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ArcelorMittal : possible pathways towards

THE LOW EMISSION PLAN(T)

July 2018

Largest steel producers (in mt crude steel)

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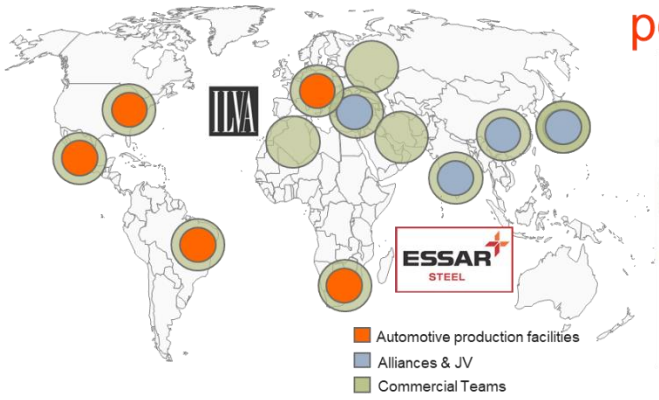
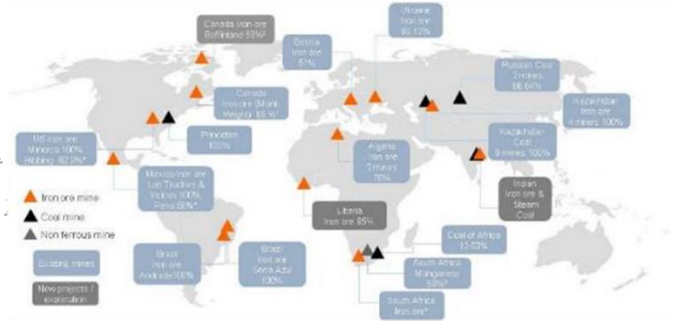
ArcelorMittal's industrial and commercial network



Mining business portfolio



* Source: Worldsteel

Agenda :

1. European history of steelmaking
2. Others are still at the very beginning of this history
3. What can Europe afford ?
4. Low emission principles
   a) Gas separation
   b) CO re-use by chemical industry
   c) CO_2-H_2-chemistry : new technologies
   d) CO_2 sale
   e) CO_2 storage
5. Some political issues

The challenge of the steel industry = C-footprint reduction

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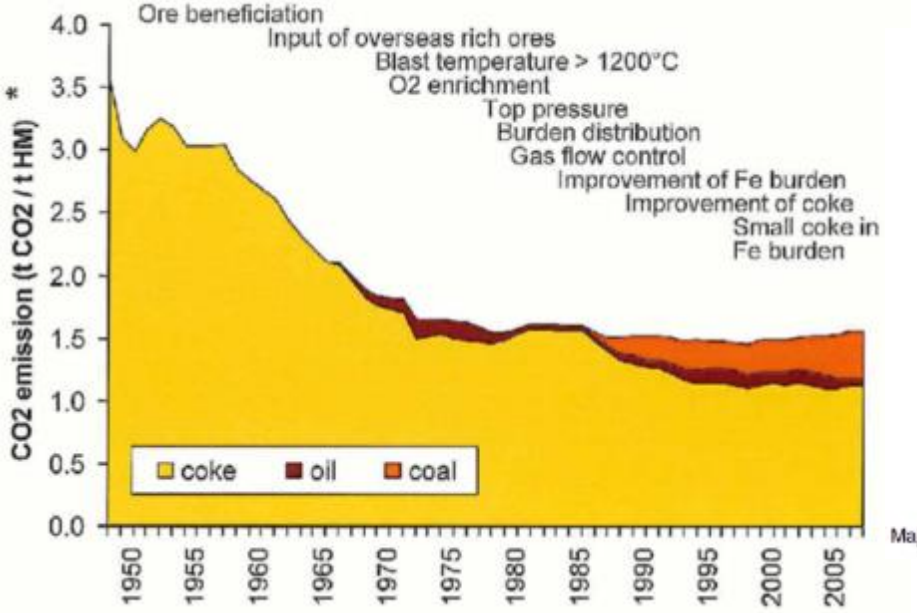
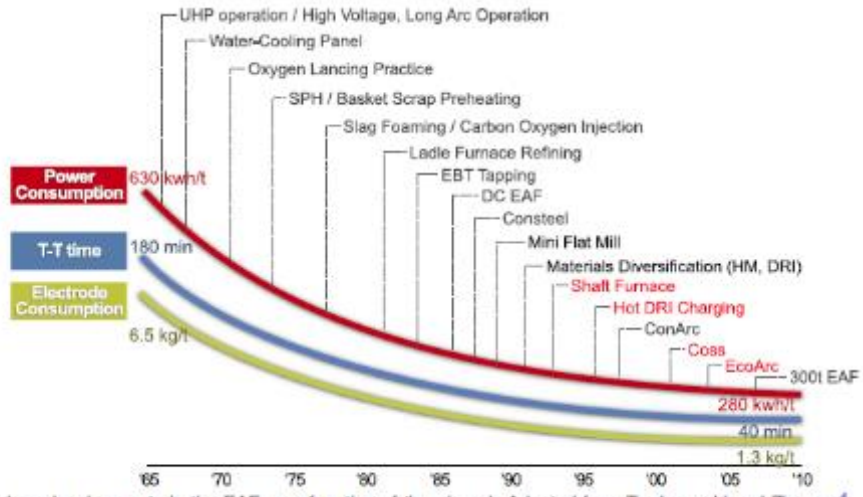
Conventional steel making = blast furnaces (BF)



Electrical steel making = electric arc furnaces (EAF)



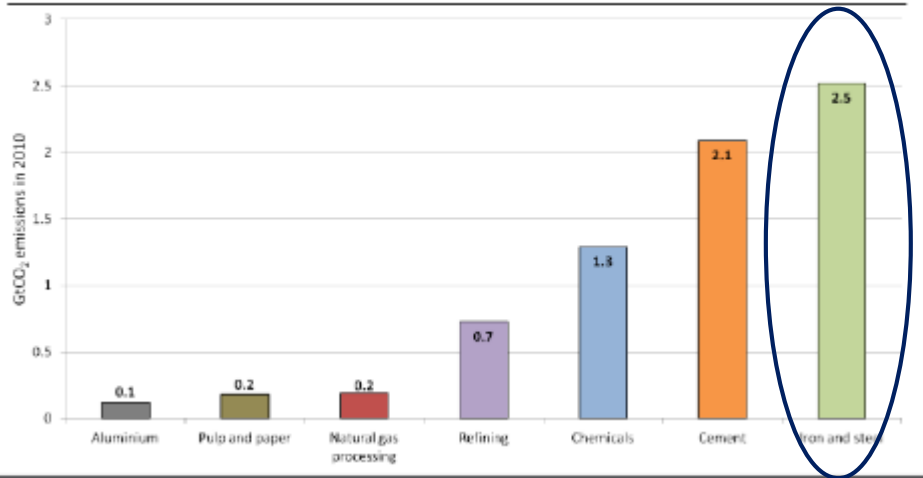
Major technology developments in the EAF as a function of time (year). Adapted from Toulouevski and Zinurov.[4]

1,8 billion tons of steel in 2018

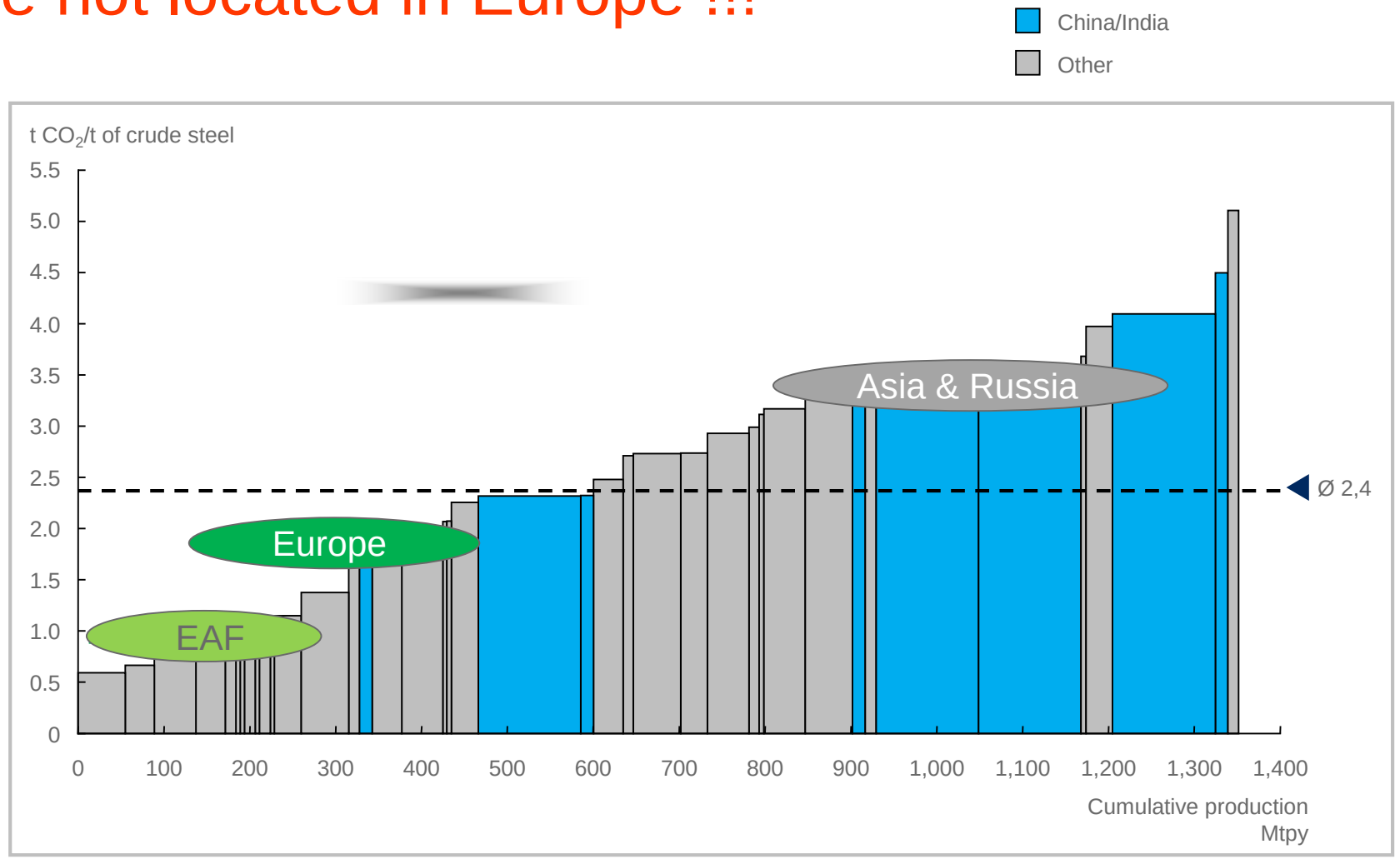
30% of industrial CO_2-emissions.
6,7% of anthropogenic CO_2-emissions

They are amongst the highest of industries….

Figure 1. Global emissions from the seven most CO_2-intense industrial sectors in the IEA *Energy Technology Perspectives* (*ETP*) analysis

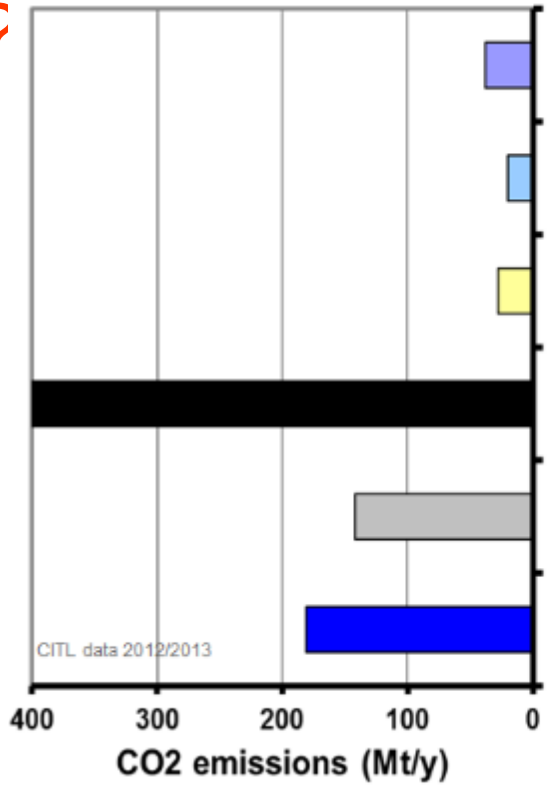


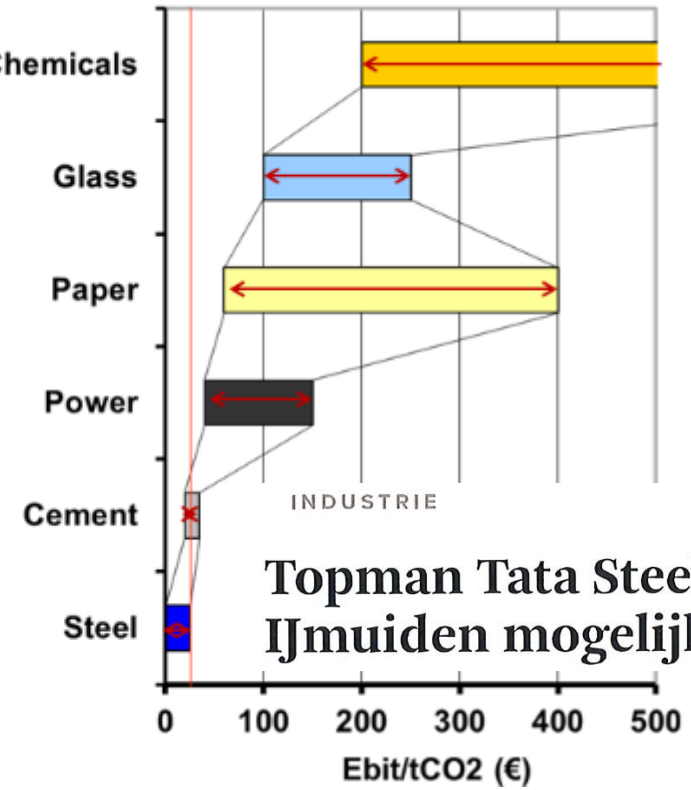
C-footprint reduction : the main emittors are not located in Europe !!!



global CO_2 curve

How much can Europe afford to stay in business ?





INDUSTRIE

Topman Tata Steel: 'Met CO_2-heffing moet IJmuiden mogelijk dicht'

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

$2C + O_2 \rightarrow CO + FeO \rightarrow Fe + CO_2$ $\quad CO_2 + C \rightarrow 2\,CO$

You can not lower the CO_2 emission from the steel industry by installing one more windmill… ETS is made for power generation, not for chemical processes !!!

Carbon can be re-used :

European Commission

Scientific Advice Mechanism (SAM)

Novel
carbon capture and utilisation technologies

Group of Chief Scientific Advisors
Scientific Opinion 4/2018

Scientific Opinion
Novel Carbon Capture and Utilisation Technologies

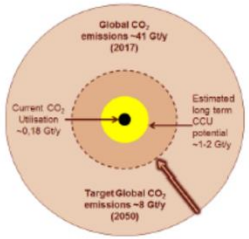


Figure 8 – Global CO_2 emissions and the role of CCU. The figure shows also the target global emissions for 2050 as well as a simplified estimation for the CCU potential including all the possible uses (simplified and adapted[21,22]).

CORESYM

CarbOn-monoxide RE-use through industrial SYMbiosis between steel and chemical industries

CORESYM

CarbOn-monoxide RE-use through industrial SYMbiosis between steel and chemical industries

CO-rich waste gases can be converted into products with a reduction of CO_2 emissions and other negative impacts.

Using waste gases as a feedstock, instead of for energy, can result in emission reductions from the production of energy and products of up to 21-34% compared to the baseline. In addition, the process of cleaning up waste gases for use as a feedstock also results in a concentrated stream of CO_2, which lends itself to Carbon Capture and Storage (CCS). While roughly a third of the direct emissions from waste gases can be mitigated through use as a feedstock, an additional third is made capture ready in the process. If CCS is impleme alongside waste gas recycling at a European scale could result in a reduction of up to 3% of Europear emissions. In addition to reducing CO_2 emissions, substituting waste gases for biobased feedstocks, demands, wastewater production, and land use ca reduced, with positive implications for biodiversity.

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Carbon Capture and Utilisation in industry refers to processes where CO_2 is captured and then converted into a new product. E-fuels can be an example where the CO_2 gets released again when the fuel is combusted, displacing emissions of fossil fuels. Other CCU products such as plastic and building materials exist, which contain the CO_2 for long periods of time.

Centre for Low Carbon Futures 2050

recent Risk Management position paper (DNV, 2011) states that using a variety of carbon utilisation technologies can potentially reduce annual CO_2 emissions by 3.7 Gt. This equates to approximately 10% of current annual CO_2 emissions. A 10% replacement of building materials by CO_2 captured in stable minerals would reduce CO_2 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.

Take home message

Trading renewable energy by using CO_2 has a potential impact on mitigation of climate changes of over 7 Gtons CO_2 equivalent.

Green Energy Trading

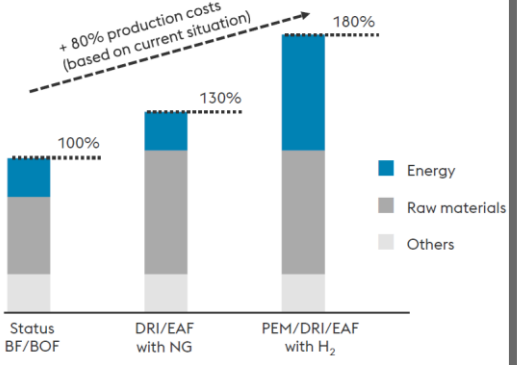
nova Institute for Ecology and Innovation

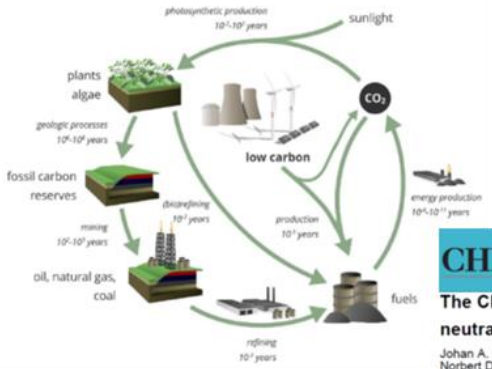
Hitchhiker's Guide to Carbon Capture and Utilisation

Carbon is expensive to replace (H_2) :

Investment costs with the example of voestalpine (7.5 million t/a)

- EUR 7 bn for breakthrough technology
- EUR 3 bn for electrolysis
- EUR 20 bn for renewable electricity generation (wind power)





CHEMISTRY & SUSTAINABILITY
CHEMSUSCHEM
ENERGY & MATERIALS

The Chemical Route to a CO_2-neutral world

Johan A. Martens,[a-c] Annemie Bogaerts,[b,c] Norbert De Kimpe,[b,c] Pierre A. Jacobs,[b,c] Guy B. Marin,[b,c] Korneel Rabaey,[c] Mark Saeys[a,c] and

The different steps of the Zero Emission Plan(t) concept of ArcelorMittal

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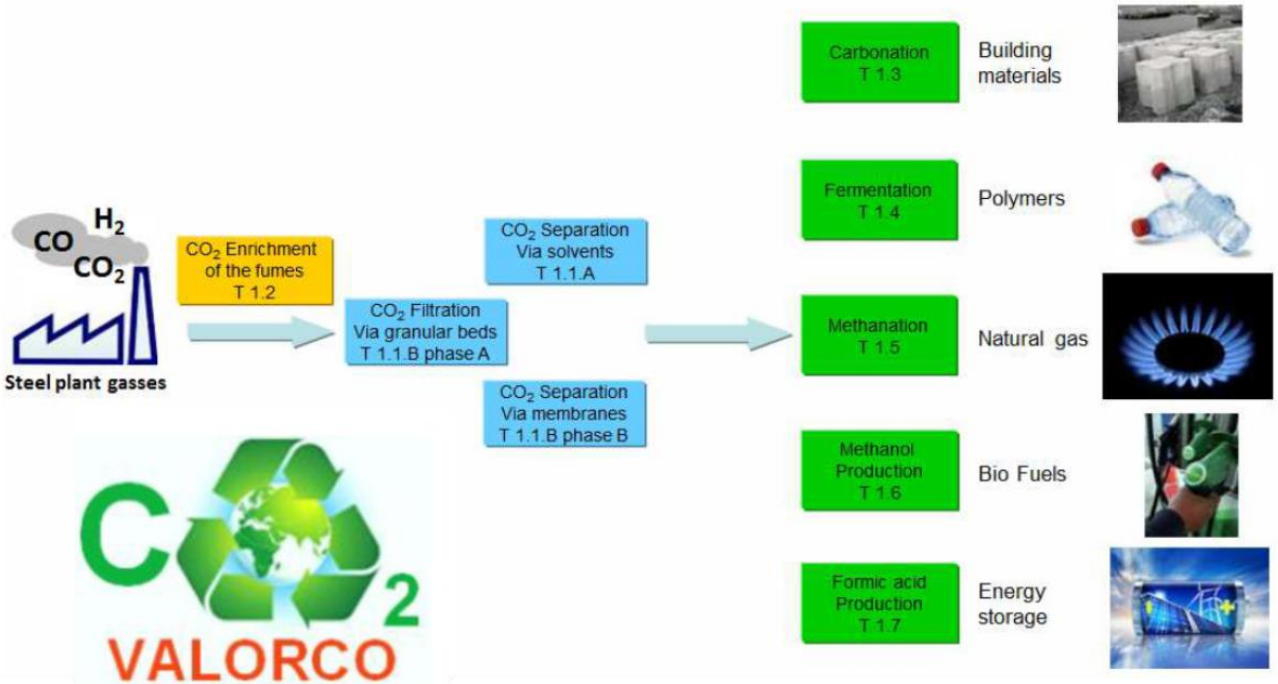
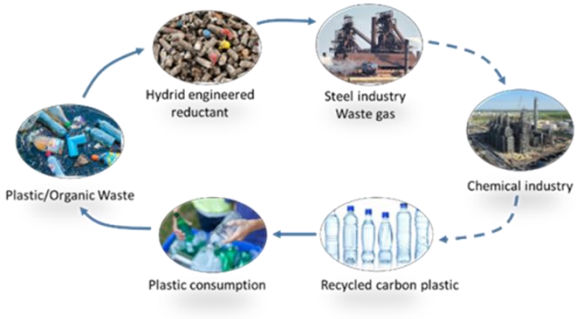
Steel mill gas → Gas separation → CO (+ H_2) re-use; CO_2 + H_2 re-use; CO_2 fixation; CO_2 storage → Circular economy





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The steel mill of the future …. will still produce gasses

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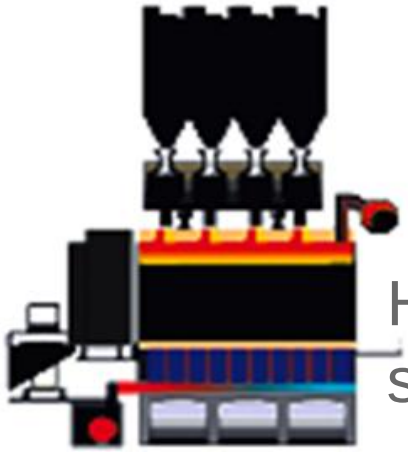
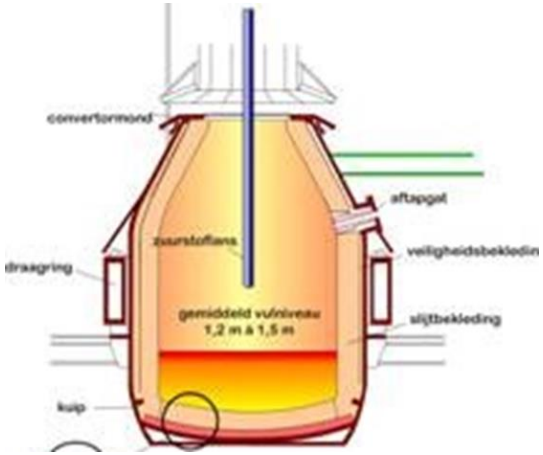
Coke Oven gas



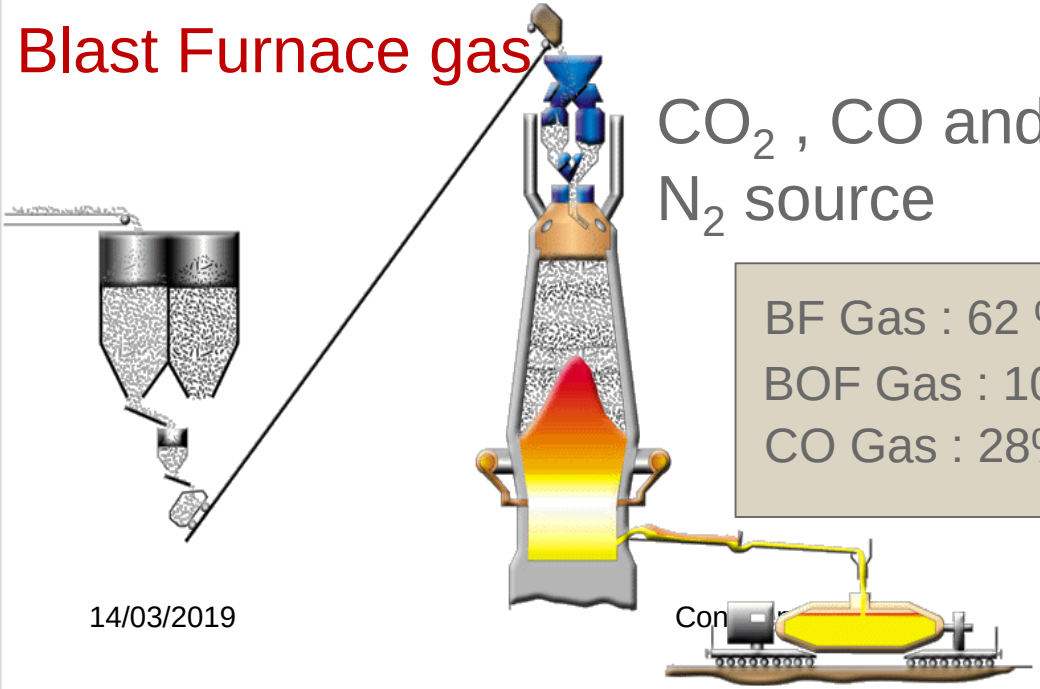
H_2 and CH_4 source

Basic Oxygen Furnace gas



CO source

Blast Furnace gas



CO_2 , CO and N_2 source

BF Gas : 62 %
BOF Gas : 10%
CO Gas : 28%

52% of the gas energy replaces natural gas in the plant

Power plant : 48%

Peak name
Benzene
Toluene
Ethylbenzene
p-Xylene
m-Xylene
o-Xylene
DCPCD
Styrene
Ethylacetylene
Vinylacetylene
Hydrogensulfide
Corbonylsulfide
Methylmercaptan
Carbondisulfide
Thiophene
Ethane
Ethylene
Propane
Propylene
iso-Butane
n-Butane
Acetylene
trans Butene-2
1-Butene
iso-Butene
cis Butene-2 + Neopentane*
n-Pentane
Butadiene 1-3
Methyl Acetylene

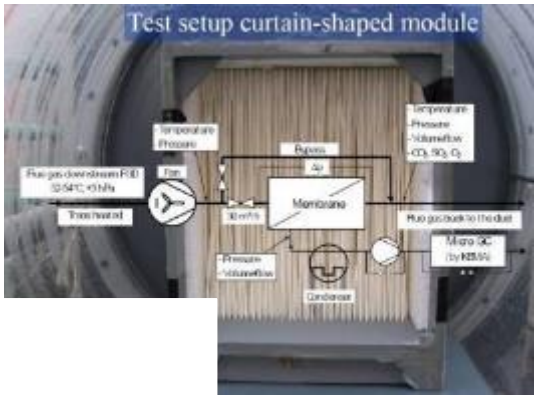
The steel mill of the future …. will provide the single gas components

Steel mill gases $CO/CO_2/H_2/N_2$

DMEA Solvents

(V)PSA

AM Saldanha Works VPSA



MEMBRANE

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

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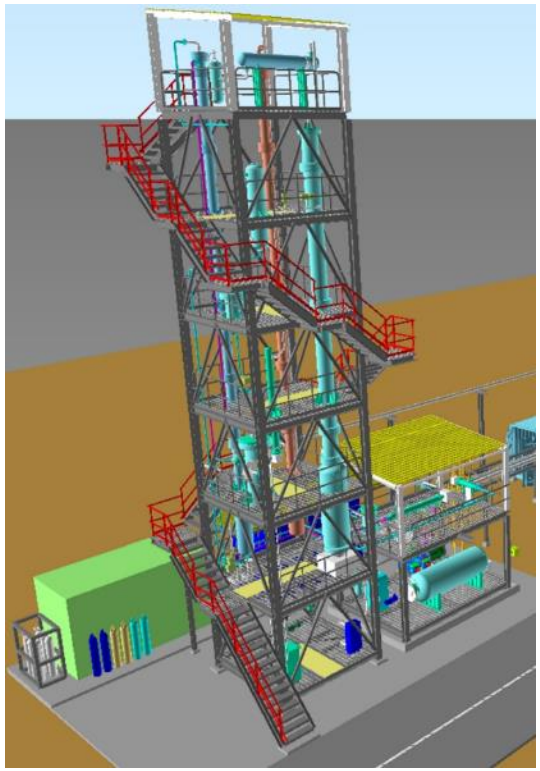
3D : pilot project 2019 – 2023 (Dunkirk)

pré-FEED done by IFPEN



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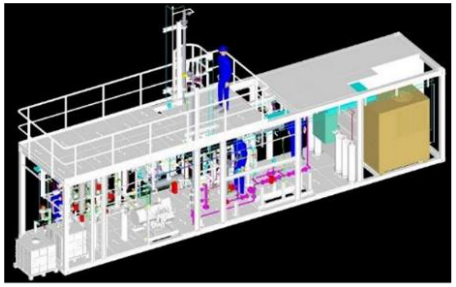
IFPEN mini-pilot in Solaize

Carbon2Value : pilot project 2018 – 2020

INTERREG sponsored project

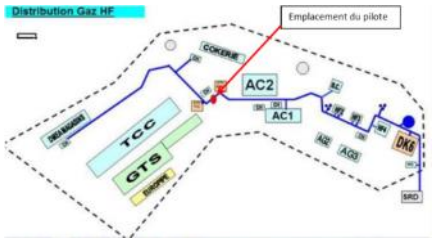


GENESIS : pilot project 2019 – 2021

Membrane separation :

genesis

Capture of 0,5 t/h CO2 from 1.100 Nm³/h BF-gas to study feasability

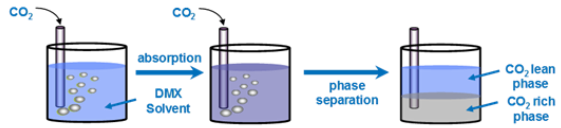


IFP Energies nouvelles

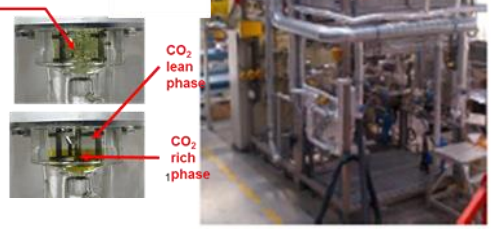
Carbon capture : from the lab (VALORCO) to the AMAL plant (3D): overview

DMX™ process

Use of solvents capable of demixing under specific conditions



Stage 0 : lab
Parameter check of DMX



IFPEN mini-pilot in Solaize

Stage 1 : lab pilot
Check of DMX on syn BF Gas

ifp Energies nouvelles

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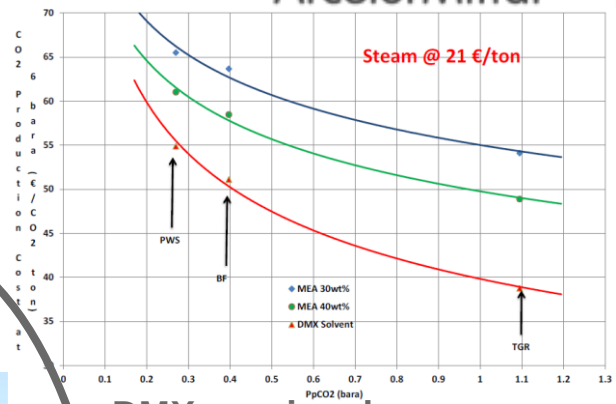
Conclusion : ArcelorMittal



DMX requires less energy (2,4 GJ/t) than MEA (3 GJ/t) to capture CO_2 from BF Gas. Hence cost decrease of 10 – 15 €/t CO_2

Stage 2 : 3D
Industrial pilot
0,5 t/h CO_2

Stage 3 : 3D
Industrial demonstrator
100 – 120 t/h CO_2

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HORIZON 2020

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

INNOVATION FUND
Driving clean innovative technologies towards the market

14/03/2019

Different stages :

The steel mill of the future …. will sell CO

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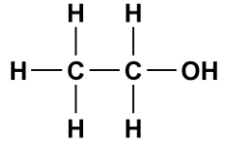
Valorisation of steel mill CO

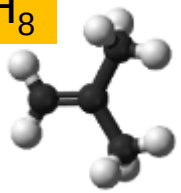
Sale to chemical industry
Conversion into valuable hydrocarbons

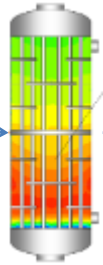
C_2H_6O



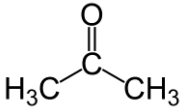
H_2- sources =
- Coke Oven gas
- H_2 surplus from chemical partner
- Electrolysis

C_4H_8





C_3H_6O

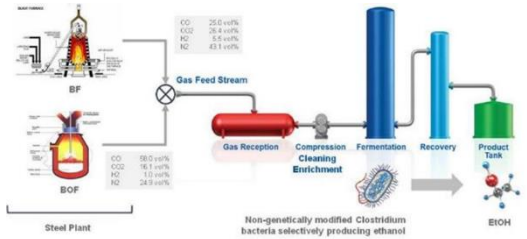


14/03/2019

The steel mill of the future …. will sell CO

The Gent Ethanol plant

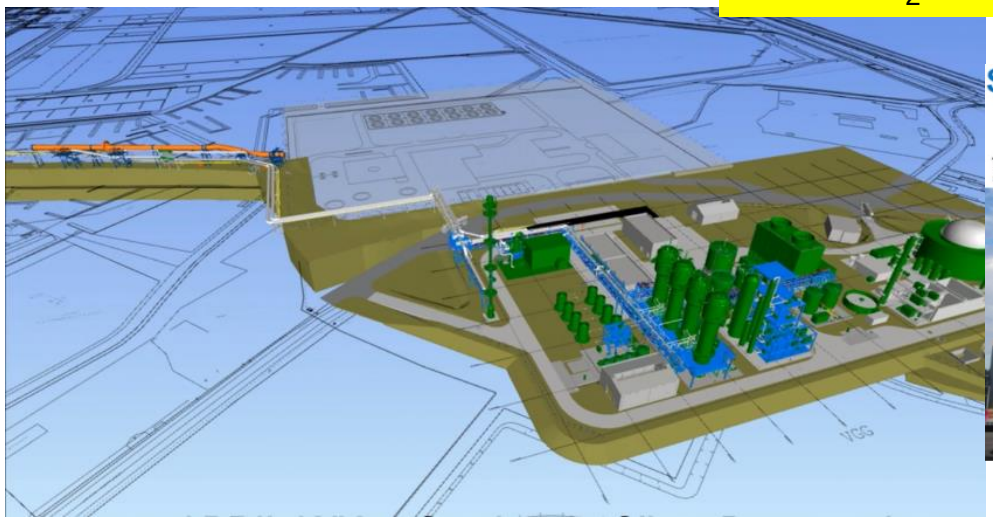
Steelanol
Fueling a sustainable future



Potential of 300 kton EtOH/year = 380 Ml/year= over 700 kT/y of CO_2 savings

CCU
CCS

EtOH production = X T/y
CO_2 avoided = 2,1 X T/y
CO_2 captured = 6,6 X T/y
Total CO_2 = 8,7 X ton/y

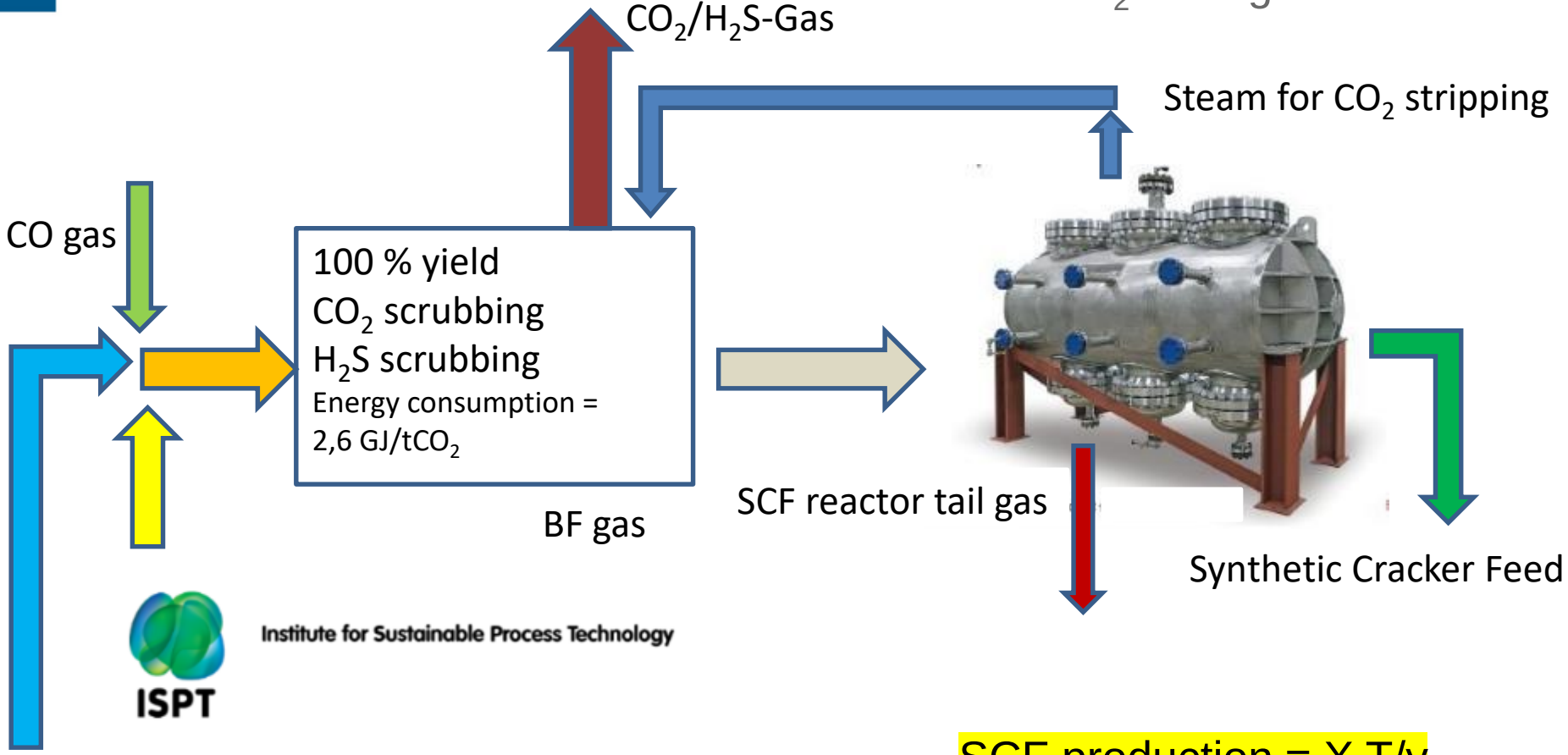


Shougang Commercial Plant

The steel mill of the future …. will sell CO

Rijksdienst voor Ondernemend Nederland

CAPEX = 10% of investment cost of wind energie, for the same CO_2 saving



CCU
CCS

SCF production = X T/y
CO_2 avoided = 3 X T/y
CO_2 captured = 7 X T/y
Total CO_2 = 10 X ton/y

The steel mill of the future …. will sell CO_2 - derivates

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Valorisation of steel mill CO_2

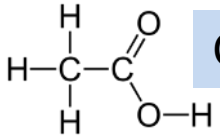
Fuels - chemicals

Raw CO_2

H_2- sources =
- Coke Oven gas
- H_2 surplus from chemical partner
- Electrolysis

CH_4

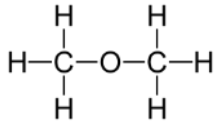
$C_4H_8O_2$

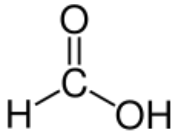


CH_3COOH + C_2H_6O

H_3COH

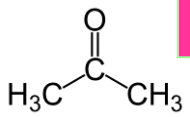
H_3COCH_3

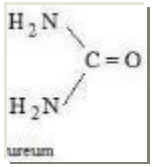


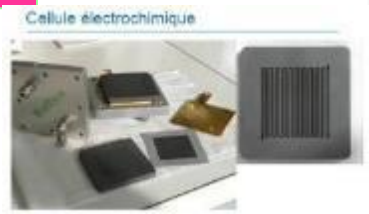


CH_2O_2

C_3H_6O







The steel mill of the future …. will sell CO_2 - derivates

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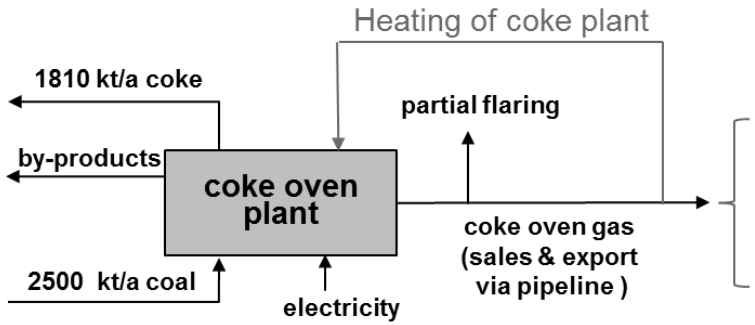
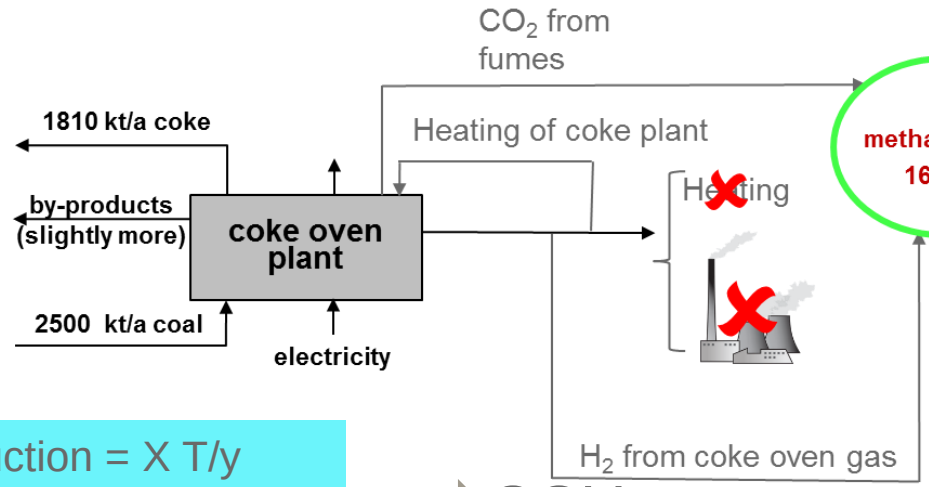


Today

In a standby coal fired power plant



recycled carbon transport fuel

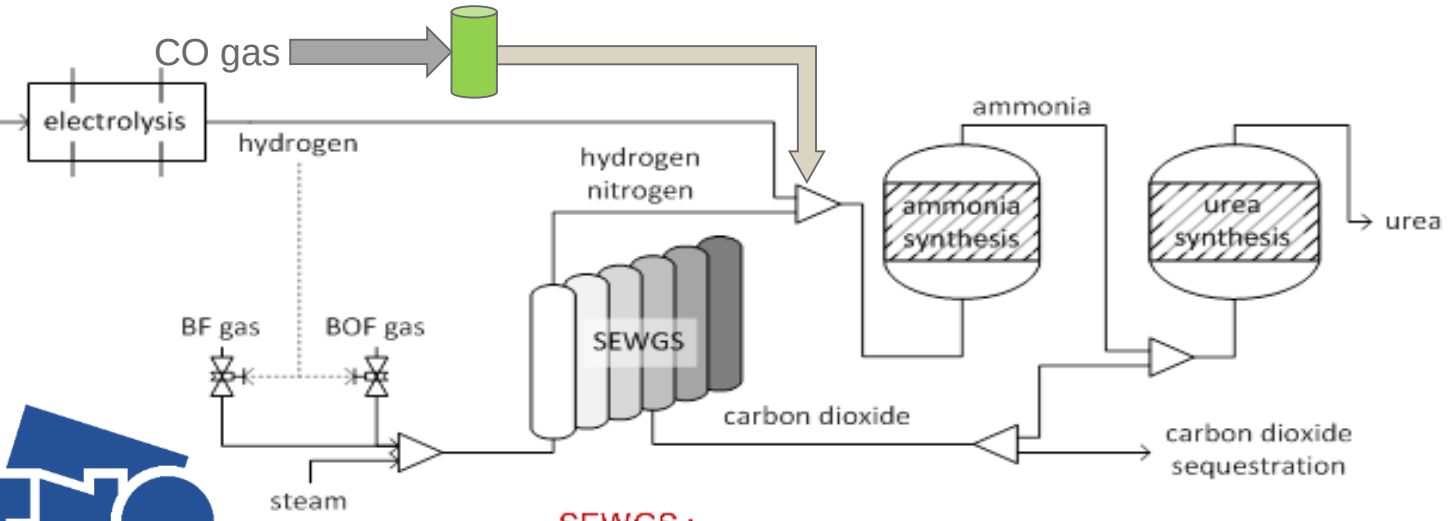
In Future

MeOH production = X T/y
CO_2 avoided = 1,3 X T/y
CO_2 captured = 1,3 X T/y
Total CO_2 = 2,6 X ton/y
+ additional PP closure
Total CO_2 = 7 X ton/y

CCU
CCS

C2VALORCO

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



ECN

TNO

SEWGS :

$CO + H_2O \leftrightarrows CO_2 + H_2$

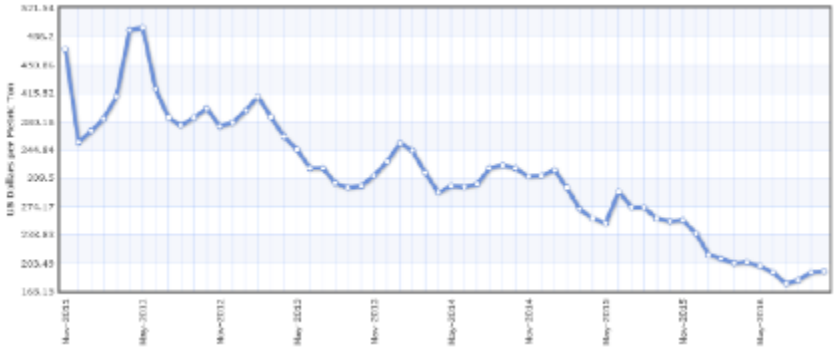
Ammonia production :

$N_2 + 3H_2 \leftrightarrows 2NH_3$

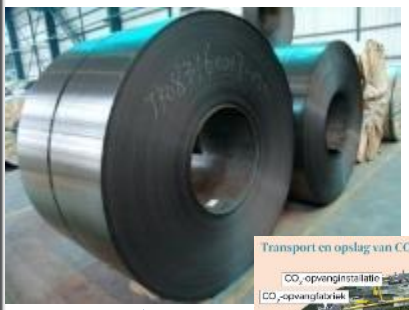
Urea production :

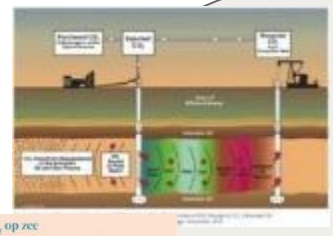
$2NH_3 + CO_2 \leftrightarrows NH_2COONH_4$ (ammonium carbamate)

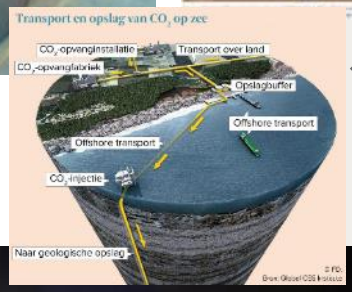
$NH_2COONH_4 \leftrightarrows H_2O + NH_2CONH_2$ (urea)

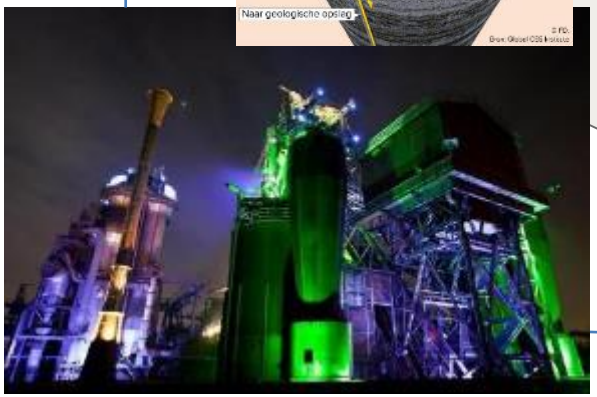


The steel mill of the future …. will sell CO_2









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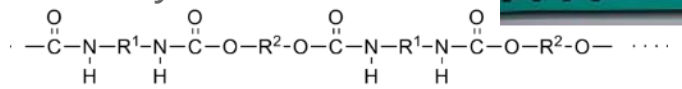
C_2H_6O

Sale of the CO_2 (industrial gas supplier, green houses, EOR …)

Carbonation minerals – slags - ..

Polyurethane



14/03/2019

Raw CO_2

Valorisation of steel mill CO_2

CO_2 high temperature electrolysis with renewable electricity

CO_2 reforming in plasma torches with renewable electricity

CO + H_2

The steel mill of the future …. will sell CO_2

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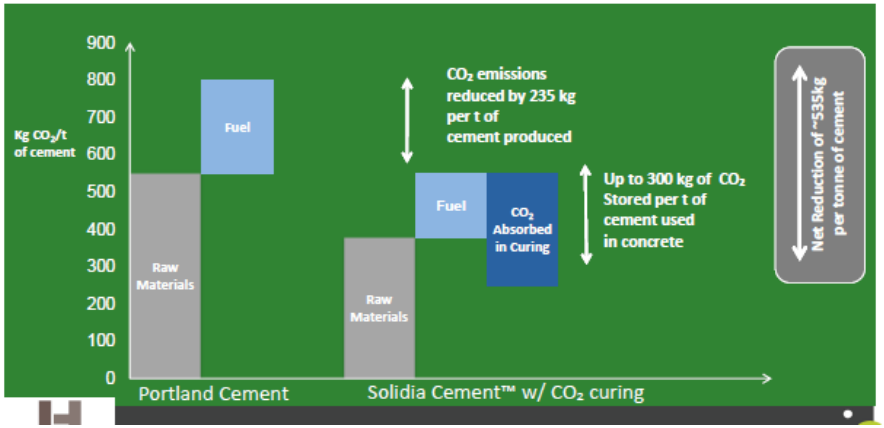
LafargeHolcim

PCC production

Up to 70% reduction in CO_2 footprint/t of cement used in concrete



CO_2 VALORCO

Carbon8

CRH

RECOVAL

INDUSTRIAL PRODUCTION IN THE NETHERLANDS

CO_2Mpensatie steen

Carbon4PUR

SPIRE
Sustainable Process Industry through Resource and Energy Efficiency

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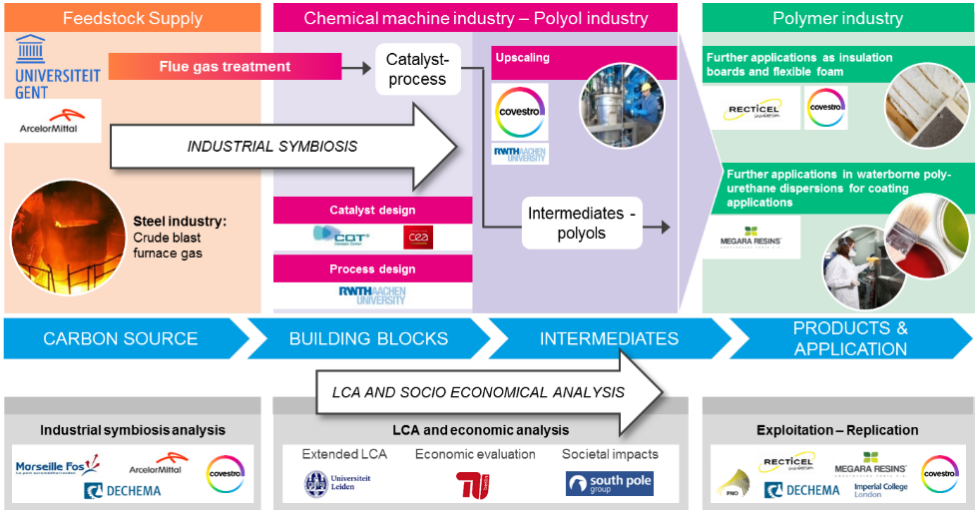
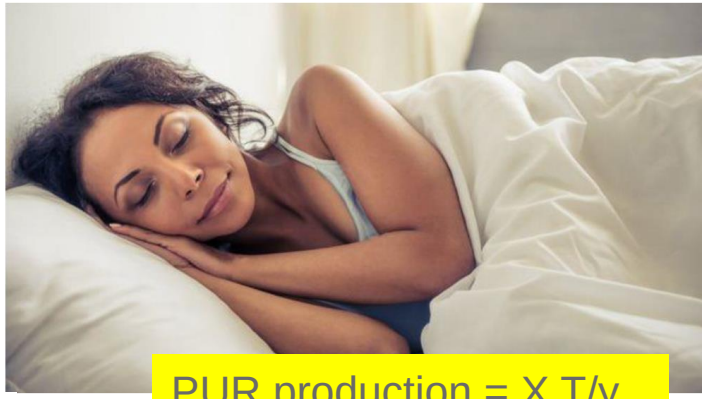
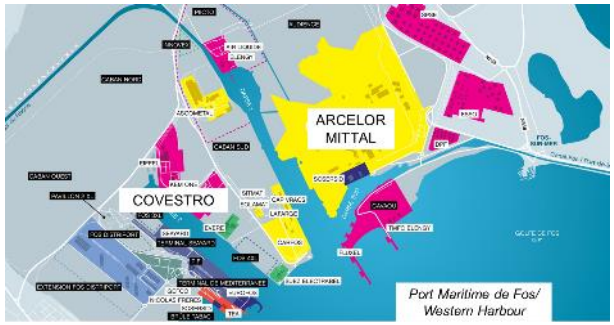




PUR production = X T/y
CO_2 avoided = 0,2 X T/y

CCU

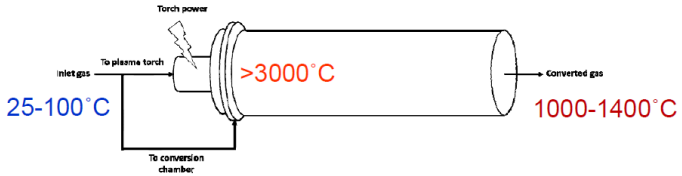


ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

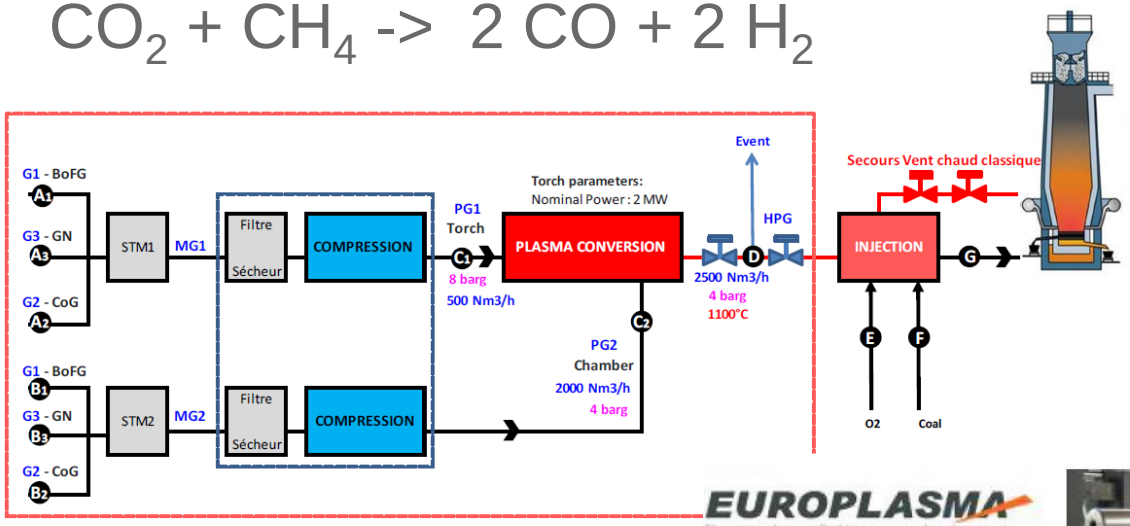
Vasco2I

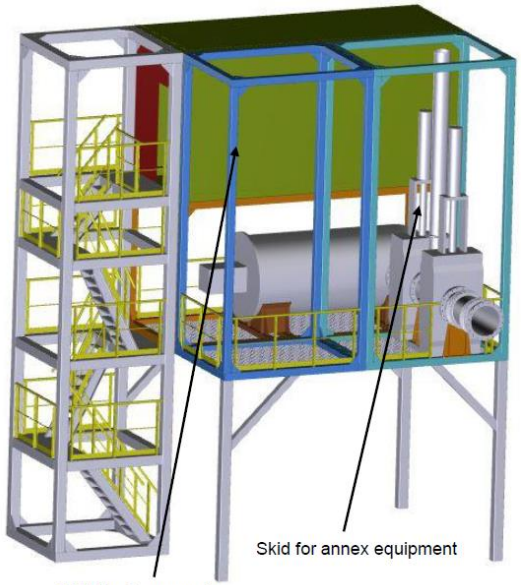
Photo 3 : Bassin 10 m² de culture de micro algues marines avec fumées industrielles – site Arcelormittal.

IGAR project at AMAL Dunkirk



$$CO_2 + CH_4 \rightarrow 2\,CO + 2\,H_2$$

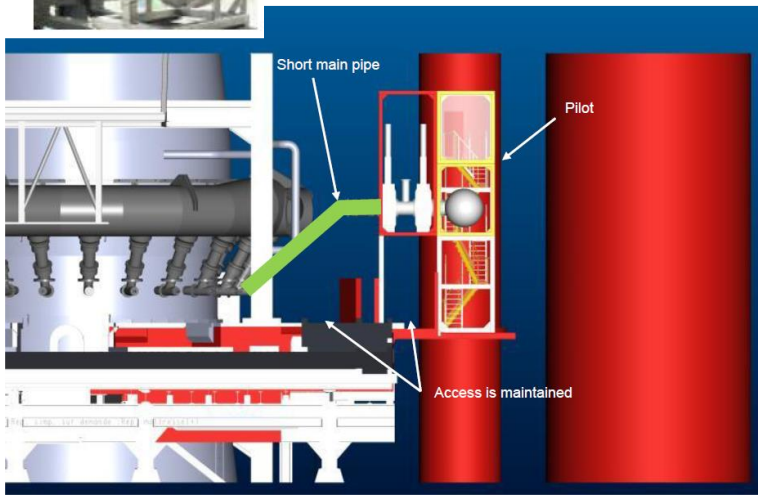




EUROPLASMA
Plasma torches applied to energy and environment

DK HF2 Situation – Outside view

View of BoFG, CoG, O2 connections (pipes to be installed)



The steel mill of the future …. may have a legal problem
… and no market for its products

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RED 2 : 2020 - 2030 Recycled Carbon Fuels

Many of these products will cost more than the fossil products

1. The LCA-methodology has to be defined and accepted in a delegated act. The minimum threshold of GHG reduction is not yet fixed (renewable electricity is privileged for transport = EV)

2. Member states can decide themselves if they allow Recycled Carbon Fuels in the energy mix for transport

3. The CO_2 taxes for re-used carbon may not be eliminated (ETS)

EUROPEAN COMMISSION

The promotion of recycled carbon fuels can also contribute towards the policy objectives of energy diversification and transport decarbonisation when they fulfil the appropriate minimum greenhouse gas savings threshold. It is therefore appropriate to include those fuels in the obligation on fuel suppliers, whilst giving Member States the option not to consider these fuels in the obligation if they do not wish to do so. Since those fuels are of non-renewable nature, they should not be counted towards the overall EU-target for energy from renewable sources.

greenhouse gas emission savings from renewable liquid and gaseous transport fuels of non-biological origin and recycled carbon fuels, which shall ensure that no credit for avoided emissions be given for carbon dioxide whose capture already received an emission credit under other legal provisions.

The steel mill of the future …. Conclusions :

1. A quick increase of renewable electricity capacity in the EU is to be installed

2. A clear and unambiguous LIFE CYCLE ASSESSMENT methodology is necessary (DG Energy : start 2018)

3. This will allow us to calculate the real CO_2 abatement potential of the new technologies, and rank them for support measures

4. This will determine a CO_2 support price to deploy new technologies

5. This will create new industries, jobs, .. and make Europe less depending from energy from other continents (gas, oil, coal,)

6. As as result the EU will have cleaner air to breathe

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

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- Still to 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 CO_2 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


Herald Sun
Sun
MELBOURNE
NEWS SPORT ENTERTAINMENT BUSINESS LIFESTYLE VIDEO CLASSIFIEDS
BUSINESS
Australia's carbon tax has gone for good

Ecofys: CO_2-opslag niet essentieel voor klimaatdoelen

DEUTSCHLAND CCS-TECHNIK OHNE CHANCE

Österreich verbietet CO_2-Speicherung

The Zero Emission plant….

Steel mill gases $CO/CO_2/H_2$

Clean H_2
From COG, electrolysis or excess from chemical industry

Clean CO/H_2

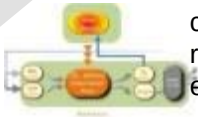
Sale to chemical industry

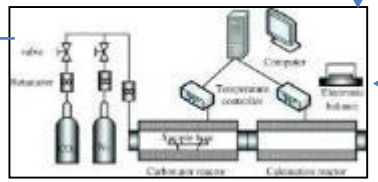
Clean CO_2/H_2

Clean CO

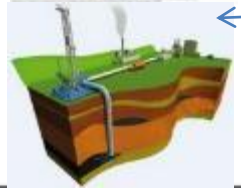
Ra…

CO_2 conversion with renewable electricity





EOR

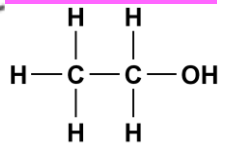


CSS

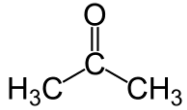
Sale to gas industry

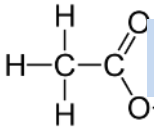
Public pipe

C_2H_6O



C_3H_6O

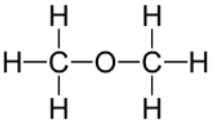




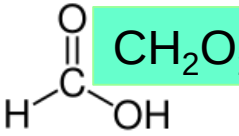
CH_3COOH

H_3COH

H_3COCH_3



CH_2O_2



C_3H_6O

C_2H_6O

Thank you for your attention