



ArcelorMittal

$$\frac{\partial f_{i,j}(\vec{x}, \vec{c})}{\partial x_i} = \sum_{k \neq i} c_{k,j}$$



Decarbonisation of steel production by electrification

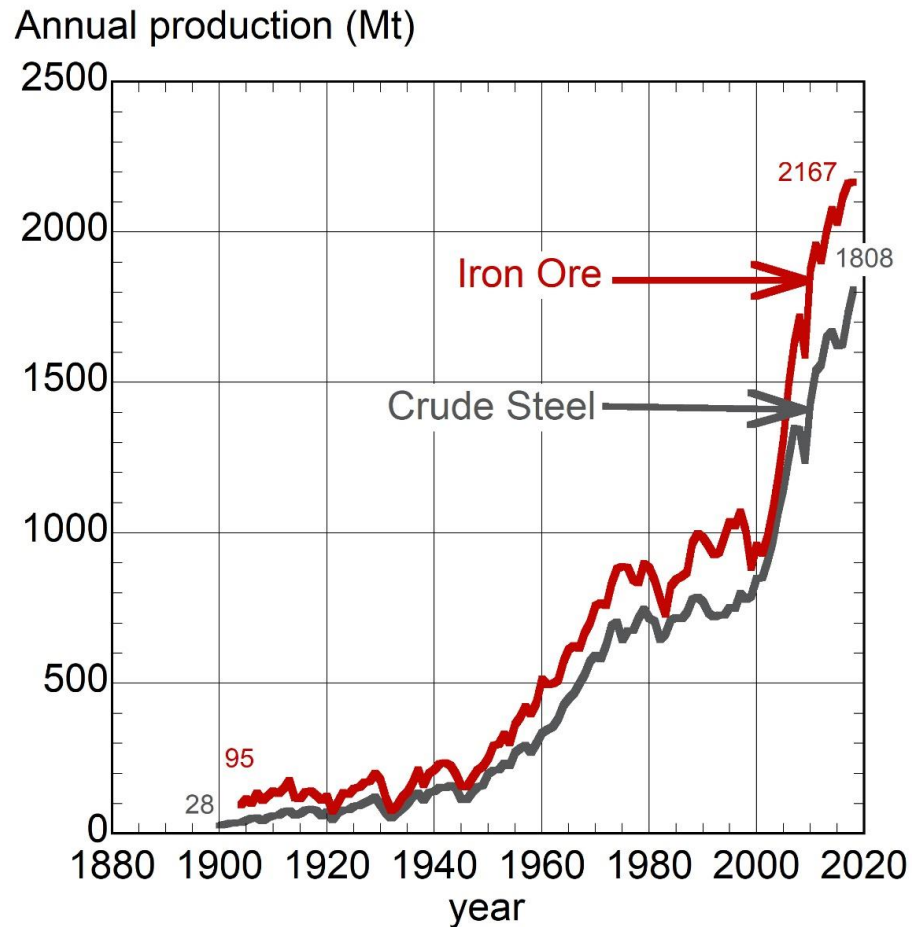
Bruxelles, 2019 December 4th

The right formula
for the steels of the future

Decarbonisation of steel production by electrification



- Steel production



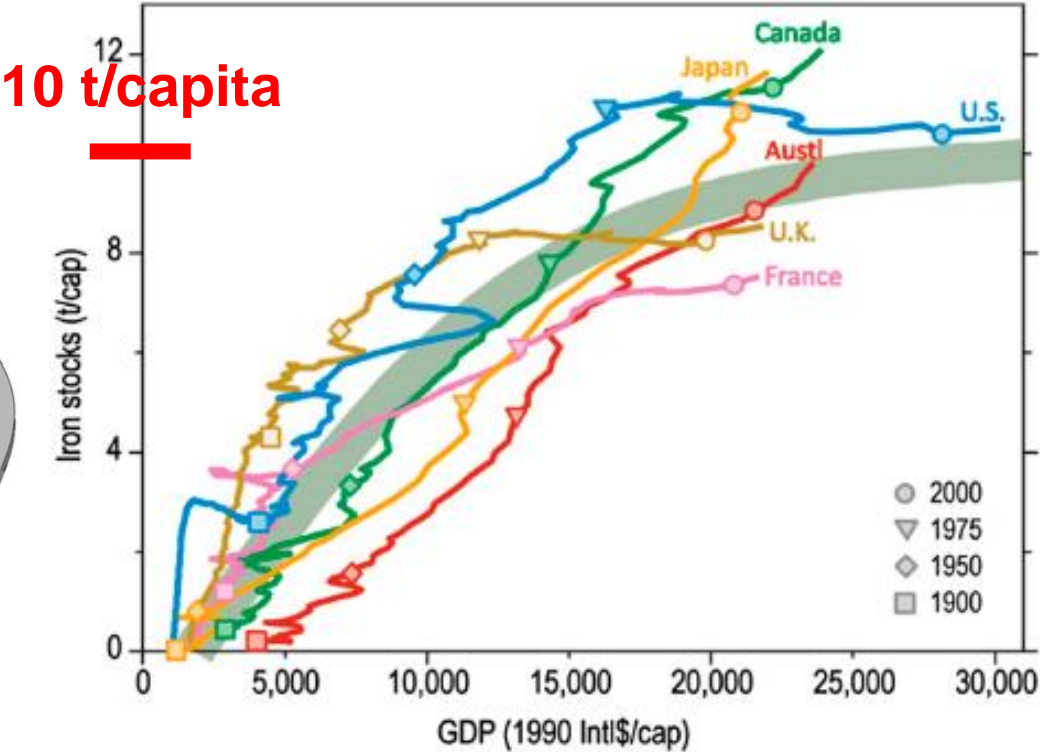
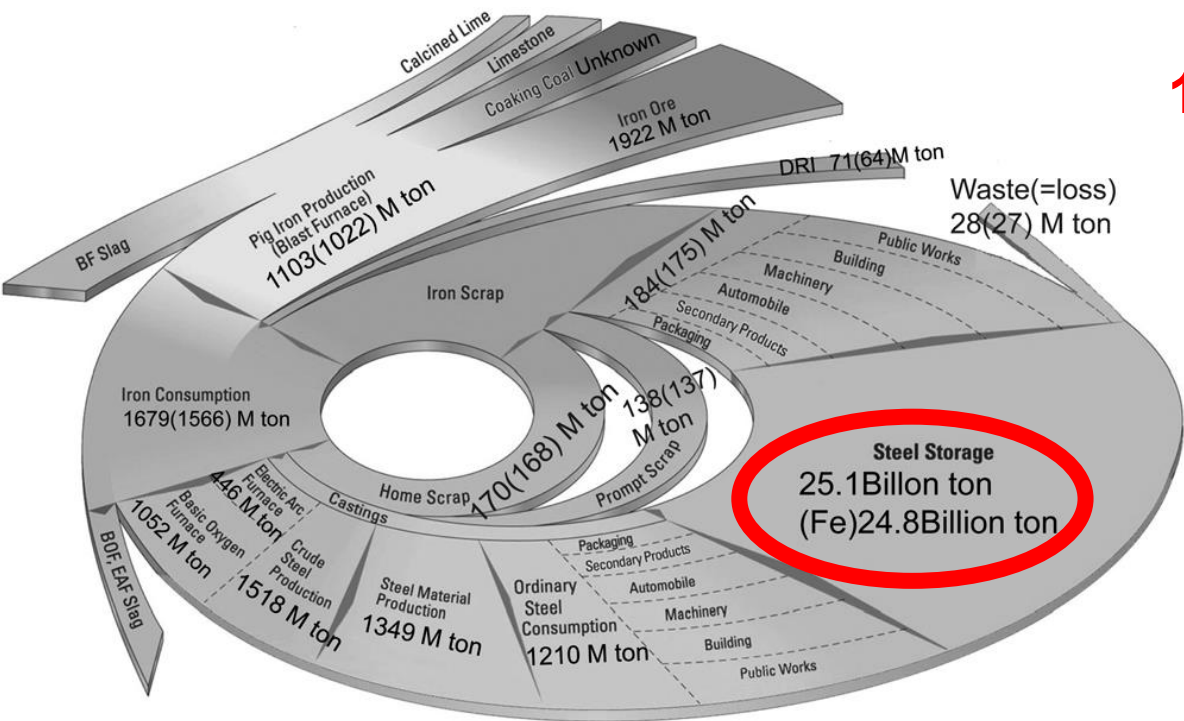
WorldSteel statistics, USGS

- 1 808 Mt of crude steel.
- 71% primary steel.
- 2 167 Mt of iron ore.
- Fe = 18 x Al, in tonnage.
- Fe = 84 x Cu, in tonnage.
- Iron ore: second raw material transported by shipping.

Decarbonisation of steel production by electrification



- Steel use



Nobuhiko TakamaTsu, Kimitoshi Yonezawa, Hironori ueno, Wakana Tamaki and Seiichi HaYasHi
Tetsu-to-Hagané Vol. 100 (2014) No. 6

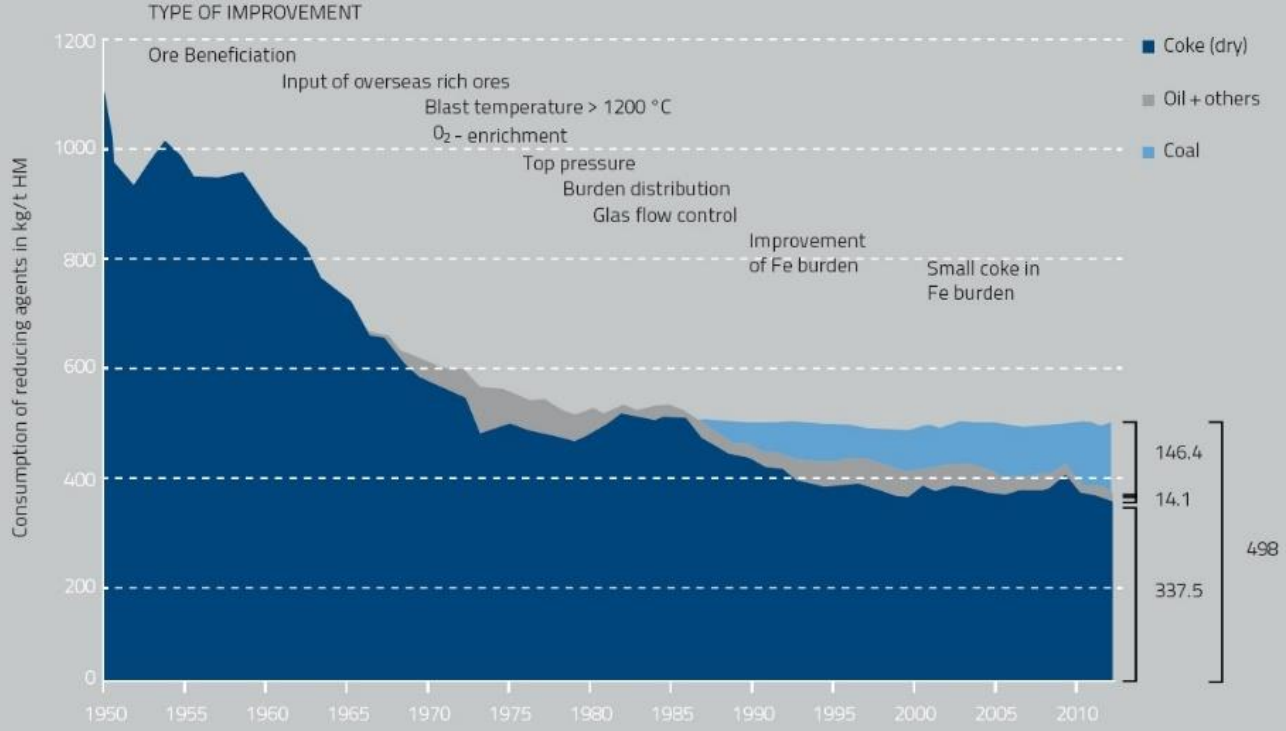
D. Müller et al. Patterns of Iron Use in Societal Evolution (2011)

Decarbonisation of steel production by electrification

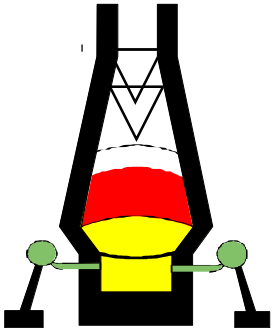


- CO₂ emissions

Use of reducing agents in the blast furnace in Germany



A Steel Roadmap for a Low Carbon Europe Eurofer (2013)



~600 kg _{Carbon}	per t _{Steel}
20 GJ or 5.5 MWh	
2 t _{CO2}	

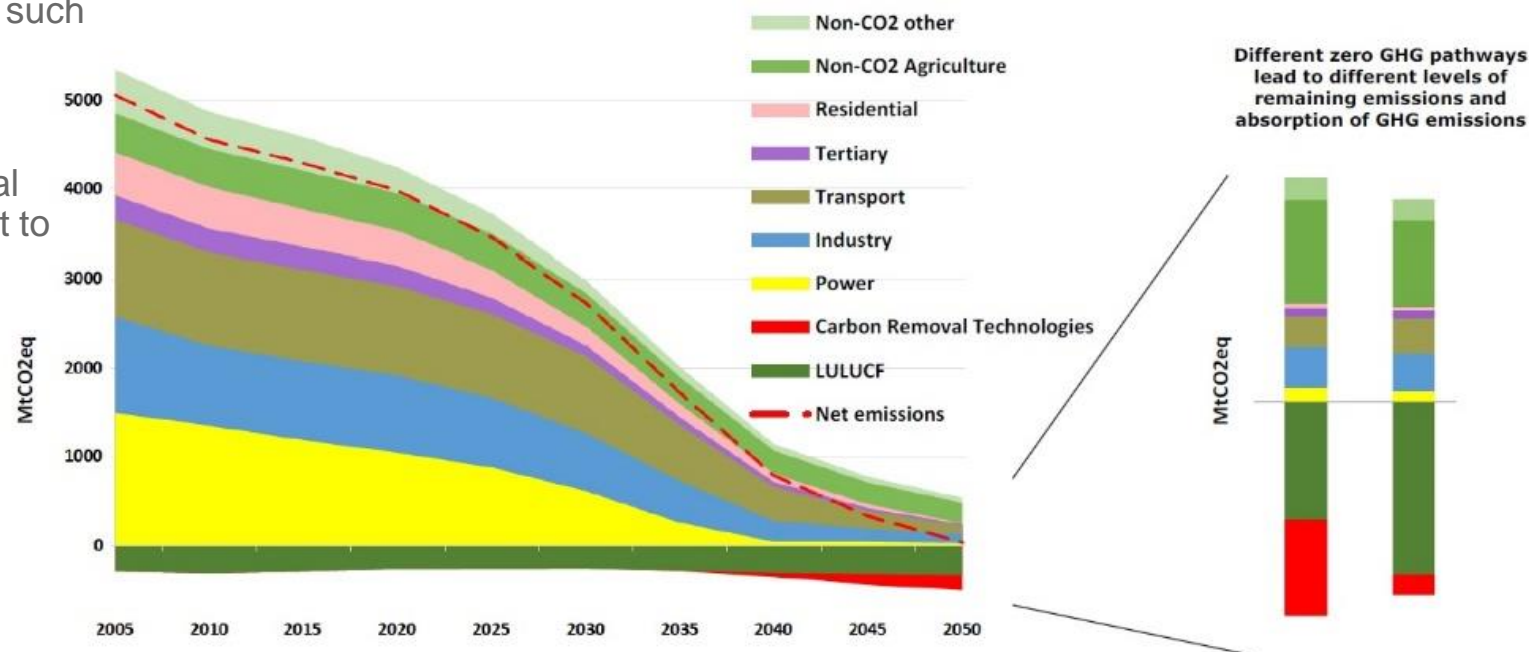
WorldSteel

The steel industry generates between 7 and 9% of direct emissions from the global use of fossil fuel.

Decarbonisation of steel production by electrification

- Climate neutral Europe by 2050

- The goal is to reach net-zero emissions by 2050. Switching to low and zero carbon energy sources such as renewables-based electrification.
- Steel emissions are process-related from chemical reactions other than combustion which are difficult to reduce.



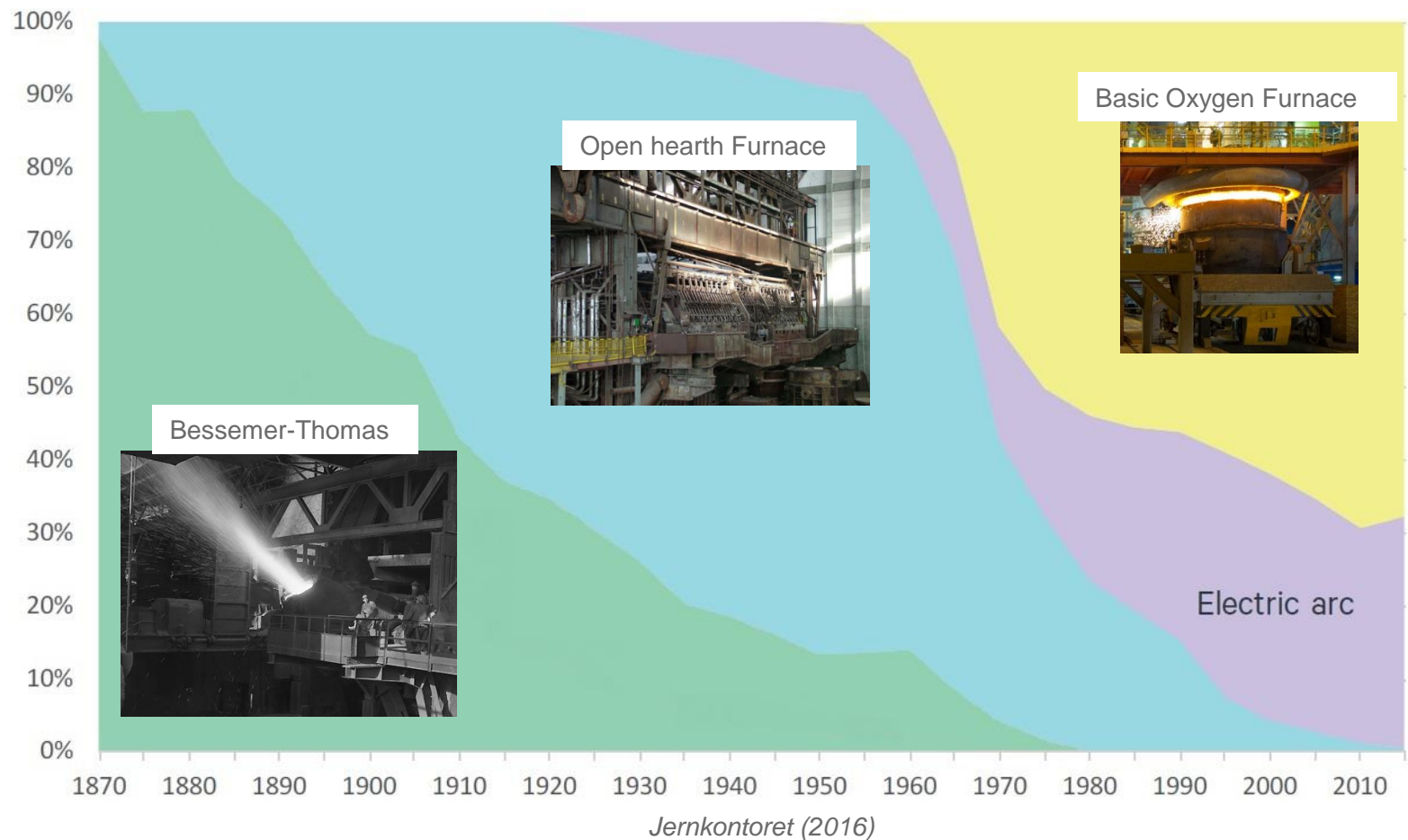
European Commission - Strategy for a climate neutral Europe by 2050 (2018)

European Commission - A Clean Planet for all (2018)

Decarbonisation of steel production by electrification



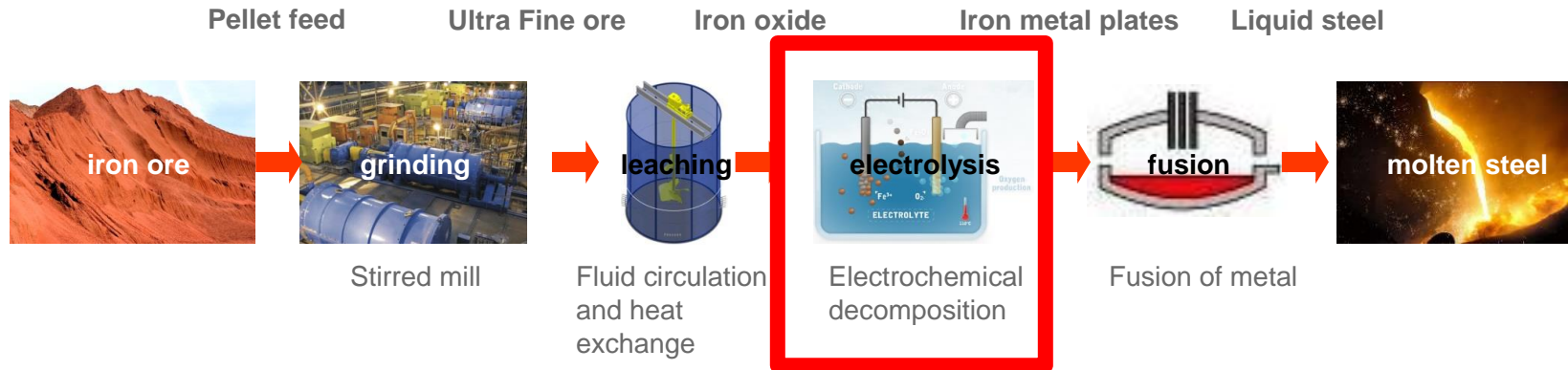
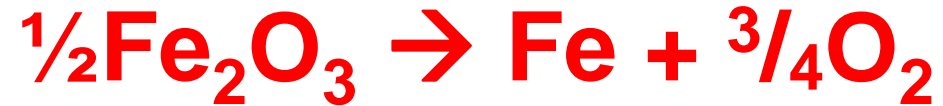
- Electrification of steel production



Electrification of secondary steel
=
1/3 of crude steel



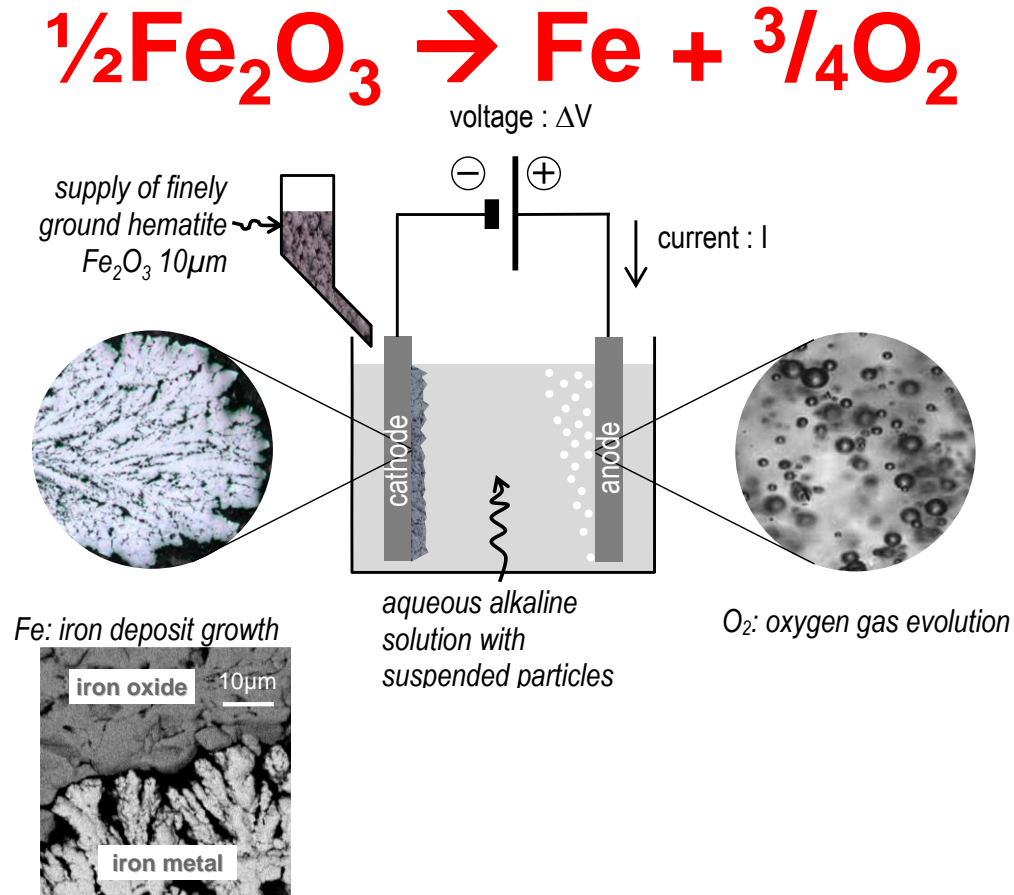
- Electrification of primary steel production



- A new processing route for steel.
- Overall energy consumption $3.6 \text{ MWh.t}^{-1}_{\text{Fe}}$ or $13 \text{ GJ.t}^{-1}_{\text{Fe}}$.
- Reduction by 31% of the direct energy use.
- Reduction by 87% of the direct CO_2 emissions.

Electrification of today Europe primary steel production 100 Mt.a^{-1} would require 360 TWh.a^{-1} compared to 35 TWh.a^{-1} for 70 Mt.a^{-1} of secondary steel

- Iron Electrowinning



- Low temperature electrolysis: 110°C.
- Conductive aqueous alkaline electrolyte medium 50wt% NaOH - H₂O.
- No separator as membrane or diaphragm between electrodes.
- Electrolysis is applied to 10 μm hematite solid particles rather than dissolved ions.
- High reaction rate with current density 1000 A.m⁻².
- Low distance between electrodes 1cm.
- Cathodic iron grown as self-standing, stiff, compact and conveyable metal plates.
- Full recovery of anodically produced O₂.
- Non-consumable anode.
- Non critical elements in electrode materials, Ni anodes.

Decarbonisation of steel production by electrification

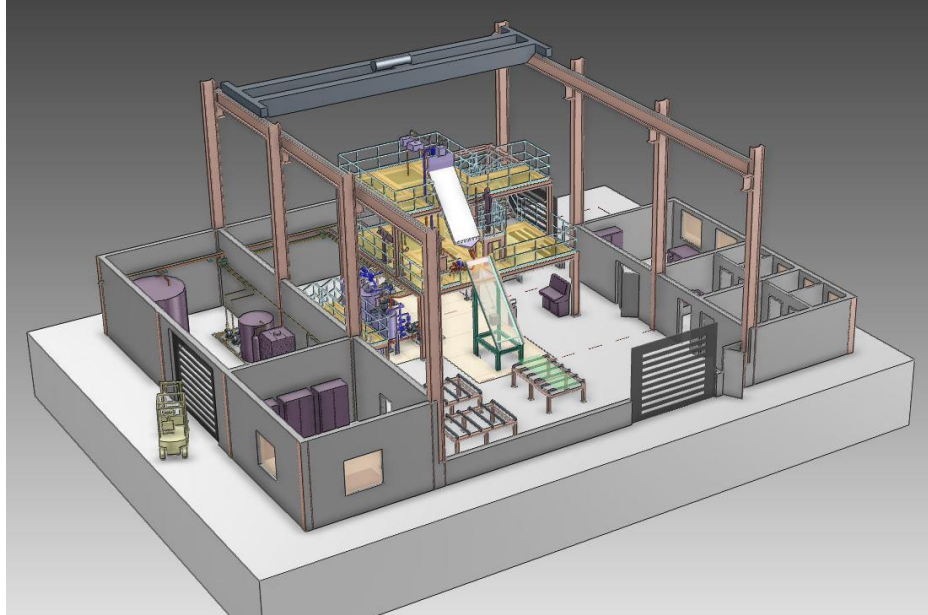
- ΣIDERWIN project



- 5 years project 2017-2022
- Budget: 6.8 M€ includes 2.2 M€ for pilot.
- 7 different countries.
- 12 partners : 4 Companies + 4 SMEs + 4 RTO
- Multisectorial: steel, non-ferrous and power.
- Coordinated by ArcelorMittal.
- <https://www.siderwin-spire.eu/content/home>



- ΣIDERWIN project – TRL6 pilot








- Continuous and automated iron ore supply.
- Gas oxygen collection.
- Metal harvesting system.
- Vertical extension for low footprint.

– Electrodes	2.75x1 m
– Current intensity	3kA
– Power	6kW
– Electrolyte volume	300L
– Production: iron metal samples of	100kg.

- Flexible metal production, interruptible for grid controlled by a communication system.
- Enlarged iron oxide sources.

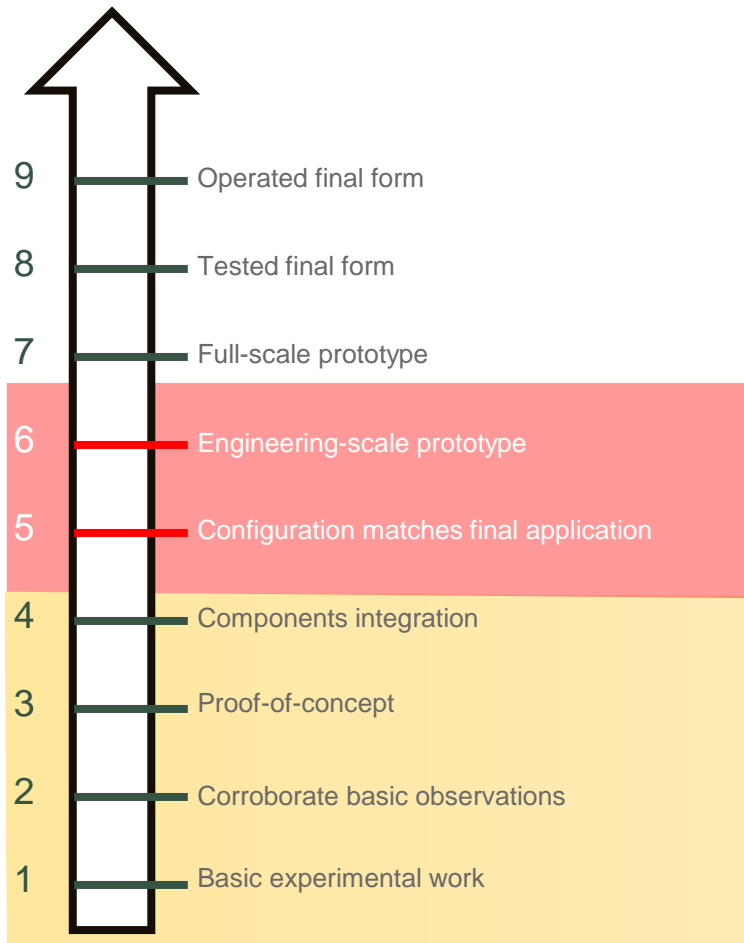
Decarbonisation of steel production by electrification



- ΣIDERWIN project for future mass steel production
- Oxygen production.  Beneficial effect to the atmosphere
- Reduction of wastes from mineral industries.  Access to mineral resources
- Participation in electric grid balancing.  Contribution to the integration of variable RES
- Massive electricity storage.  Long term storage of electricity
- Direct production of primary steel.  Radical simplification of the chemical route and high energy efficiency

Decarbonisation of steel production by electrification

- ΣIDERWIN project: path for upscaling





2017-2022 6.8M€





IERO



AGENCE NATIONALE DE LA RECHERCHE



iron oxide 10µm

iron metal





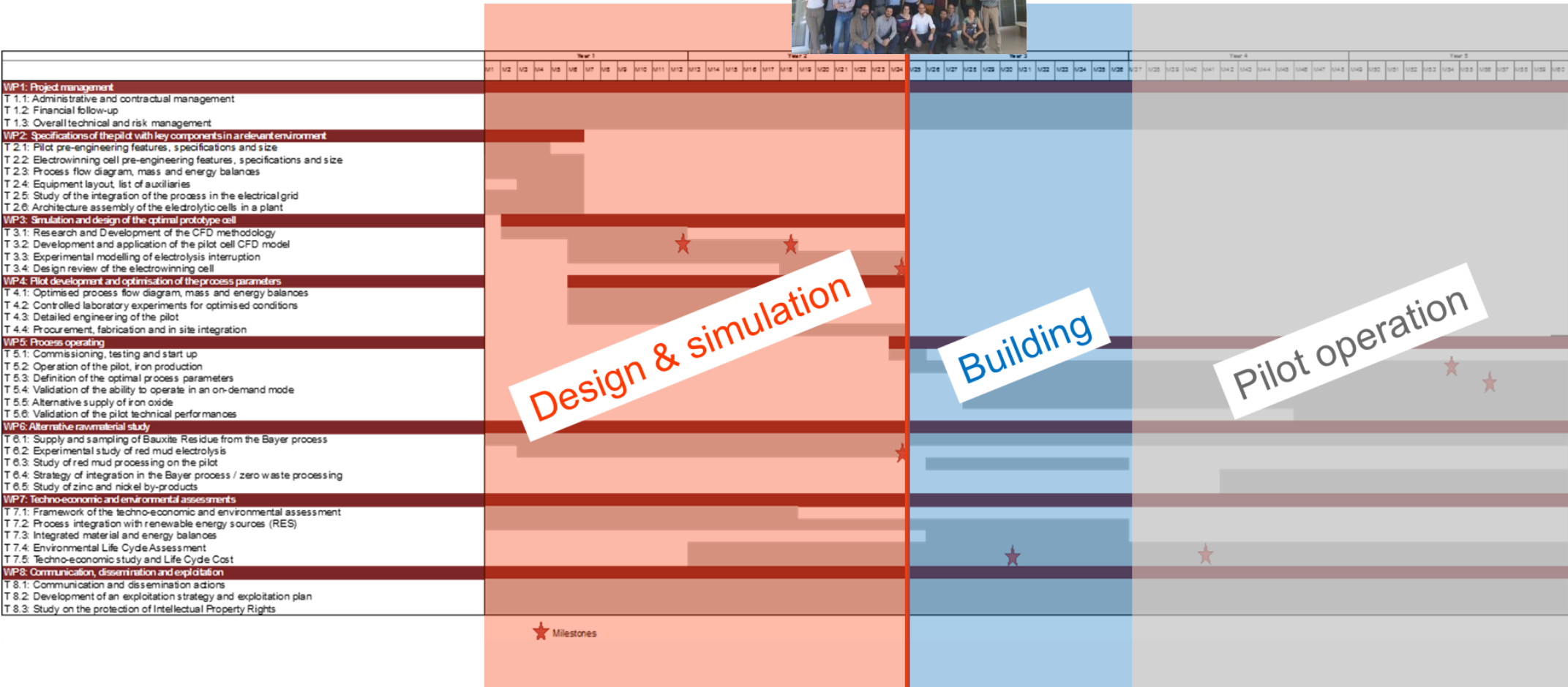
Decarbonisation of steel production by electrification



- ΣIDERWIN project: Planning Start October 2017

M24

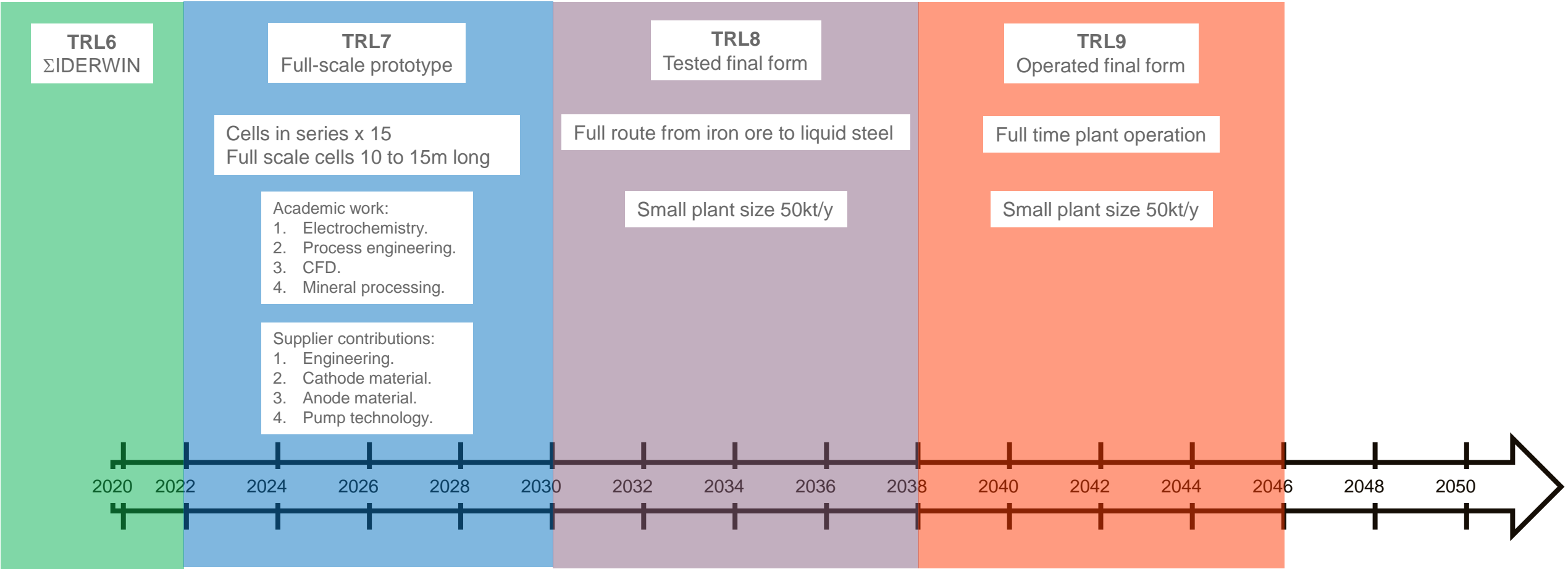
End October 2022



Decarbonisation of steel production by electrification



- ΣIDERWIN project: path to achieve carbon neutrality before 2050



- ΣIDERWIN project
- This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768788".



- “This study reflects only the author’s views and the Commission is not responsible for any use that may be made of the information contained therein”