygen)	mol%	0,22	0,02
CO	carbonmonoxide	mol%	4,25	0,10
CO ₂	carbondioxide	mol%	1,23	0,09
CH ₄	methane	mol%	22,49	0,37
C ₂ H ₄	ethene	mol%	1,55	0,06
C ₂ H ₆	ethane	mol%	0,73	0,04
C ₃ H ₆	propene	mol%	0,13	0,01
C ₃ H ₈	propane	mol%	0,05	0,01
som		mol%	99,71	0,39

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The steel mill of the future ... principal flow sheet



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Steel mill gases contain
 $\text{CO}/\text{CO}_2/\text{H}_2/\text{N}_2$

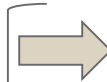


Steel mill available waste
heat = 500 MW



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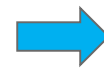
Gas
separation



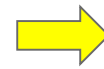
CO



CO_2



O_2 : is a valuable byproduct



H_2 : valuable gas agent to
combine with carbon gases



N_2 : sale

- Sale
- Conversion to low value product (high volumes)
- Conversion to high value product (low volumes)
- Re-use in the process

A typical size for a standard mill = 5 – 6 Mt/y capacity

CO_2 –emission = 9 – 11 Mt/y

50 Vol % is in the gas as CO

50 Vol% is in the gas as CO_2

=> targeted CO_2 -reduction > 30%

The steel mill of the future will provide the single gas components



Steel mill
gases
CO/CO₂/H₂/N₂



DMEA
Solvents

Pure CO₂ /H₂S

High need of low
cost steam

PSA Plant for CO₂-removal, Vereeniging, South



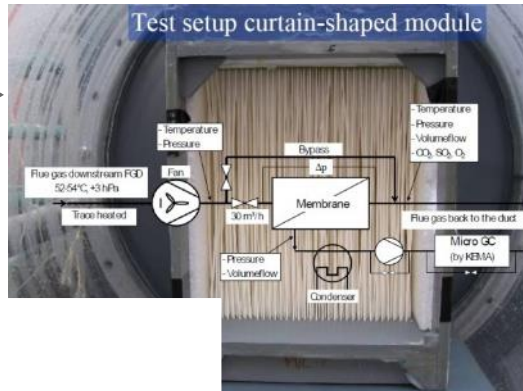
(V)PSA

Less pure CO₂ /N₂
/CO

High need of
compression energy



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MEMBRANE

Unpure CO₂ /N₂/CO

Lower need of energy

The steel mill of the future will sell CO

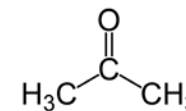
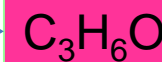
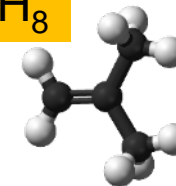
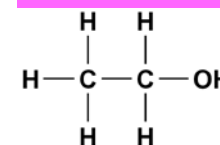
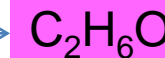


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Sale to chemical industry
Conversion into valuable hydrocarbons

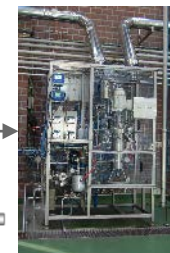
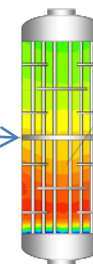


Valorisation of steel mill CO



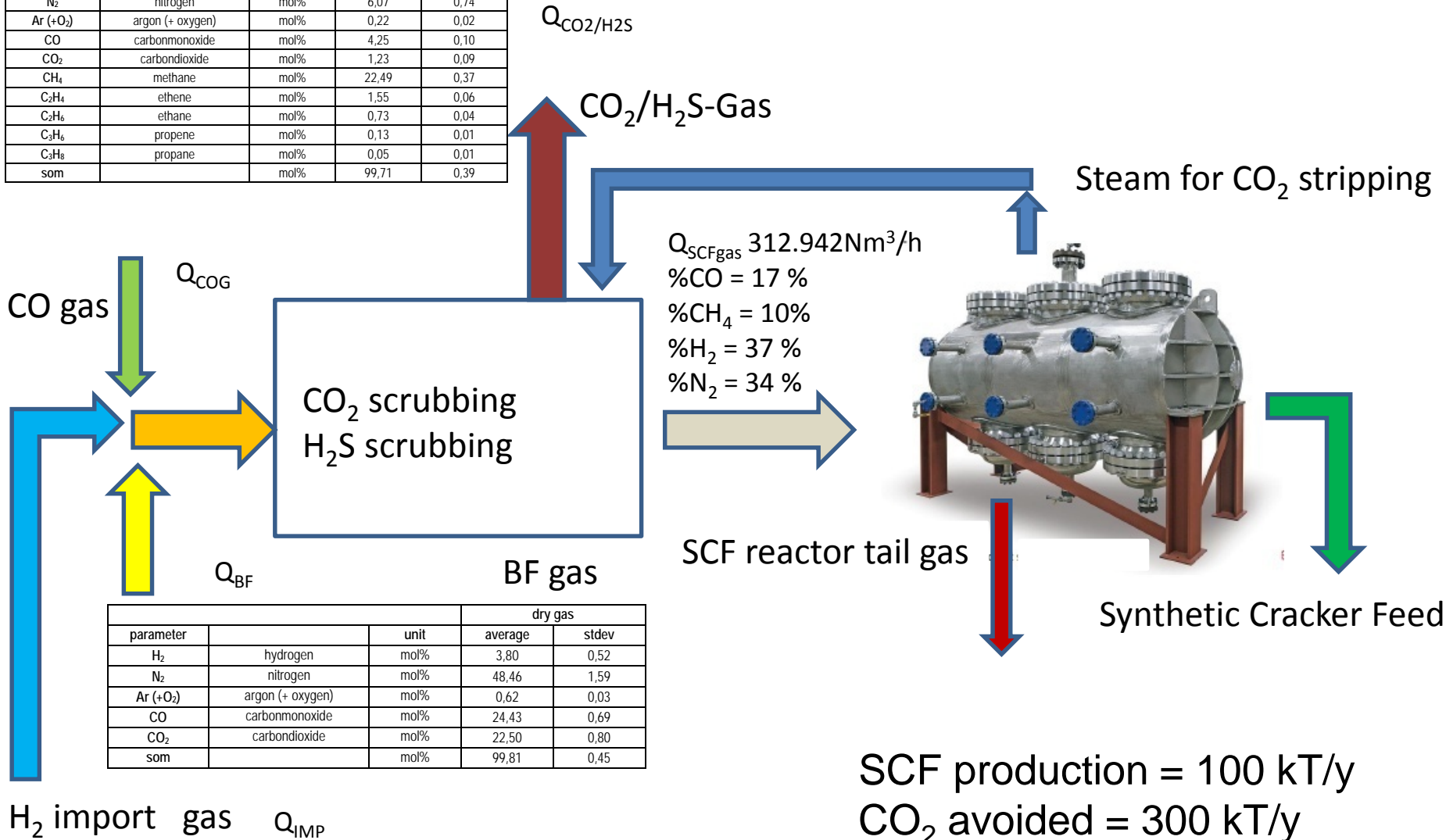
H₂- sources =

- Coke Oven gas
- H₂ surplus from chemical partner
- Electrolysis



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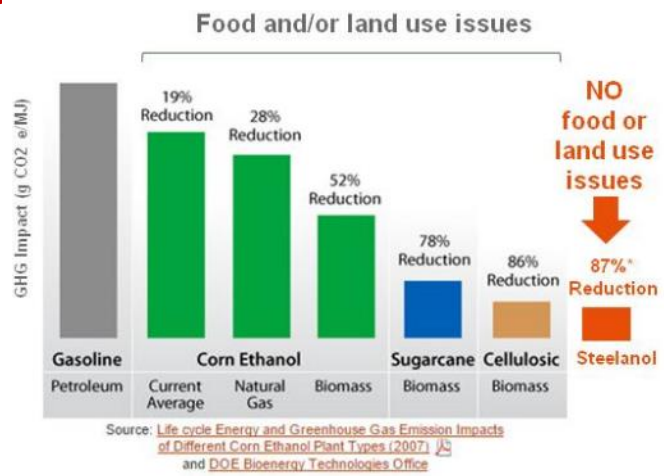
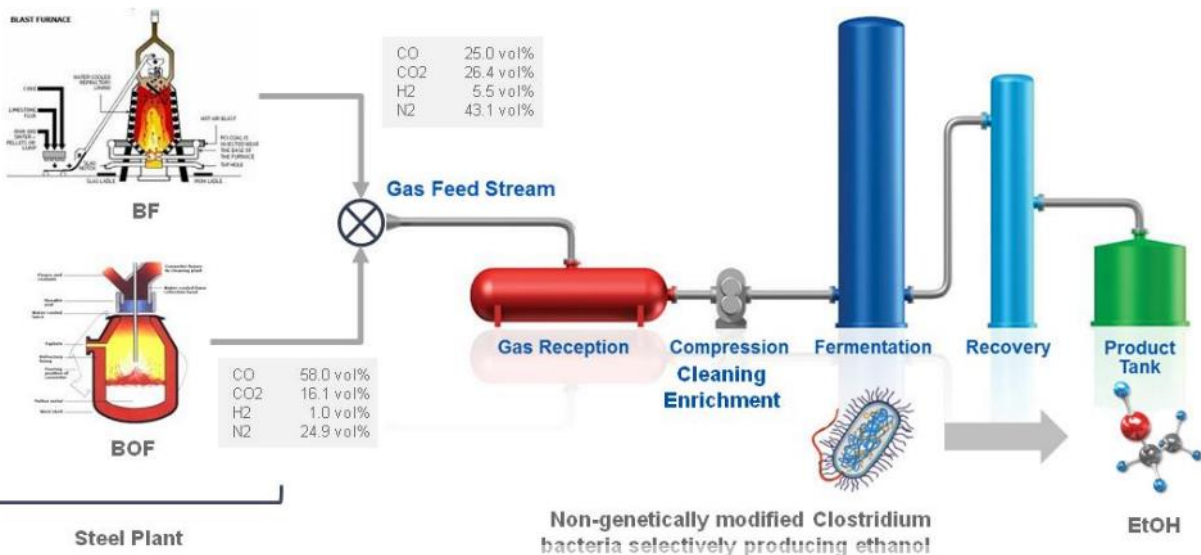
parameter		unit	dry gas	
			average	stdev
H ₂	hydrogen	mol%	62,99	0,70
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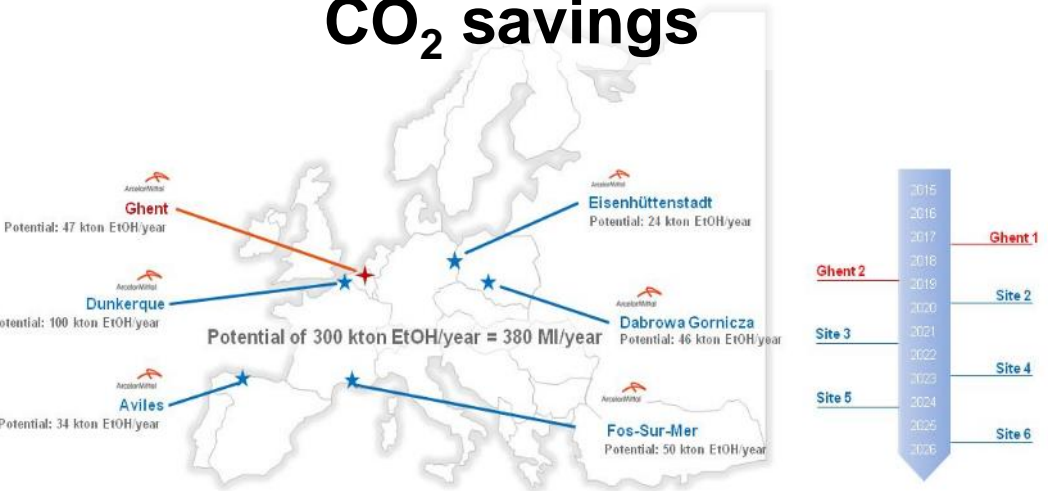
parameter		unit	dry gas	
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CO ₂	carbondioxide	mol%	22,50	0,80
som		mol%	99,81	0,45

Mass & Energy Overview

The steel mill of the future will sell CO

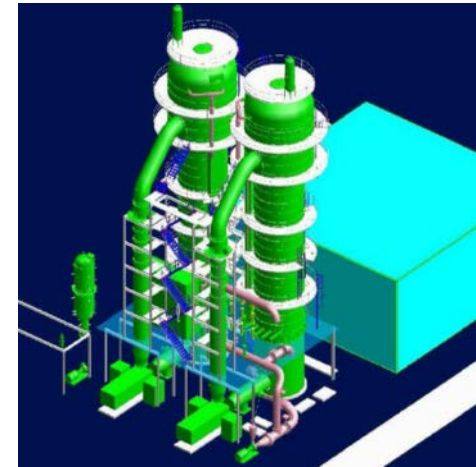
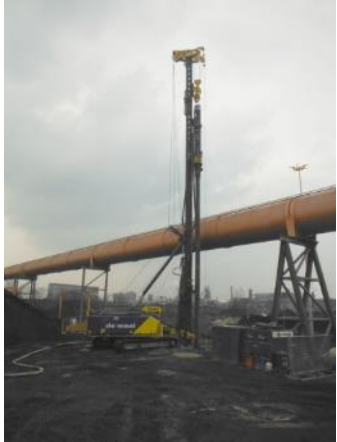


Potential of 300 kton EtOH/year = 380 MI/year = over 700 kT/y of CO₂ savings



The steel mill of the future will sell CO

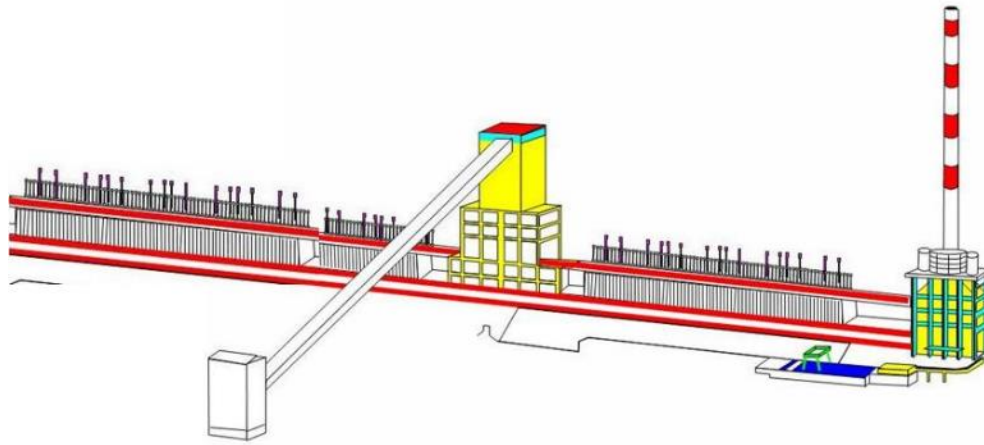
The Gent Ethanol plant



The steel mill of the future will need more H₂ - gas



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coke oven gas

Supply from
neighbouring chemical,
chlorine electrolysis
plant

by electrolysis or rSOEC

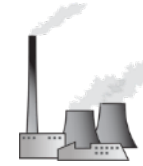


The steel mill of the future will sell CO₂ - derivatives

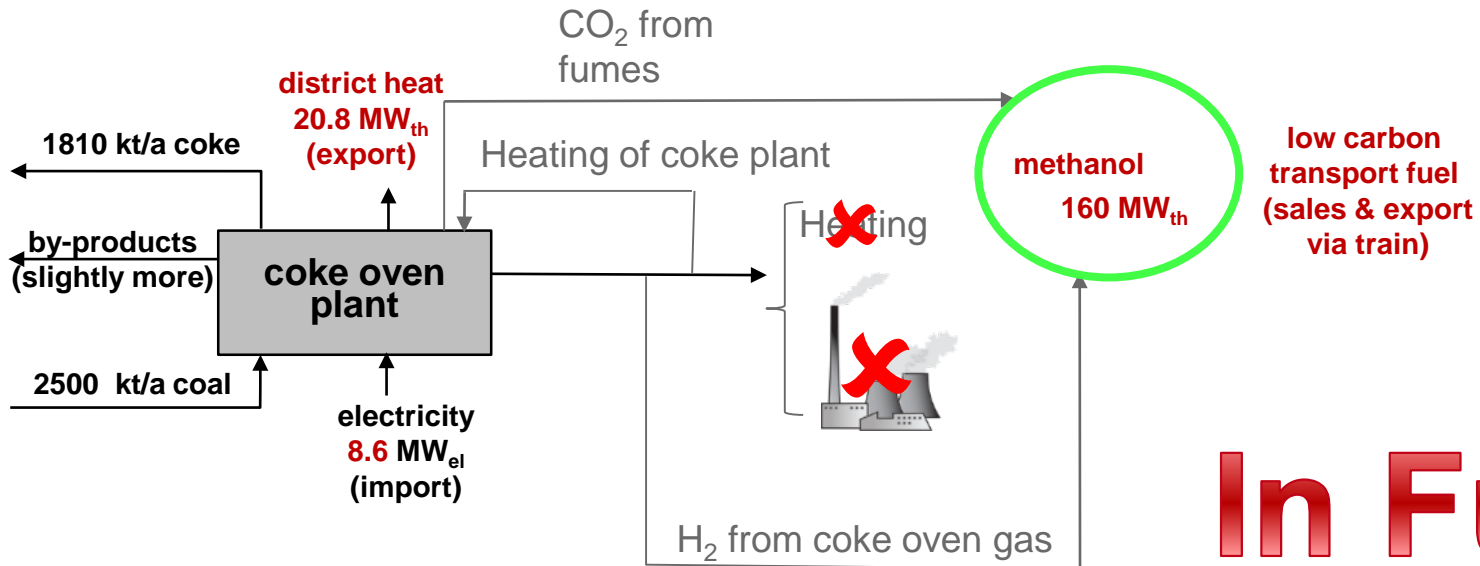
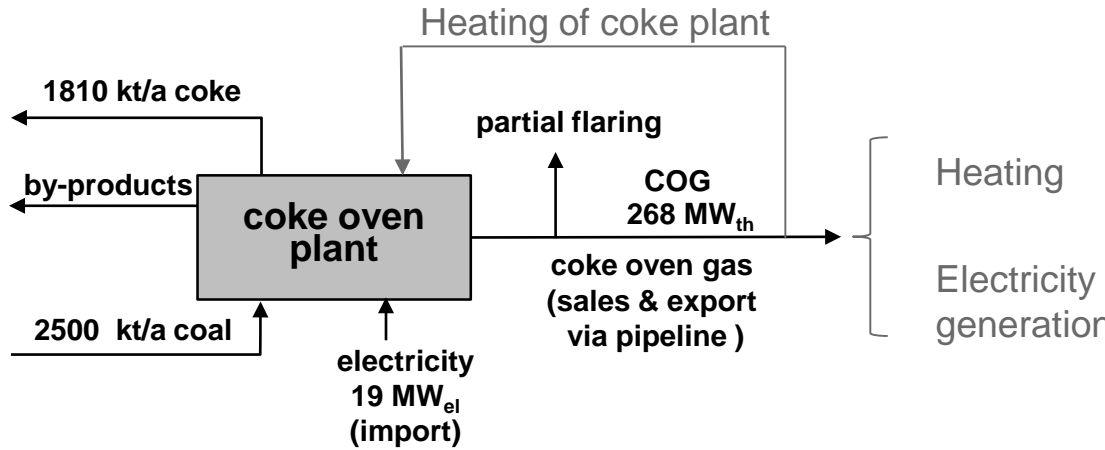


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Today

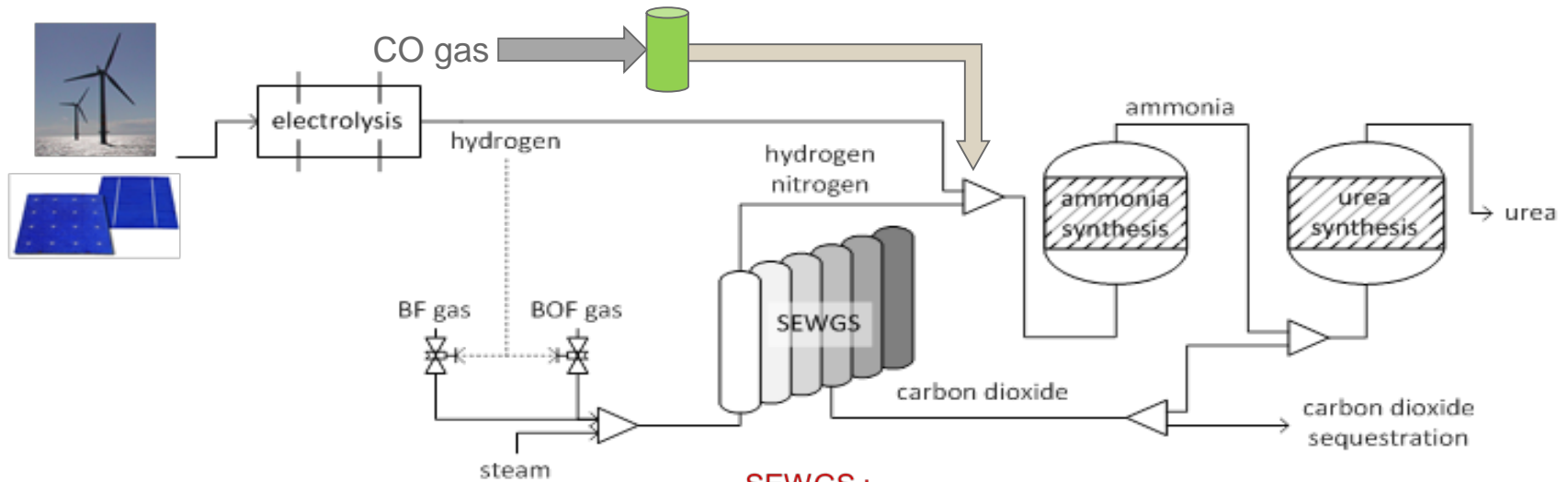


In a standby coal fired power plant

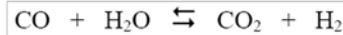


In Future

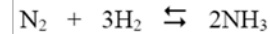
In integrated steel mills .. a combination of gases can be used



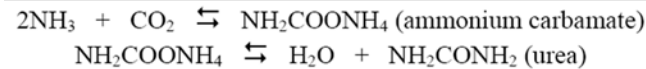
SEWGS :



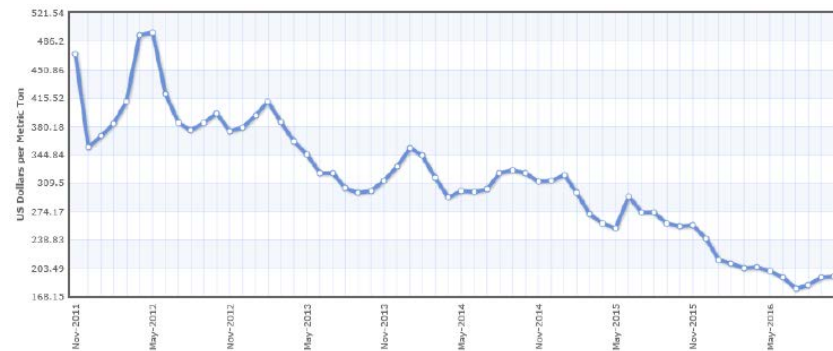
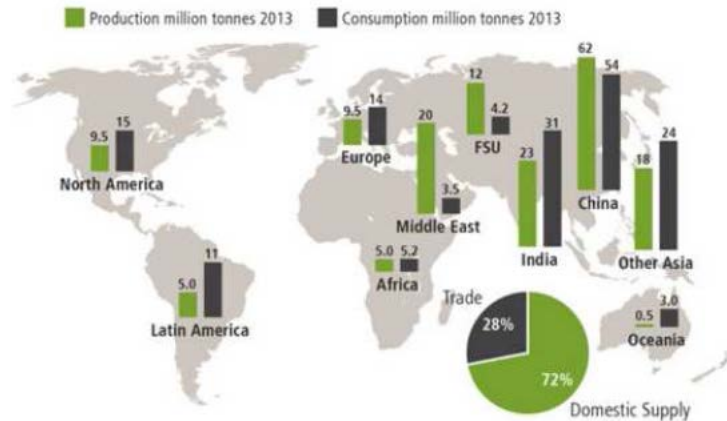
Ammonia production :



Urea production :



Global Urea Profile

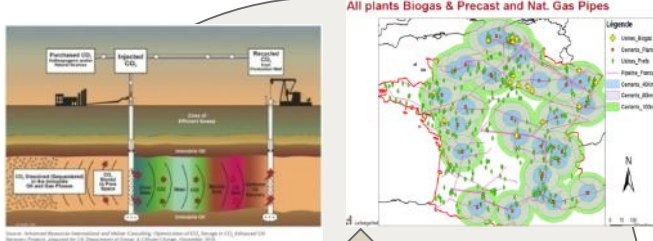


The steel mill of the future will sell CO₂



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C₂H₆O



Sale of the CO₂ (industrial gas supplier, green houses, EOR ...)



Photo 1: overview of the rotating batch autoclave



Carbonation minerals - slags - ...

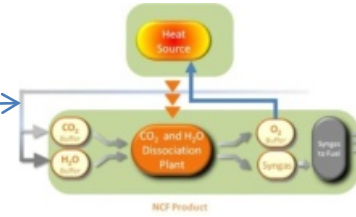
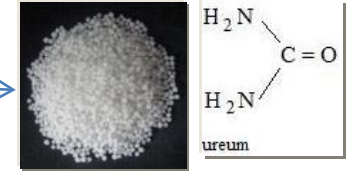


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Raw CO₂

Valorisation of steel mill CO₂



CO₂ high temperature electrolysis with renewable electricity

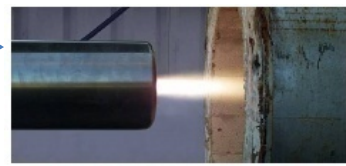


Figure 1: plasma flame of a 2 MW torch

CO₂ reforming in plasma torches with renewable electricity



In fact the EU regulations are promoting the fossil fuels and chemicals ... and are unjust to the new technologies the new EU regulations will now consider low C fuels



New: Definition

"Renewable liquid and gaseous transport fuels of non-biological origin" means liquid or gaseous fuels other than biofuels whose energy content comes from renewable energy sources, including biomass, and which are used in transport

No definition is given for "Carbon capture and storage" purposes if the fuel is "renewable" (Is a

NEW RED = waste based Fossil Fuel status proposal = 30/11/16

No legal support for CCU products from fossil gases ... and thus all these products cannot compete with their fossil equivalent

RED:

'energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases

(ff) 'waste-based fossil fuels' means liquid and gaseous fuels produced from waste streams of non-renewable origin, including waste processing gases and exhaust gases;

The steel mill of the future will connect to the CO₂-pipe

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Landfilling of steel mill CO₂

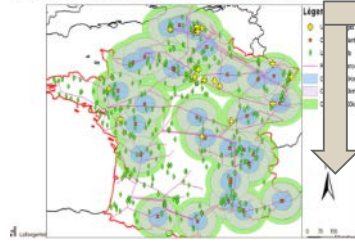
Raw CO₂



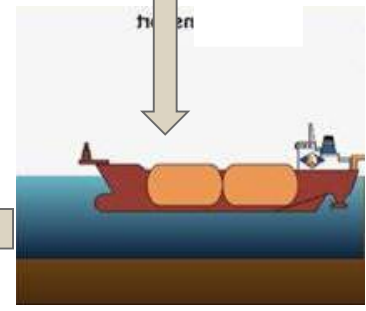
Public pipe from the authorities



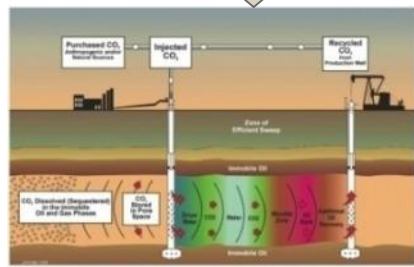
All plants Biogas & Precast and Nat. Gas Pipes



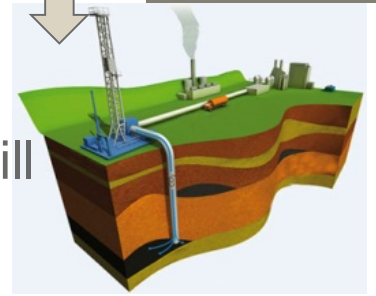
Other industries



08/04/2017



Public landfill = CCS



Source: Advanced Research International and other countries. Implementation of CO₂ Storage in Oil Refineries Pilot Plants, prepared by the US Department of Energy & Climate Change, November 2008



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The steel mill of the future Storage is not its core business .. so the authorities have to bear this responsibility...

- Still too many uncertainties : a lot more R&D is required
- Manage the social attitude towards CCS, too many bad examples already

Norway abandons Mongstad carbon capture plans

20 September 2013 Last updated at 18:10 GMT



Dutch officials stop Shell's CO₂ storage project
Ministry officials insist facility is safe, but bow to local opposition to the Barendrecht pipeline and gas reservoir.

By Agence France-Presse , Thu, Nov 04 2010 at 2:28 PM



Vattenfall Stops EUR1.5B Investment In German CCS Plant

Date: 06 Dec 2011; Source: [Wall Street Journal](#)

Vattenfall abandons Jaenschwalde Project in Germany



Ecofys: CO₂-opslag niet essentieel voor klimaatdoelen

DEUTSCHLAND CCS-TECHNIK OHNE CHANCE

Österreich verbietet CO₂-Speicherung

The Zero Emission plant....

Clean H₂
From COG,
electrolysis or excess
from chemical industry

Sale to chemical industry



Steel mill
gases
CO/CO₂/H₂

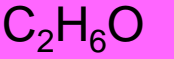
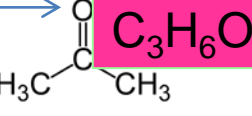
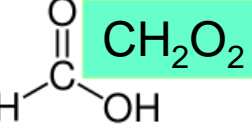
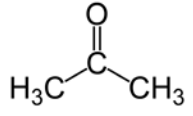
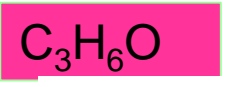
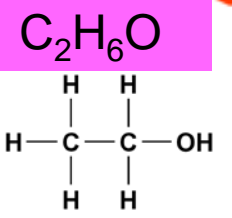
Clean CO/H₂



Clean
CO

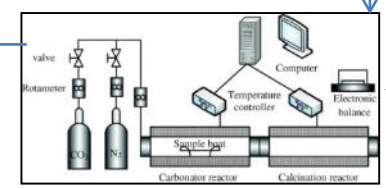
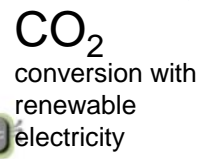


Arc



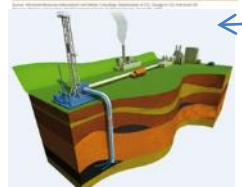
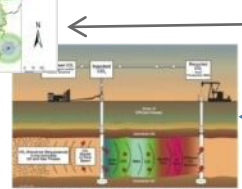
Ra

Clean CO₂/H₂

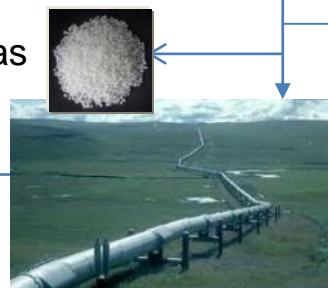


EOR

CSS



Sale to gas industry



Public pipe



Thank you for your attention

08/04/2017