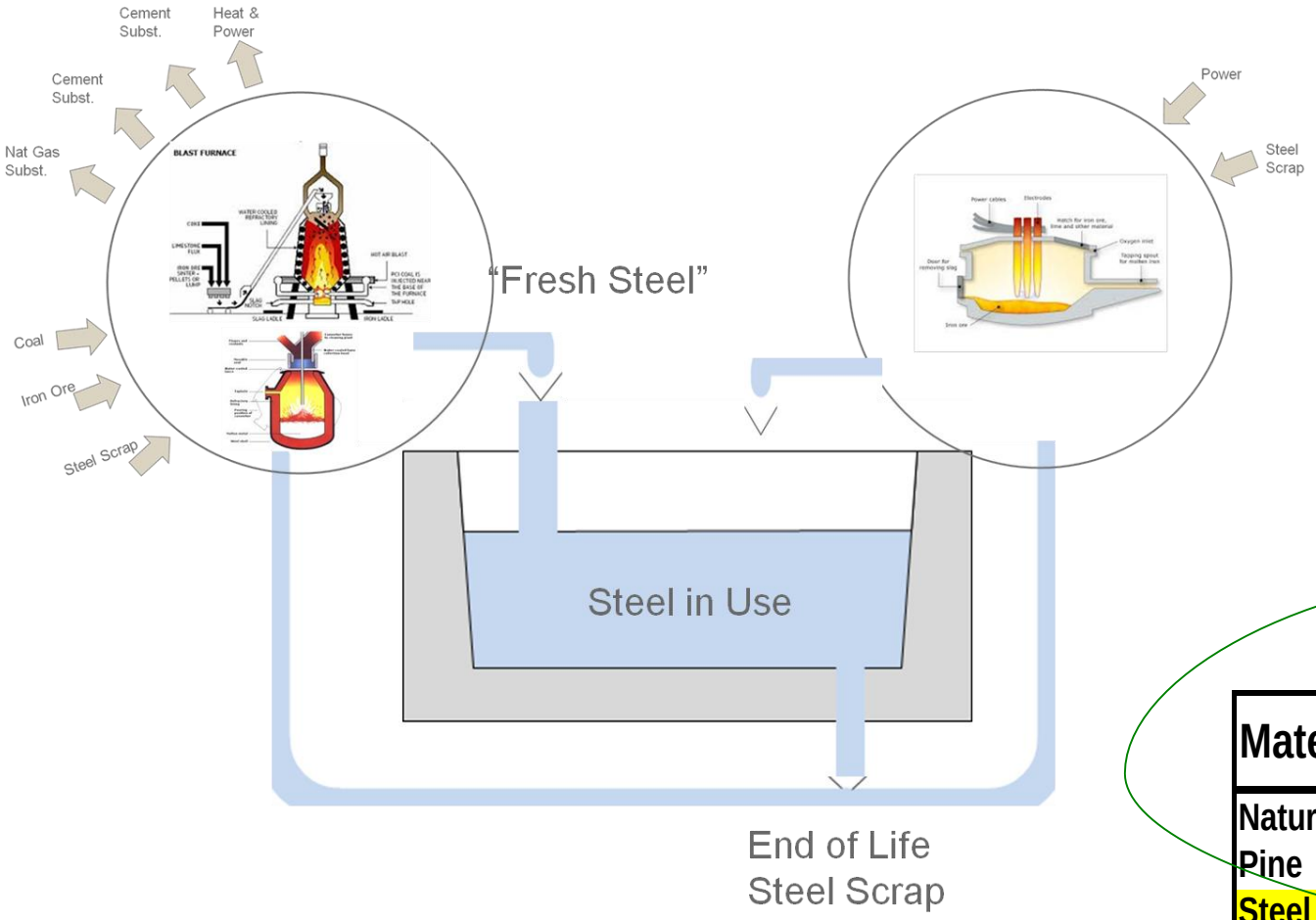
Low C steelmaking in ArcelorMittal

Roundtable on Low C innovation in Fe metals, February 17th, 2017, Brussels

Steel has over its life cycle the lowest CO2 emissions of all man-made materials



1.37 tCO2/t milk

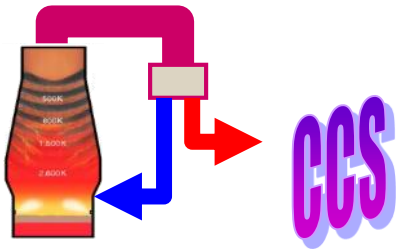
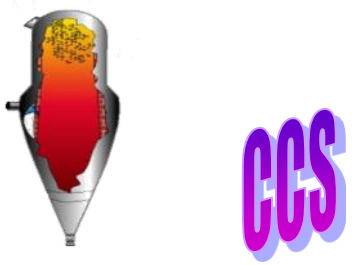
Material*	Primary CO2 tCO2/t	Life Cycle CO2 tCO2/t
Natural Stone	0.2	0.2
Pine	0.45	0.45
Steel	2.5	0.86
Clincker	0.9	0.9
Carbon fibre	17	17
Ti	40	17

*Elaboration on M. Ashby Materials and the Environment

ULCOS

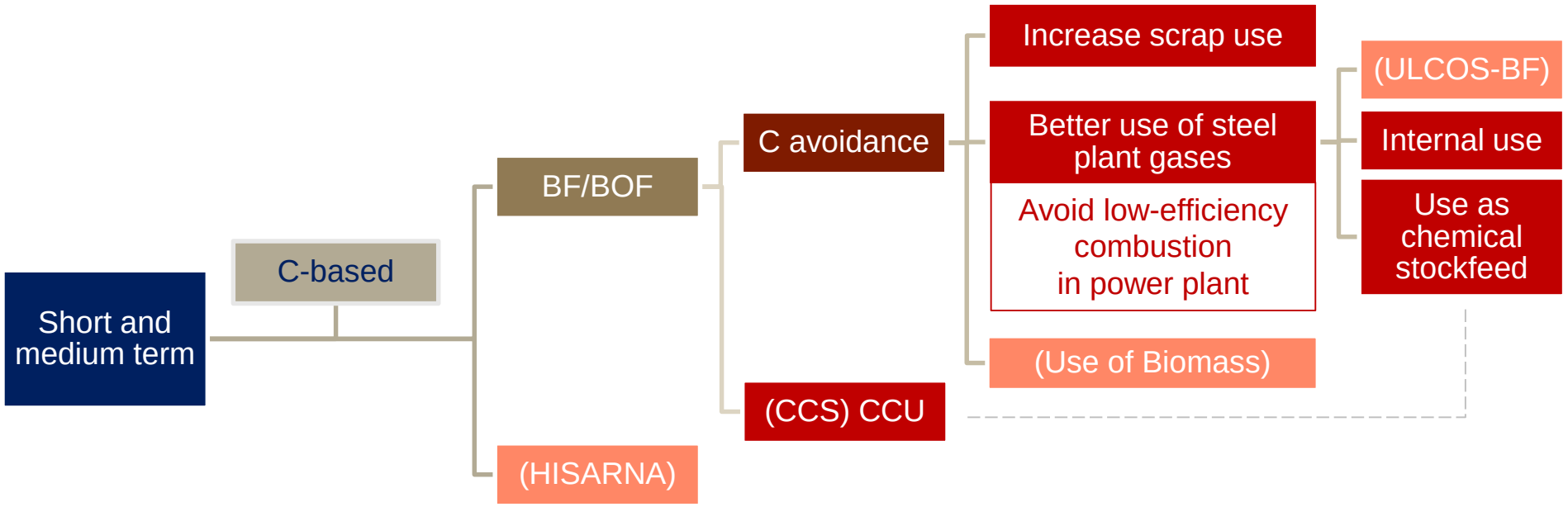
Since its early days (2002), AM is leading the ULCOS consortium

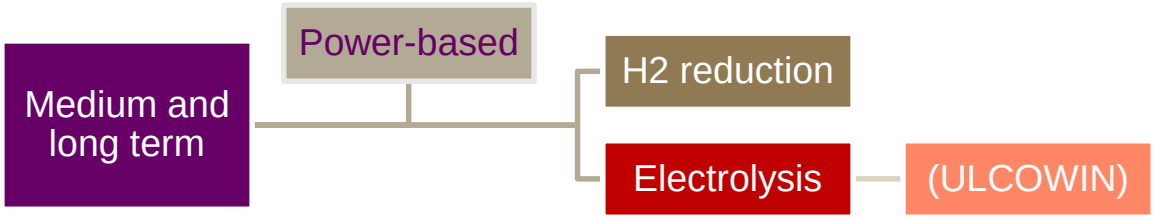
devoted to the development of breakthrough steel production routes to mitigate GHG emissions by more than 50%

Coal & sustainable biomass		Natural gas	Electricity
Revamping BF	Brownfield	Revamping DR	Greenfield
ULCOS-BF 	HIsarna 	ULCORED 	ULCOWIN ULCOLYSIS 
Pilot tests (1.5 t/h) Demo project: "no go" in NER300 Additional work on technical issues and CCUS	Pilot plant (8 t/h): 5th campaign S1 2017 Plans for demo phase	Pilot tests POx Pilot plant (1 t/h): no financing for erection to date	Small pilot & lab: scale-up on-going

Current Vision and efforts

GHG reduction strategy for primary steelmaking in EU





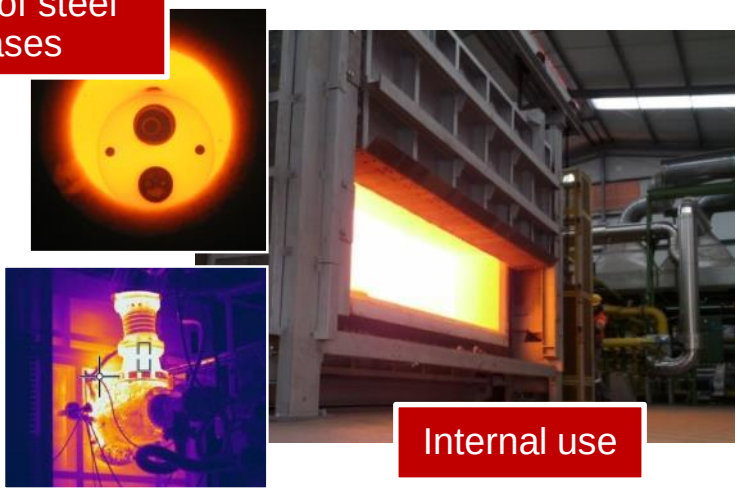
Zero CO2 emission potential
but requires breakthrough in steel production
and availability of green power

Current Vision and efforts

GasLab Asturias – Combustion laboratory

- Industrial validation of combustion systems running on low calorific gases (e.g. 100% BFG), including double pre-heating burners
- Network with main burner suppliers
- 24/7 long-term testing 500 m^2 industrial test-rig
- Availability of real steel plant gases, blending options.

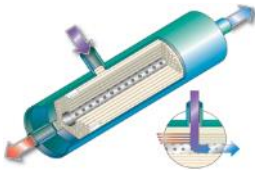
Better use of steel plant gases



Internal use

VALORCO project in France

- Testing of CO2 separation Technologies
  - Advanced amine process, membranes
- Assessment of CO2 reuse options
  - Ethylacetate via fermentation process
  - Power to Gas
  - Power to Liquid (methanol)
  - Carbonatation (with steel slag)
- Further developments on direct ore electrolysis



(CCS) CCU

Use as chemical stockfeed

Electrolysis

Current Vision and efforts

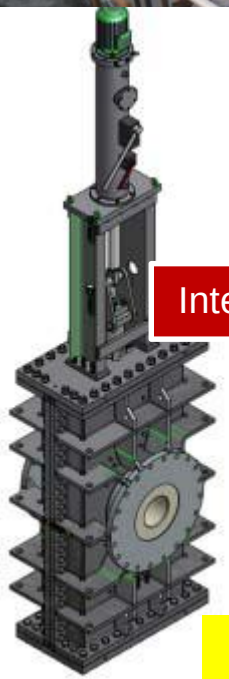
Testing platform in Dunkirk to valorize steel plant gases

- For internal use in ironmaking and steelmaking units (e.g. injection in the blast furnace): pilot units for mixing the various steel plant gases, adding H2 produced by water electrolysis, analyzing gas compositions, reforming the CO2 and heating the injection gas using a gas heater or a plasma torch.
- For testing applications towards the use of steel gases as chemical stock feeds: specific test campaigns with removable lab (e.g. bacteria fermentation of steel gases to produce biofuels)

Better use of steel plant gases

Simulation avec injection de particules de charbon (rayon X 10)

Internal use



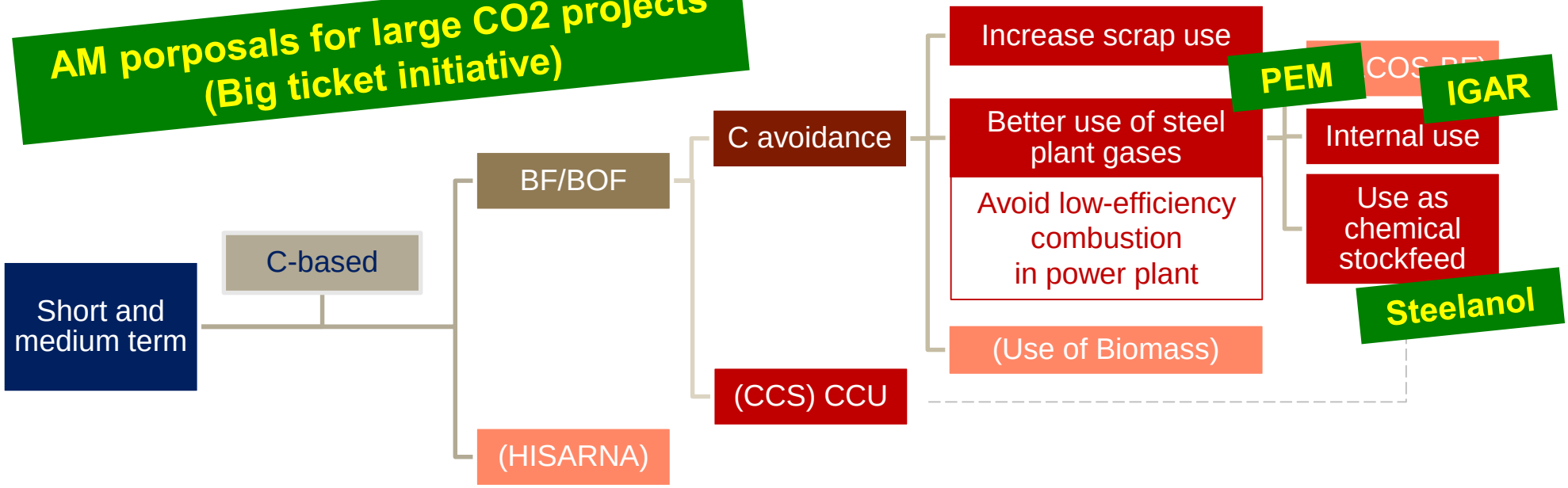
Refractory Gas Heater

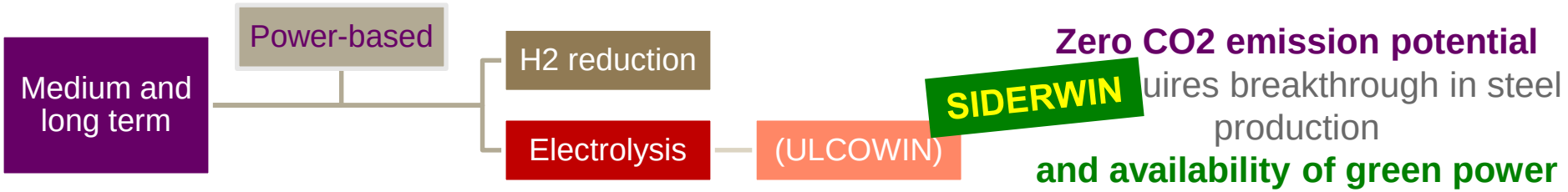
Use as chemical stockfeed

Current Vision and efforts

GHG reduction strategy for primary steelmaking in EU

AM porposals for large CO2 projects (Big ticket initiative)



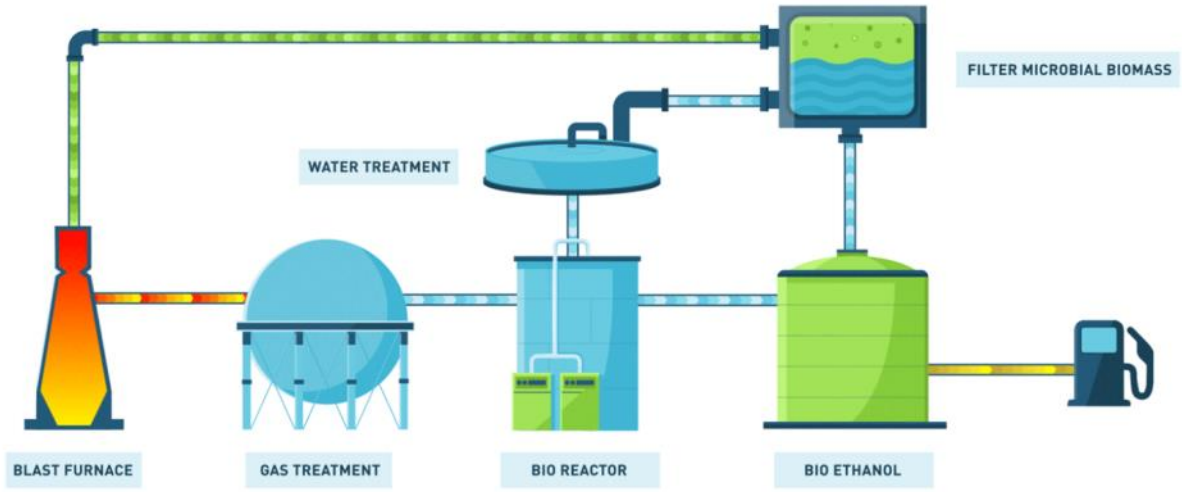


Zero CO2 emission potential
uires breakthrough in steel production
and availability of green power

Steelanol

Production of bio-ethanol via gas-fermentation of steel waste gases

- Construction of commercial scale production facility to create **bioethanol from waste gases** produced during steelmaking process
- **Investment cost** (Capex): 120 M€ for Steelanol project in Gent, with 65 kton/year ethanol
- **Timing**: go live 2019
- **Funding** 10.2 Meuro H2020



- **Primary energy saving potential**: if all steel mill gasses of the EU-28 conventional steel plants (BF-BOF route) are converted into ethanol the yearly production potential is app. 14,5 million t/y of EtOH. This is the storage of 350 million GJ/y.
- **GHG emission saving potential in percentage and in kt CO2eq/y :** if all steel mill gasses of the EU-28 conventional steel plants (BF-BOF route) are converted into ethanol the yearly production potential of app. 14,5 million t/y of EtOH will reduce CO2 emissions from industry by 33,3 million tons/y.

PEM (Primary Energy Melter)

Low Quality Scrap melting for Basic Oxygen Furnace

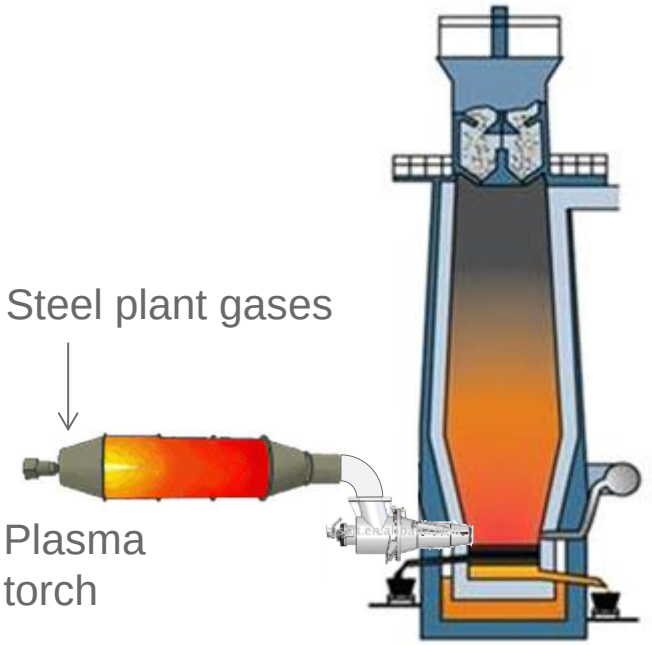
ArcelorMittal

- Development of new metallurgical process based on low quality **scrap melting with metallurgical/natural gas** in two phases: pre-melting process and superheating process
- **Technology**:
  - Scrap melting in shaft vessel with gas burners
  - Superheated melt to be charged in BOF vessel
  - Nearly pure CO2 from the shaft offgass
- **Investment cost** (CAPEX): 50 M€
- Production **pilot** capacity 200 000 ton scrap/year
- **Timing:**
  - Go live PEM installation 2019
  - Integrated in steelmaking 2021
- **Primary energy saving potential**: 30% energy reduction compared to other scrap melting processes or 1400 MJ/ton steel.
- **GHG emission saving potential in percentage and in kt CO2eq/y**: 1 ton CO2 per ton melted scrap. For one typical steel plant 200 ktCO2eq/a. Total EU scope estimated is 2500 ktCO2eq/a.
- **Potential "negative" GHG process:** in case of combined with CCUS technology in future

IGAR (Injection de GAz Réformé)

Injection of reformed steel plant gases in Blast Furnace

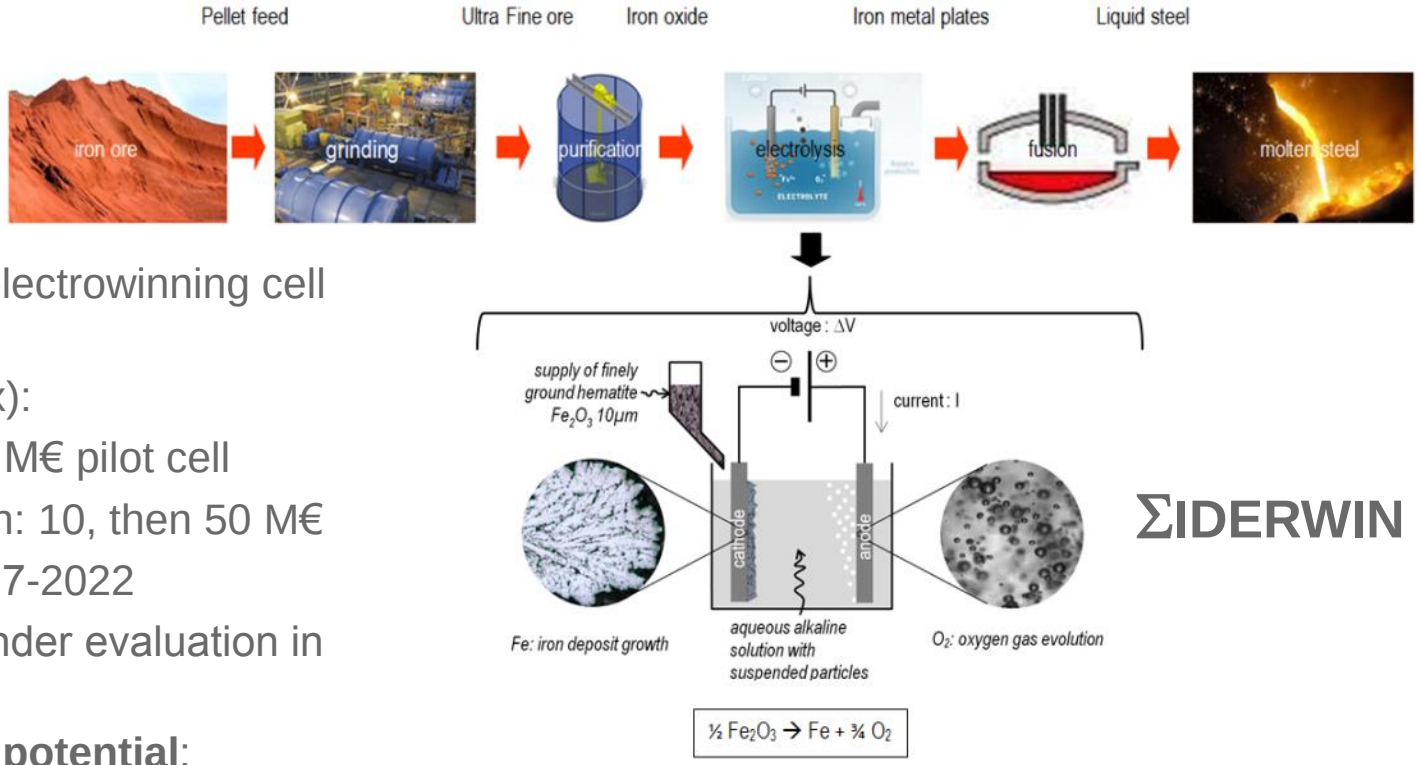
- Demonstration of the reforming of steel plant gases and injection in BF tuyeres to reduce coal/coke consumption
- **Technology:**
  - plasma torch and reactor to heat and reform gases
  - Modified BF tuyeres
- **Investment cost** (Capex):
  - Current project: 15 M€ for full-scale validation on one BF tuyere in Dunkerque
  - 75 M€ for further BF demonstration
- **Timing**: validation in 2020
- **Funding** (to be confirmed): 5,5 M€ ADEME (FR)
- **Primary energy saving potential:** Coke/coal savings at the BF of 50 to 90 kg/t of hot metal
- **GHG emission saving potential in percentage and in kt CO2eq/y** :
  - 0,1 to 0,3 tonne CO2 per tonne of crude steel
  - For one typical steel plant 500 ktCO2eq/a
  - Total EU scope estimated is 10 MtCO2eq/a.



SIDERWIN

Steel production by direct electrowinning of iron ore

ArcelorMittal



ΣIDERWIN

- Development of a fully electricity-based steel production route
- **Technology**:
  Ore purification, alkalie electrowinning cell and EAF melting
- **Investment cost** (Capex):
  - ΣIDERWIN project: 2 M€ pilot cell
  - Further demonstration: 10, then 50 M€
- **Timing**: ΣIDERWIN: 2017-2022
- **Funding:** ΣIDERWIN (under evaluation in H2020-SPIRE): 6.8 M€
- **Primary energy saving potential**:
  Improved efficiency in direct energy use: 27% compared to non electrochemical route
- **GHG emission saving potential in percentage :** Based on the objectives set for the integration of RES in EU power grid in 2050, expected reduction of specific CO_2 emissions by 70%
  - Participate in the integration of RES (renewable energy sources) by interruptibility
  - Option to recycle iron oxide wastes

Overview of large AM CO2 projects

(Big ticket initiative)

ArcelorMittal

Project	CO_2 saving	Investment (M€)	TRL - Scope	Timing Go Live
Steelanol	1.9 t CO_2 per t ethanol	120	6 → 9	Demo of 65 kton Ethanol: 2019
PEM	1 t CO2 per t of melted scrap	50	5 → 8	PEM industrial pilot 200 kt: 20201
IGAR	0,3 t CO_2 per t of crude steel	90	5 → 7 7 → 9	Full scale BF pilot: 2021 BF demo: 2025
SIDERWIN	Zero emission steelmaking	60	4 → 6 6 → 8	Single-cell pilot : 2022 First industrial small scale plant > 2030