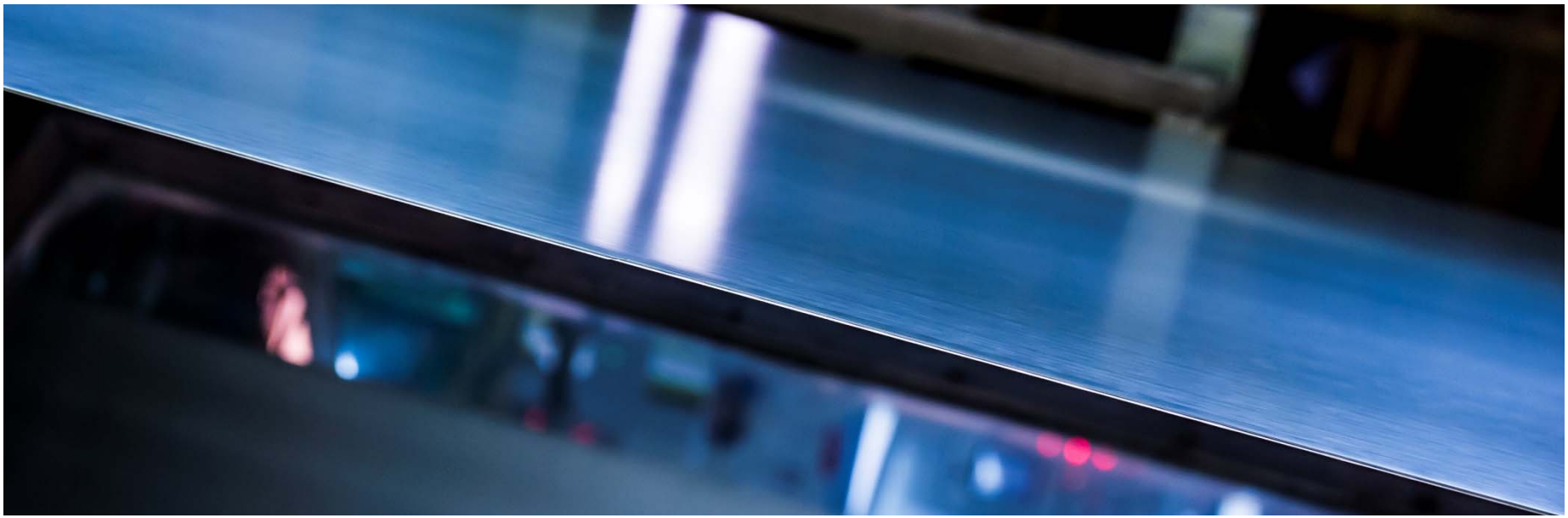
worldsteel ASSOCIATION

Low carbon alternative technologies – global perspective

IEA Latin American Expert Dialogue
22nd August 2018 São Paulo, Brazil



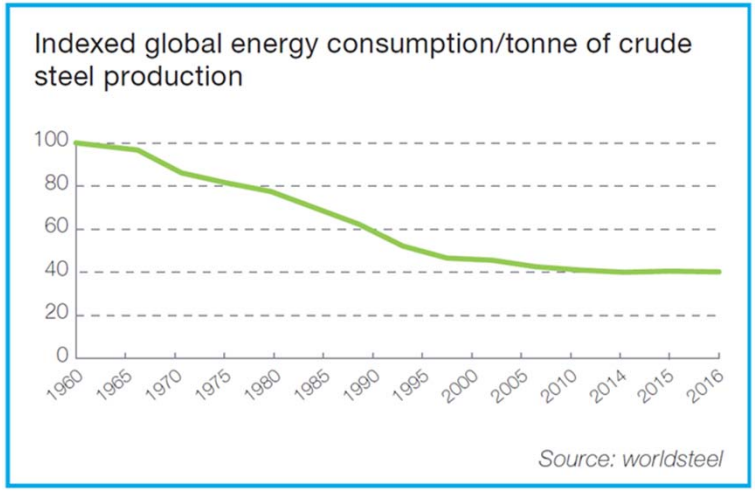
Disclaimer

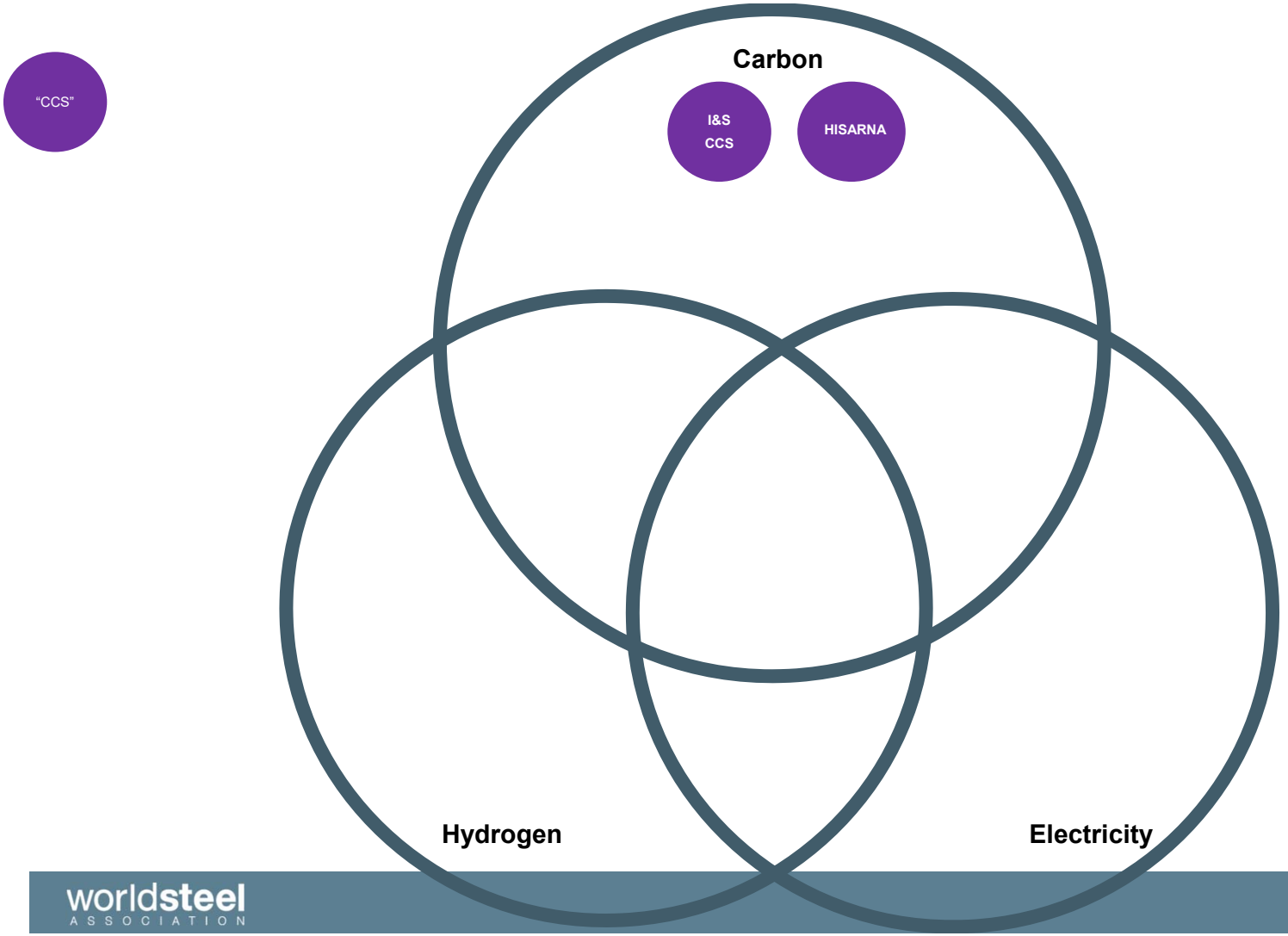
Presentation outline

- Background
- Ongoing activities outside of Latin America
- Barriers to implementation
- Observations

Background

- The steel industry is energy and material intensive and the management of its energy efficiency and efforts to increase the use of scrap have always been a focus. The sector has thereby achieved significant reductions in energy intensity over the last decades
- However, the steel industry understood early that breakthrough technologies would be needed to achieve additional and drastic reductions.
- The development of breakthrough technologies requires a considerable amount of time before possible commercial deployment
- The identification of promising technologies and their development began in the early 2000s but slowed down significantly after the economic crisis
- Though a few programmes have been cancelled due to a lack of funding others have come in their place and a large number of options are being explored in parallel.

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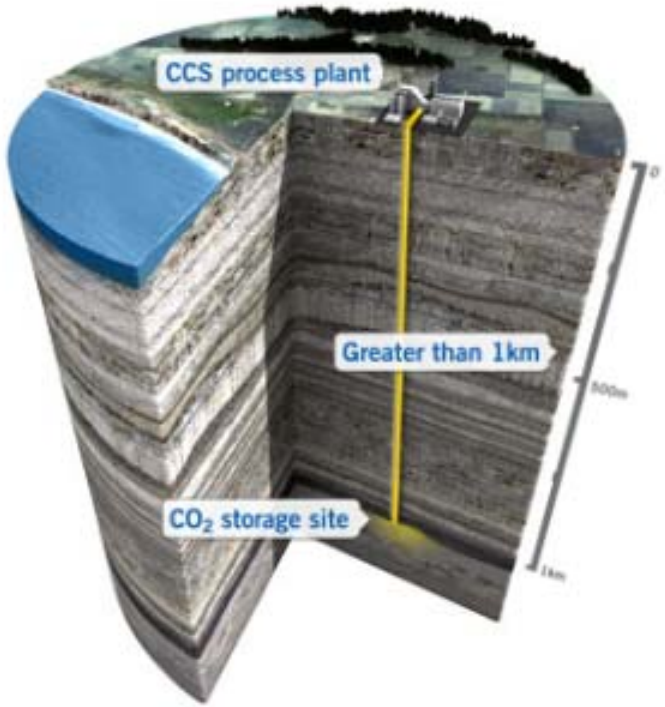
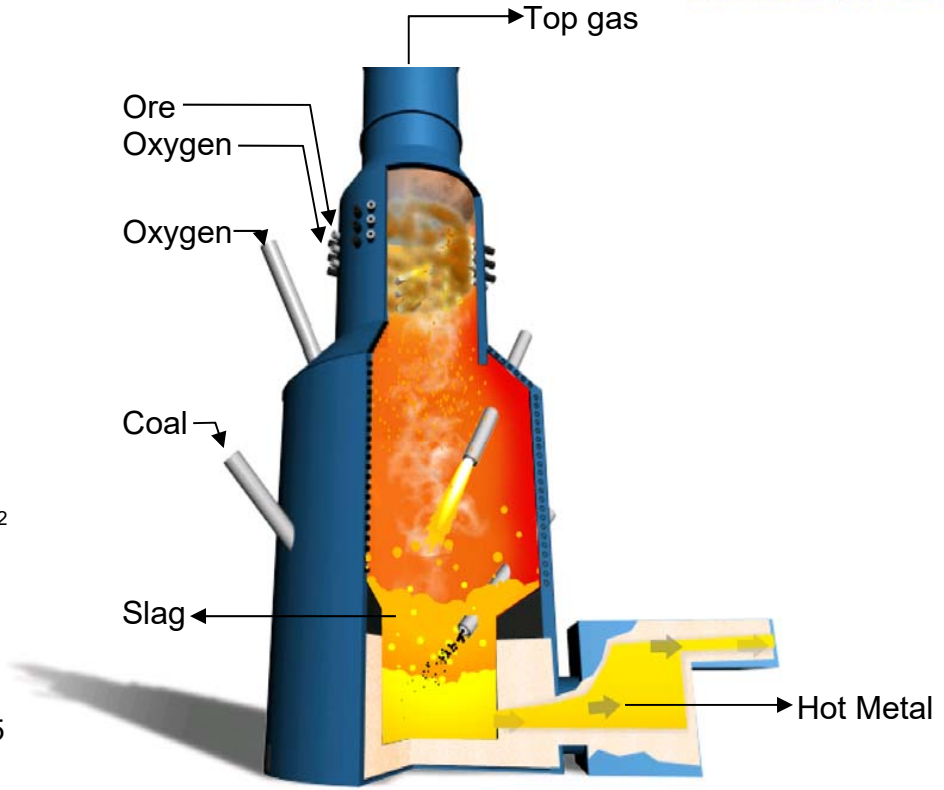
Carbon Capture and Storage (CCS)

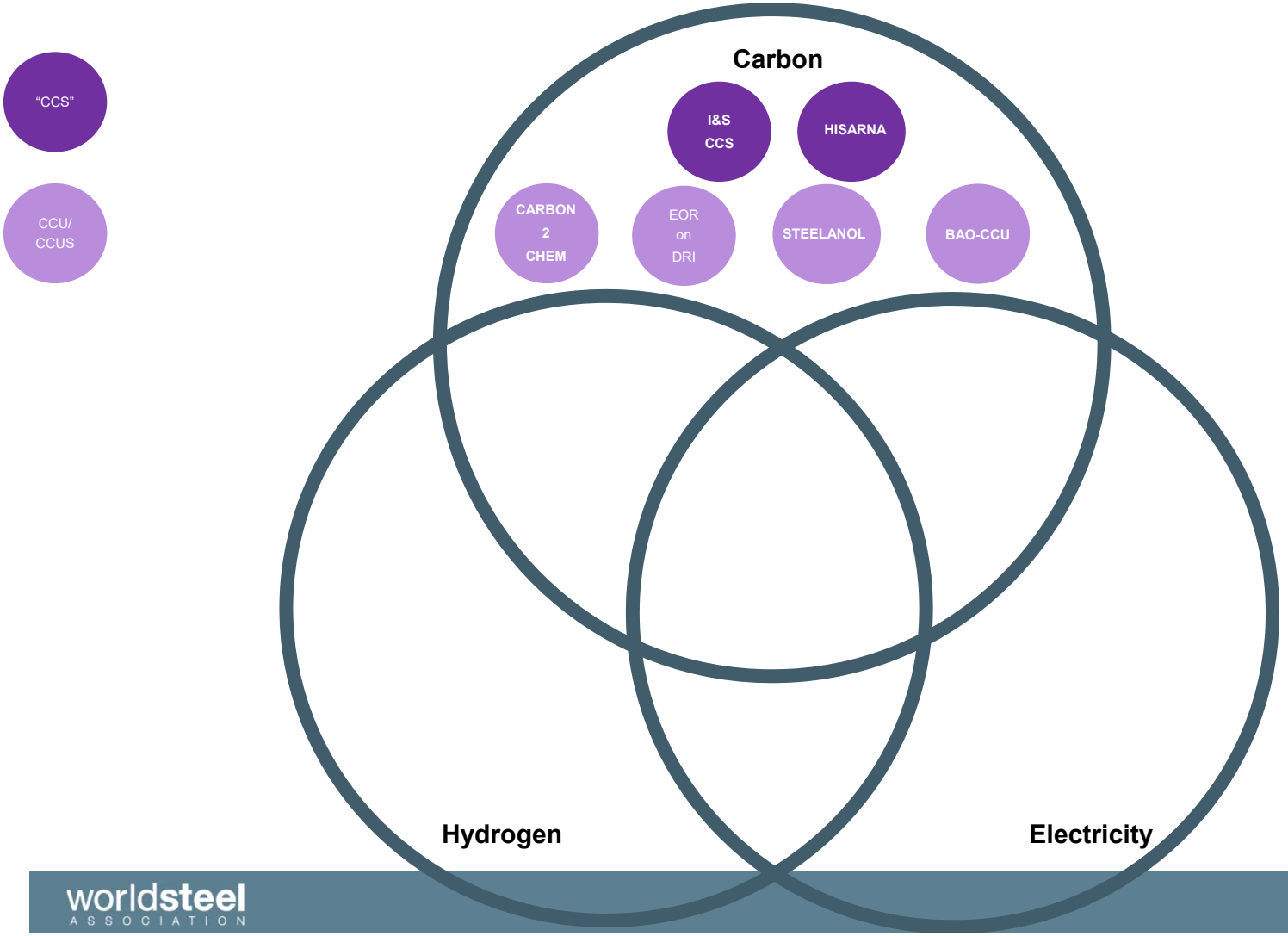
- BHP Billiton and Peking University study ongoing into the potential of carbon capture, use and storage (CCUS) for steel production in China.
- CCS looked in in other areas eg.
  - ULCOS-TGR BF
  - China Steel Corp
  - Posco
  - COURSE50 and others
- Cost, storage and infrastructure remain an issue for steelmakers



HIsarna

- A direct reduced iron process in which iron ore is processed almost directly into liquid iron or hot metal.
- The process combines two process units, the Cyclone Converter Furnace (CCF) for ore melting and pre-reduction and a Smelting Reduction Vessel (SRV) where the final reduction stage to liquid iron takes place.
- The process does not require the manufacturing of iron ore agglomerates such as pellets and sinter, nor the production of coke
- The process is able to utilise lower grade iron ores and low cost coals and has a lower Capex
- HIsarna can achieve at least a 20% CO_2 reduction, 80% CO_2 reduction with CCS
- It also reduces emissions of dust, NOx and Sox
- Long-term trial since November 2017 running continuously using the hot metal in downstream processes
- Conceptual engineering for the first industrial scale plant, 0.5 to 1.0 M t/y, has started.

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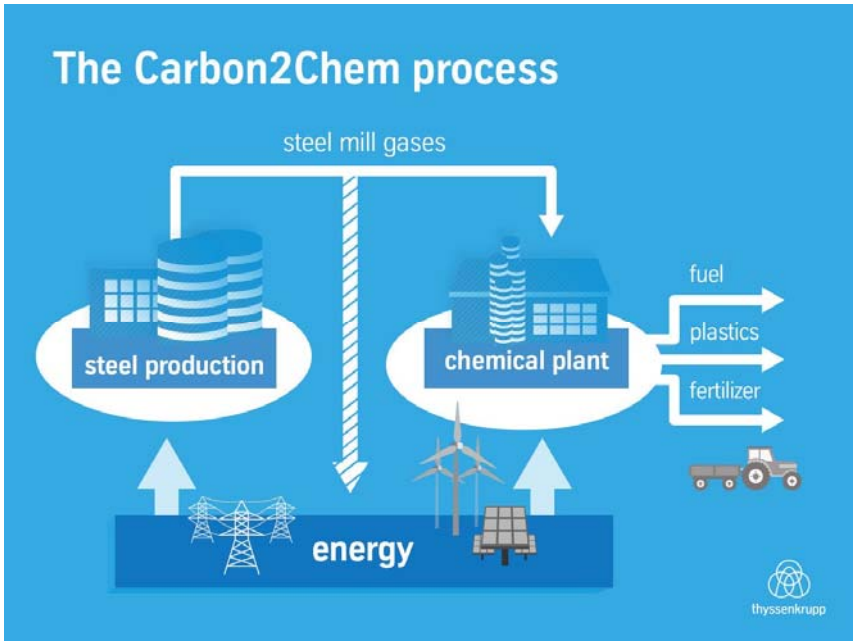
EOR on DRI

- Abu Dhabi CCS involves the capture of CO_2 from the Emirates Steel Factory in Abu Dhabi and its transportation to the ADNOC reservoirs for the purpose of enhanced oil recovery (EOR).
- The DRI process employed at ESI produces a pure stream of CO_2 (greater than 98 per cent)
- Launched in November 2016, the compression facility has a capture capacity of 0.8 Mtpa.

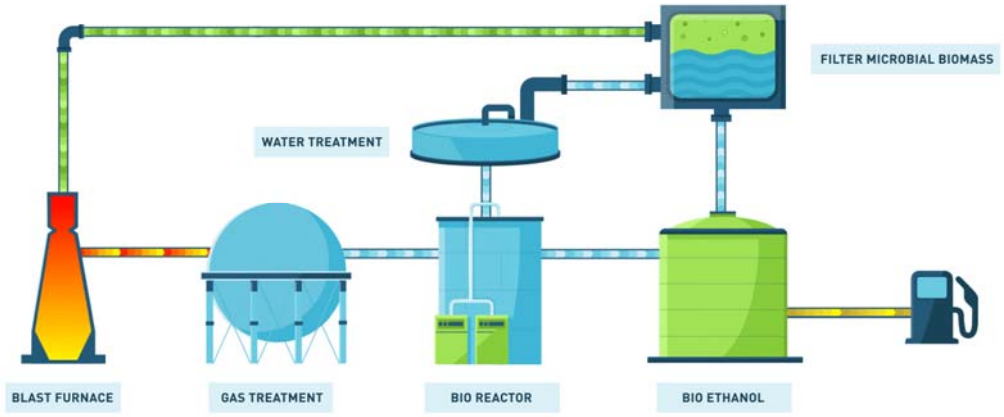
Carbon2Chem

- Initiative by thyssenkrupp
- Using the gases from the steelmaking process as a raw material for the production of chemicals such as ammonia and methanol
- Additional hydrogen is needed for the chemical processes involved in ammonia and methanol production
- Produce hydrogen whenever there is a surplus of green electricity and the cost is particularly low using large-scale industrial facilities like steel mills and chemical plants as energy buffers
- One of the central development tasks for Carbon2Chem is to find catalysts for the production of chemicals which can cope with operating fluctuations without any impact on performance.



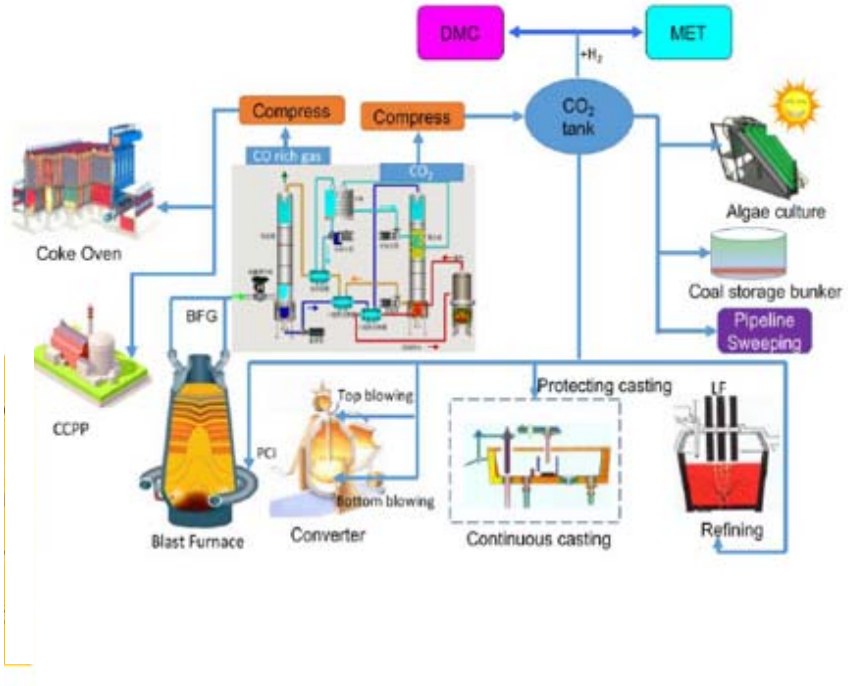
Steelanol

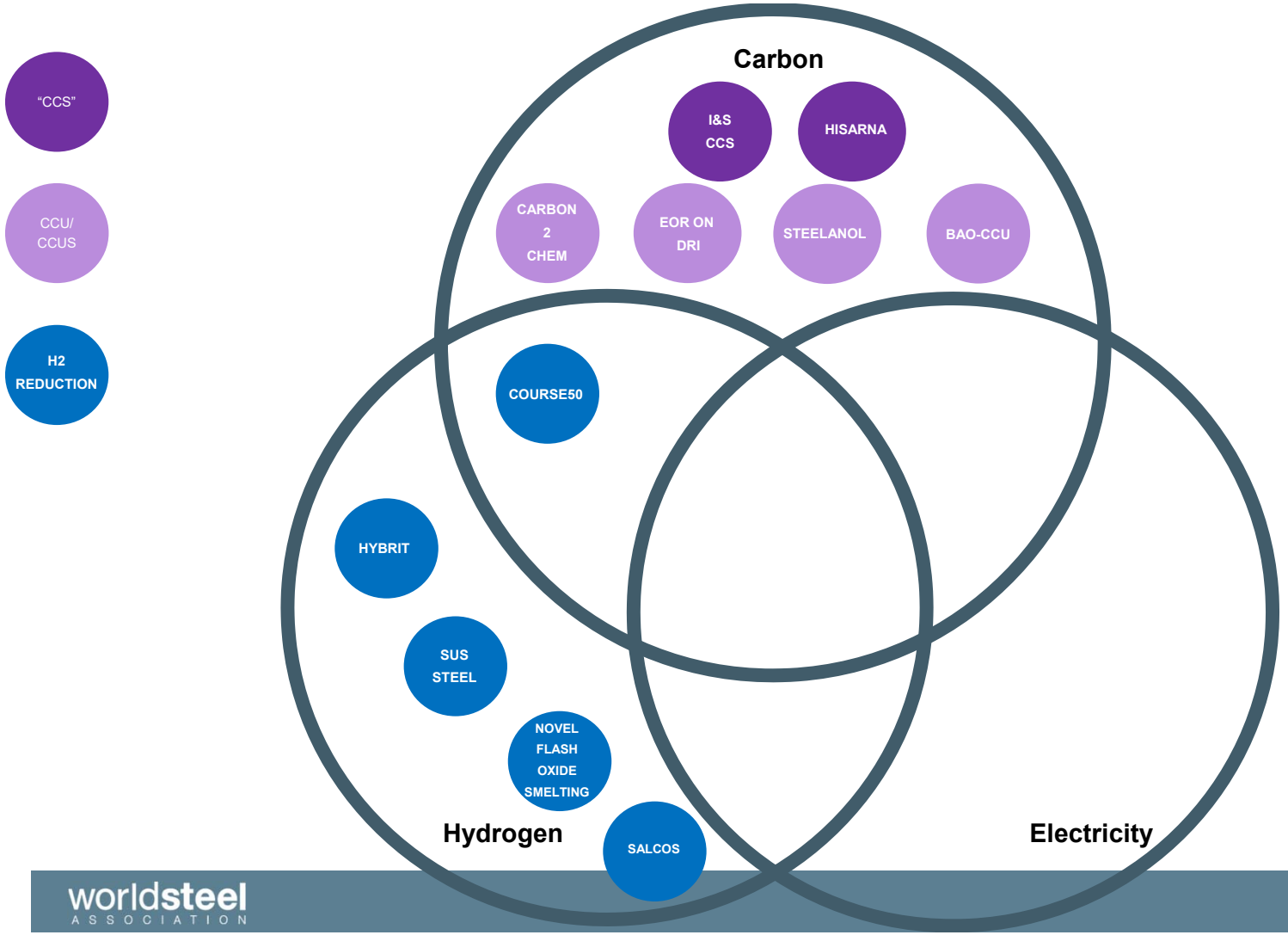
- ArcelorMittal in partnership with Lanzatech and others
- Transforming carbon-rich industrial waste gases into advanced bio-ethanol for use in the transport sector by way of a novel gas-fermentation technology using microbes that secrete ethanol
- capture and reuse of a portion of carbon emitted by the steel industry without need to rebuild the steel plant
- The flagship pilot project involves a combined investment package of over €100 million from ArcelorMittal, EU Horizon 2020 and the European Investment Bank, and will start to yield results in 2019. Also China.
- The design of this first plant is larger than originally anticipated, and will produce 80,000 million litres of ethanol.



BAO-CCU

- Development of low energy cost CO2 separation and integrated gas utilisation technology
- Results:
  - Development of a new absorbent with desorption energy of 3.0GJ/tCO2
  - Integration of CO2 usage in the steel making process (converter, refining and continuous casting)
  - Proposal for a new CO rich fuel for coke ovens and CCPP

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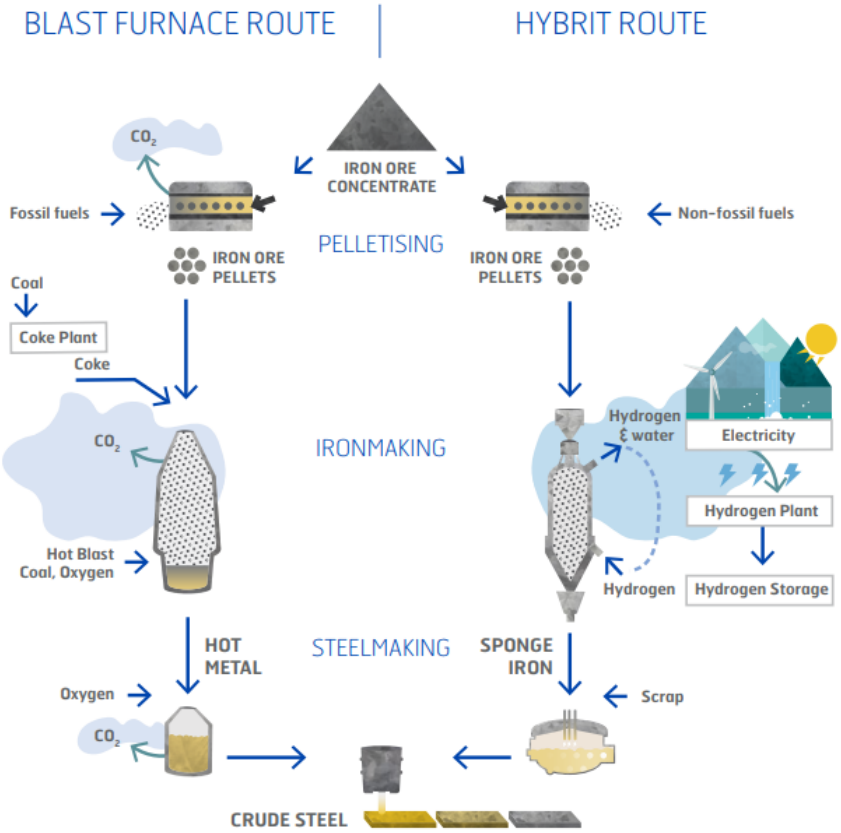
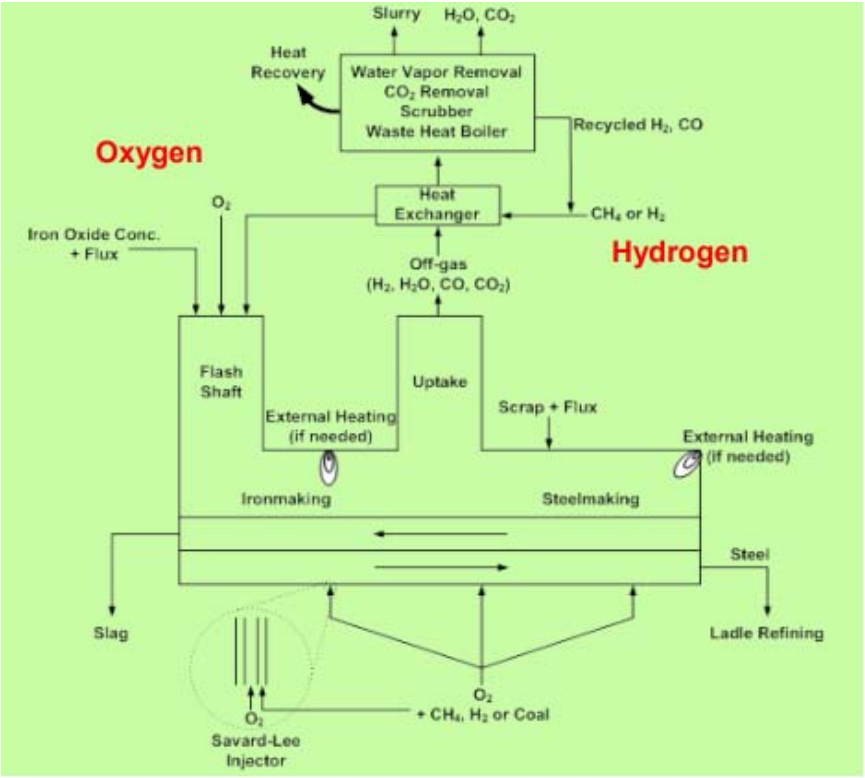
HYBRIT - Hydrogen Breakthrough Ironmaking Technology

- HYBRIT is a joint venture between SSAB, LKAB and Vattenfall, aiming to replace coal with hydrogen in the steelmaking process
- The by-product from iron ore reduction would be water
- The Pre-Feasibility Study Concluded in February 2018 with financial support from Swedish Energy Agency (50%)
- Pilot phase: 2018-2024
- Demonstration plant trials: 2025-2035



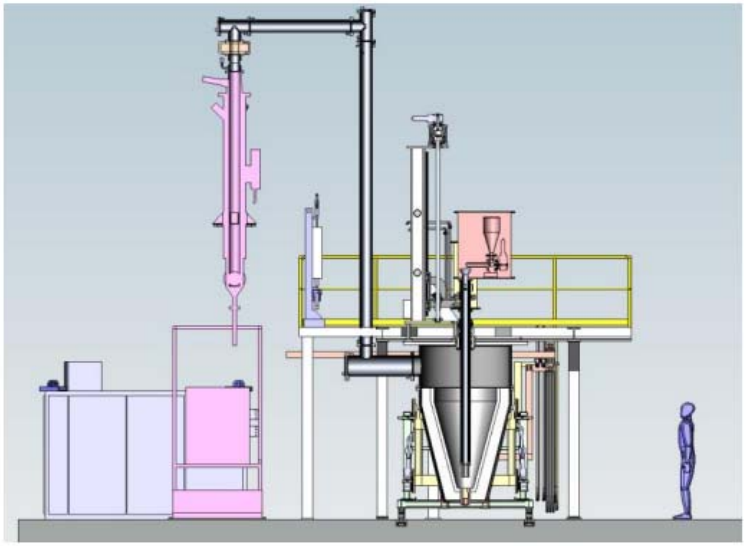
Novel flash Iron Smelting

- University of Utah
- Gas-solid suspension reduction with hydrogen or natural gas
- Uses iron ore fines and eliminates coke making and pelletising/sintering
- Significant reduction in CO_2 and energy consumption
- Next step pilot plant construction.



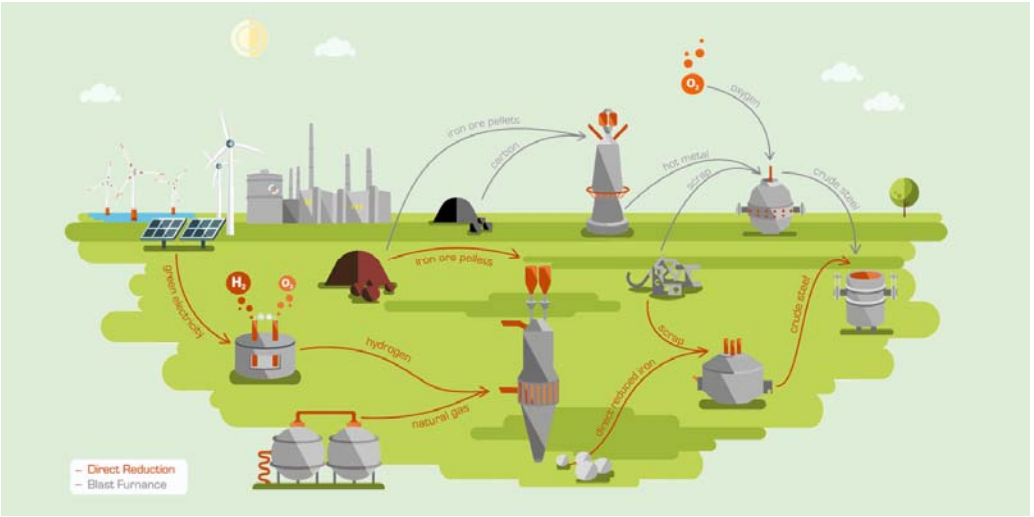
SuSteel

- Hydrogen plasma smelting reduction (HPSR)
- Research project using a pilot plant at voestalpine (Donawitz, Austria)
- Direct reduction process from iron ore to steel
- Next step: Upscaling of reactor from 100g to 50kg batch operation with power consumption of approx. 250kW



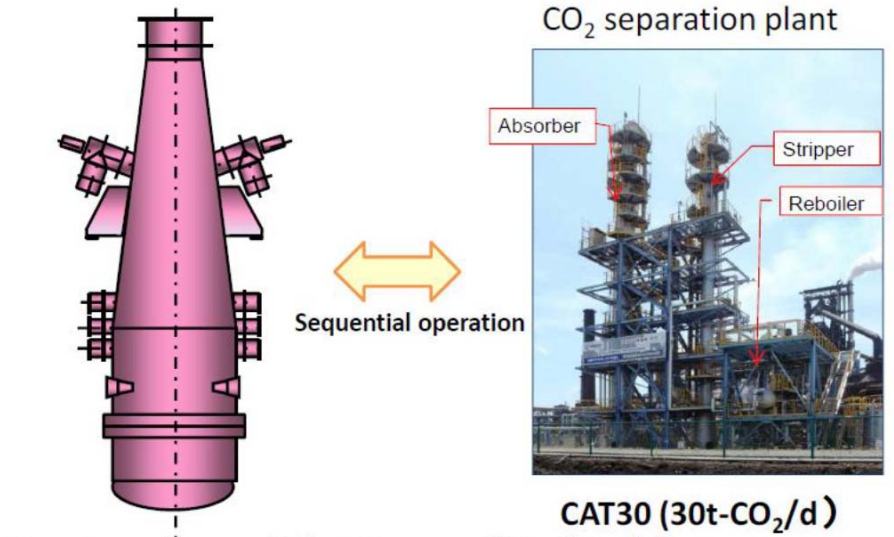
SALCOS

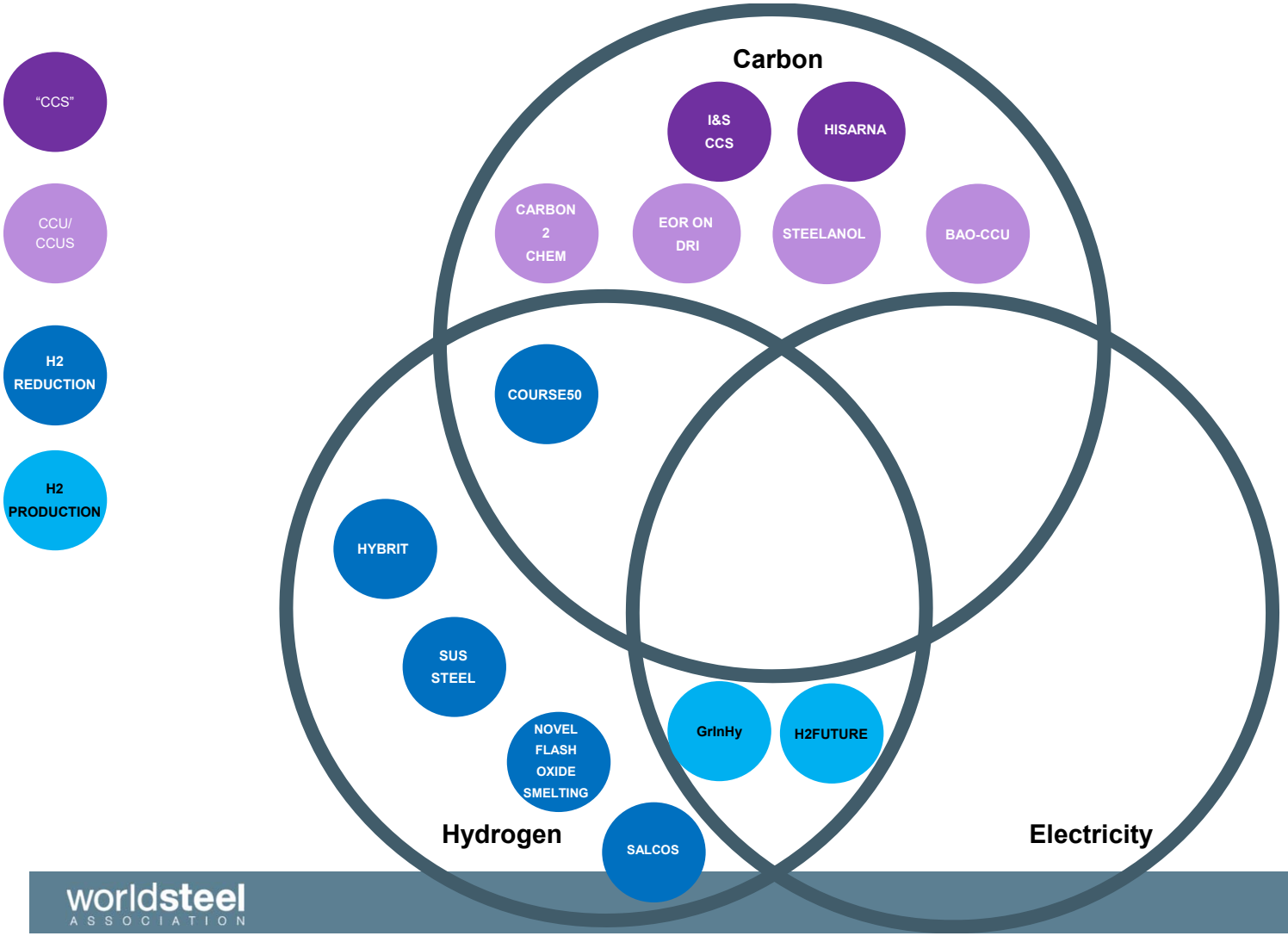
- Salzgitter and partners
- Aims to initially reduce iron ore to iron with the aid of natural gas and a higher volume of hydrogen in a direct reduction reactor. The reaction takes place at 950°, a reduction of iron of up to 85% can be achieved and sponge iron is produced.
- Gas is introduced in a circular pattern and, after separation of the water produced by the reduction, cleansed of any remaining CO2 and reused.
- Through the gradual implementation of a reactor of this kind, initial CO_2 savings of up to 50% are theoretically possible. If, in the future, switching the entire production to a direct reduction plant is possible, this figure can be raised to up to 85%.



COURSE50

- Aims to reduce coal consumption in the Blast Furnace by 10% by using a H2 rich reductant and separate and capture CO2
- A 10m3 experimental blast furnace has been built and tests are ongoing showing results close to predictions
- A 30t/day CO2 chemical absorption test plant (CAT30) has been built simultaneously in preparation of phase2
- The final goal is a reduction of CO2 emissions by 30% (2030)

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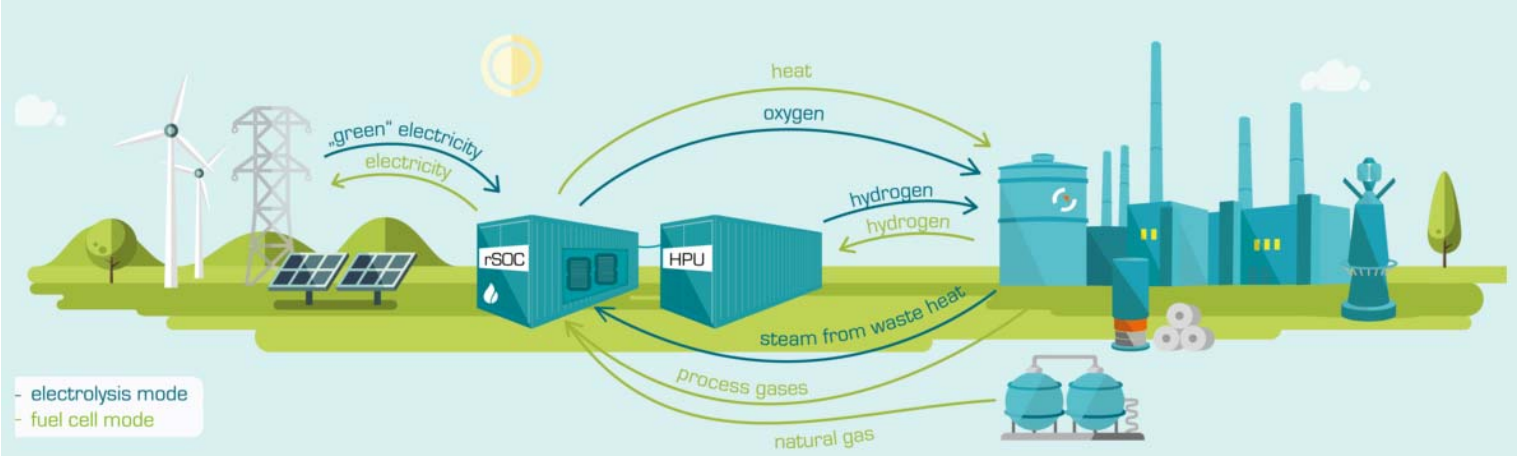
GrInHy
H2FUTURE
Hydrogen
Electricity

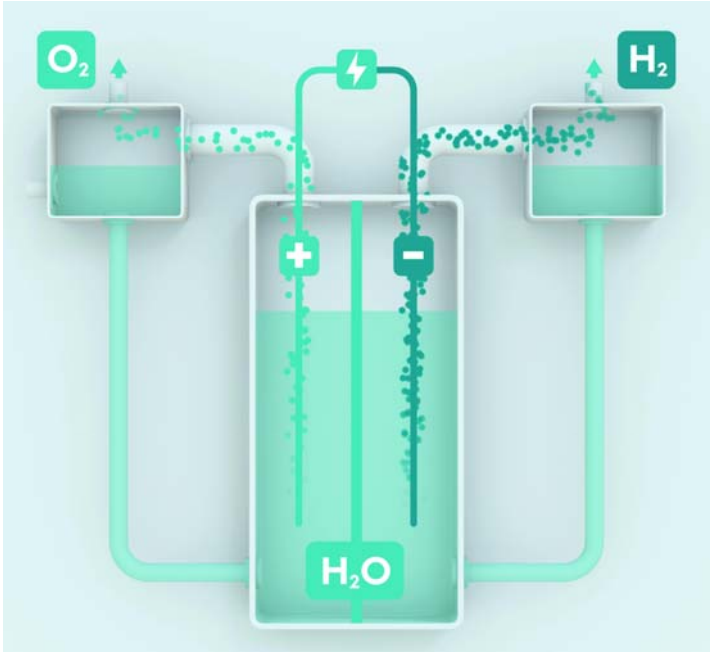
GrInHy

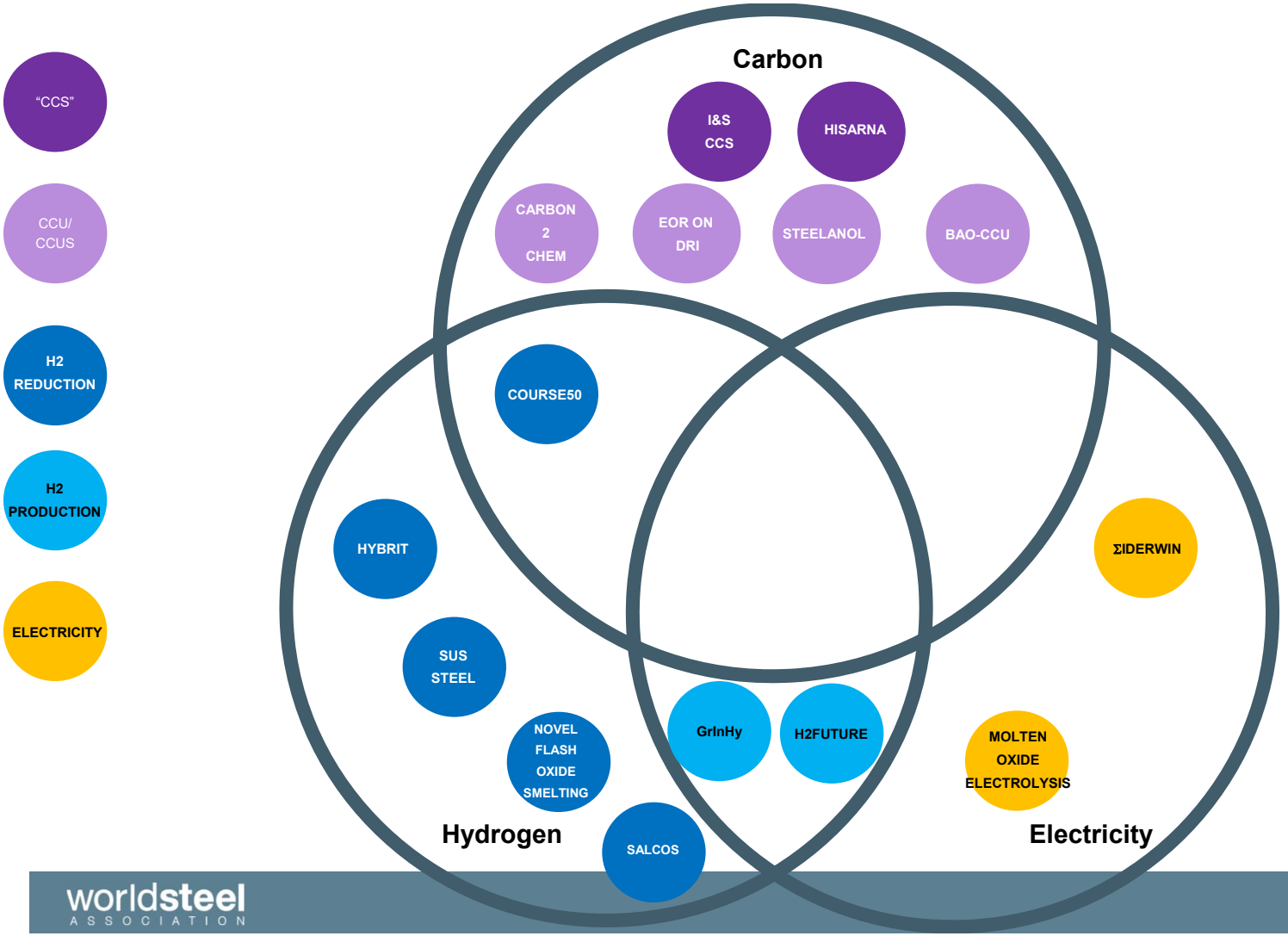
- Operation of a high-temperature electrolyser as reversible generator (rSOC, reversible Solid Oxide Cell) in the industrial environment of an integrated iron and steel work (Salzgitter, Germany).
- The concept assesses the system's flexibility to produce either hydrogen or electricity. In case of hydrogen production, the produced hydrogen shall be used on-site in annealing processes substituting hydrogen based on fossil hydrocarbons.
- The project's outcomes shall result in the development of a reversible generator based on the SOC technology towards a marketable product.



H2Future

- European flagship project aiming to produce hydrogen from renewable electricity using a PEM (proton exchange membrane) electrolyser module
- The hydrogen can be stored for use in a multitude of applications including as a raw material in the steel industry
- The construction work of a research facility has begun at voestalpine's site in Liz, Austria. The plant has a capacity of 6 megawatts and will be able to produce 1,200 cubic meters of "green" hydrogen an hour. The goal is to achieve a record output efficiency of 80 percent in converting electricity into hydrogen.

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ΣIDERWIN
MOLTEN OXIDE ELECTROLYSIS
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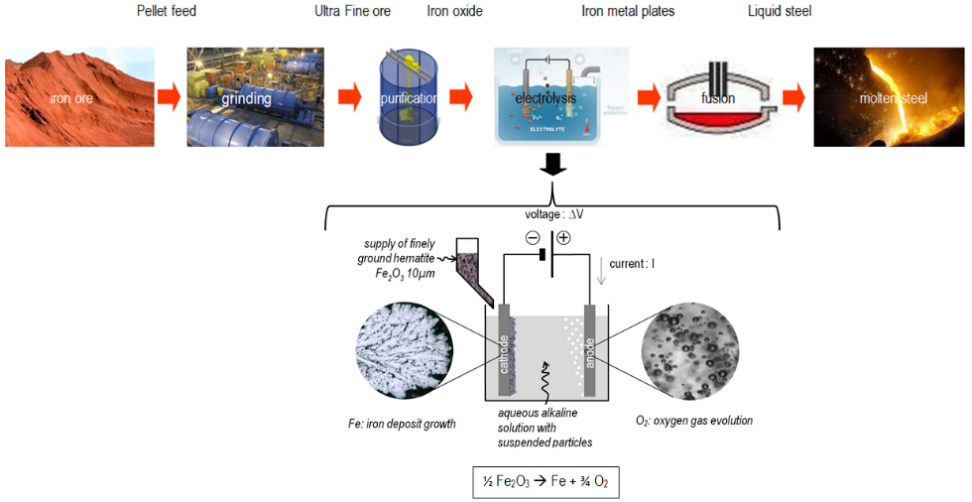
Electricity

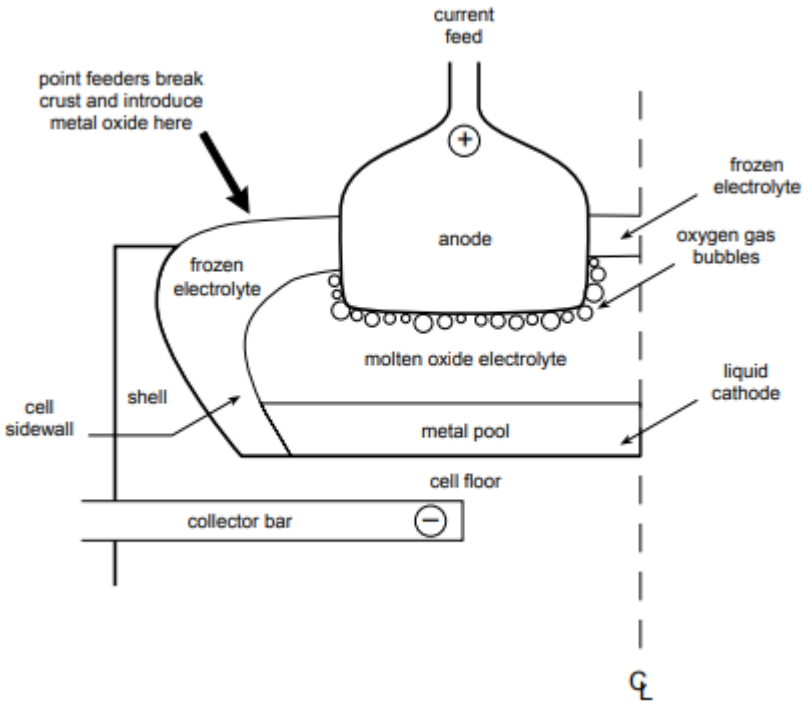
ΣIDERWIN

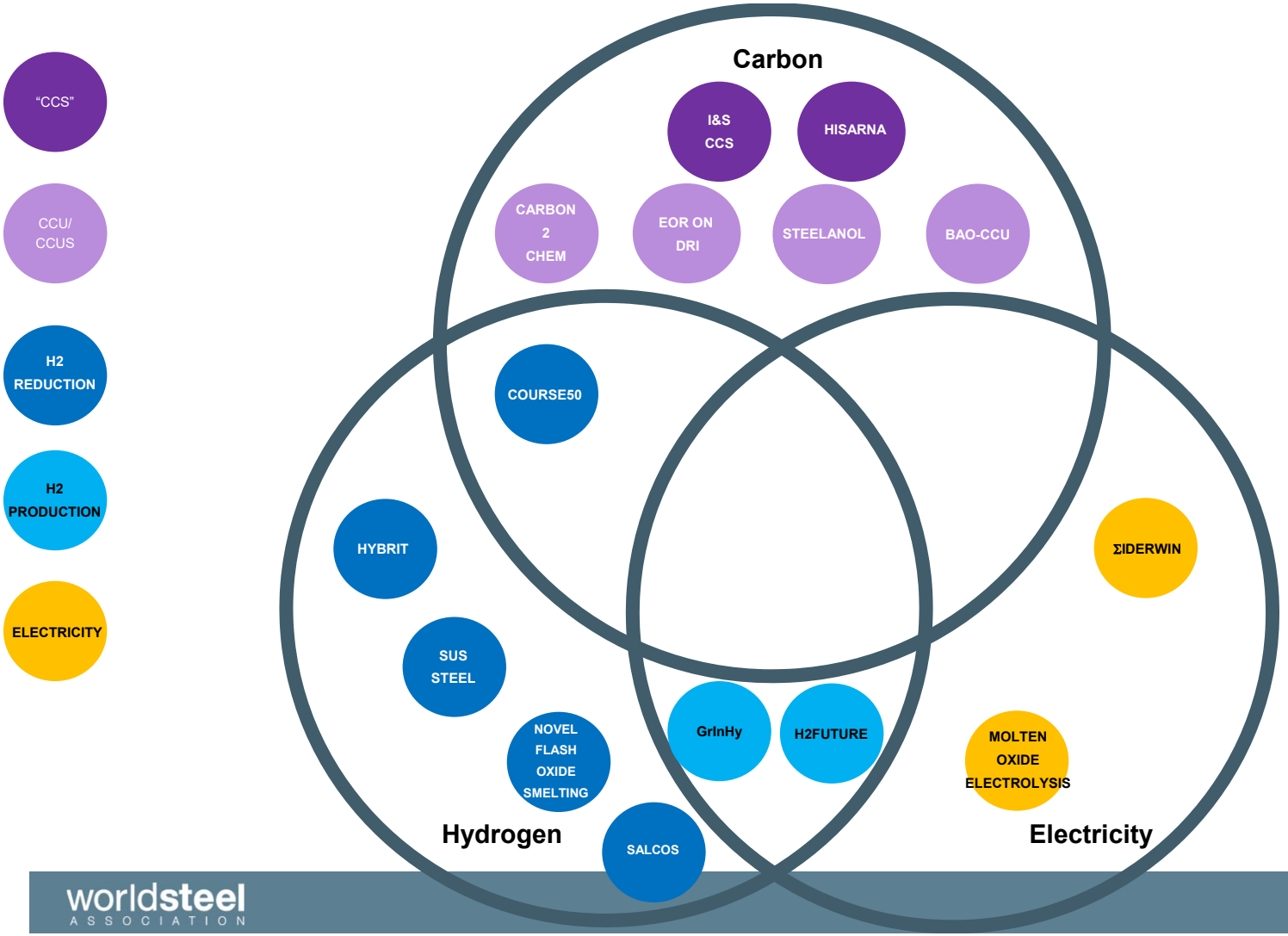
- An electrolytic process to transform iron oxides into steel plate with a significant reduction of energy use
- The process has the potential to achieve
  - a reduction by 87% of the direct CO2 emissions,
  - a reduction by 31% of the direct energy use,
  - the ability to produce steel from by-products rich in iron oxides from non-ferrous metallurgy residues, and
  - an increased integration with renewable energies with a more flexible process.
- Next step is the development of a 3 metre-long new experimental pilot to validate the technology at TRL 5-6



Molten Oxide Electrolysis

- Developed by Dr Sadoway at MIT
- Molten oxide electrolysis (MOE) is an extreme form of molten salt electrolysis using carbon-free anodes which facilitates the production of oxygen gas at the anode
- Molten oxide electrolysis has no direct CO_2 emissions
- Requires additional funding to scale up

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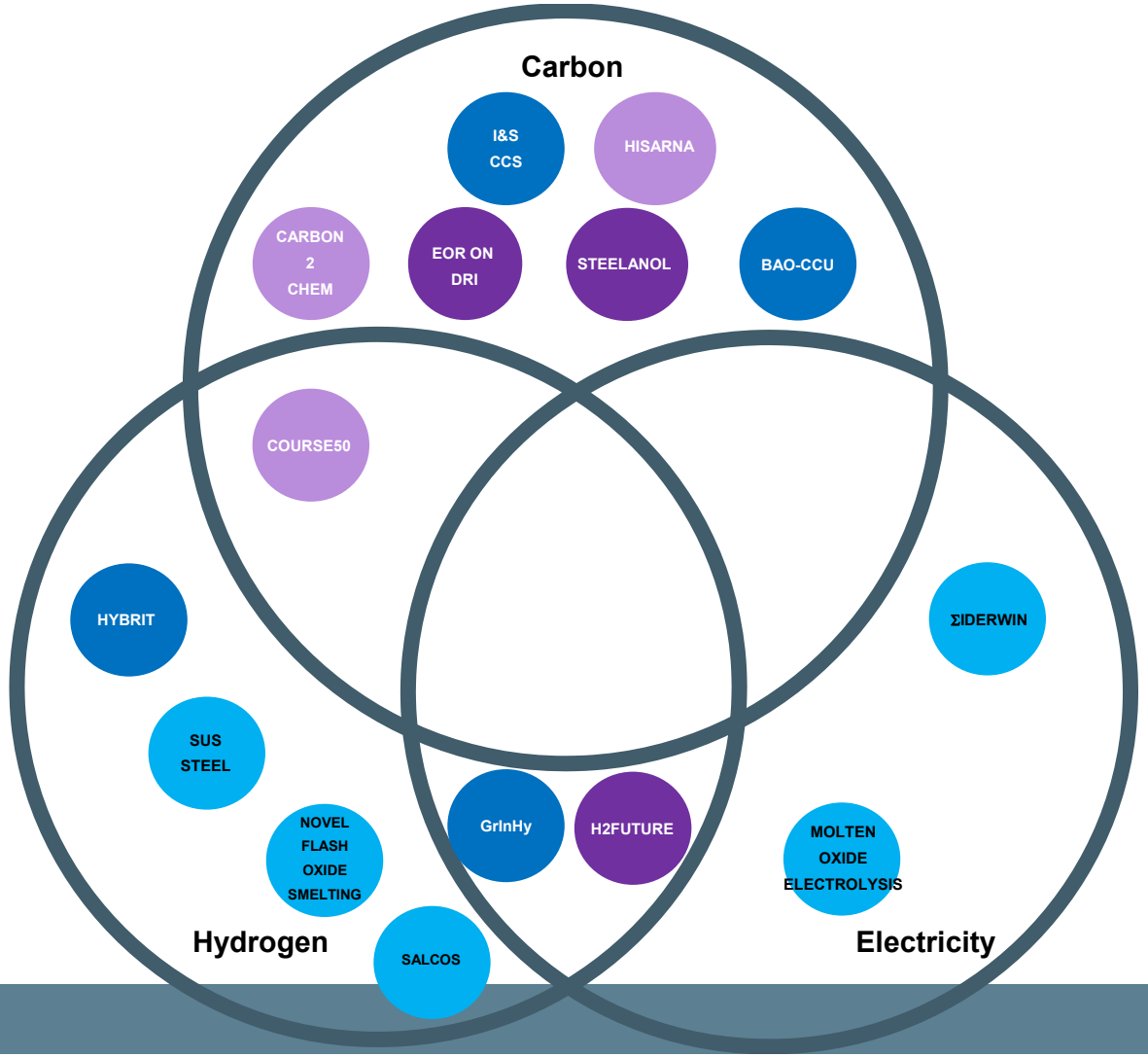
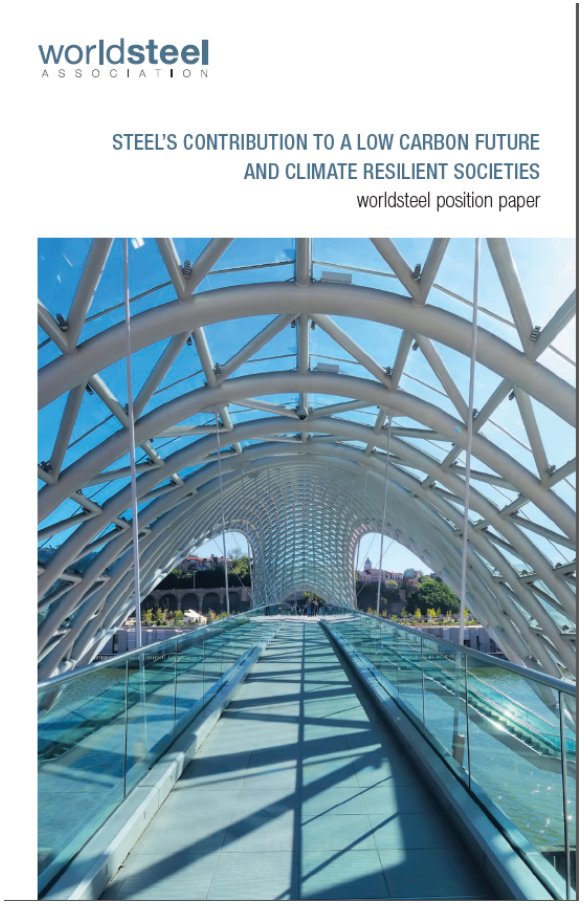


Barriers to implementation

- Funding issues
- First mover risks linked to technology and upscaling
- Risks of carbon leakage
- International traded material
- Policy issues



Observations

- Less focus on CCS as a solution
- More focus on the use of hydrogen, CCU and integrated solutions involving other industries and utility companies
- All options are dependent on large amounts of carbon free electricity or CO_2 storage
- For our industry there is no silver bullet but all options are needed at the same time and their implementation will depend on local circumstances such as availability of carbon free electricity and CO_2 storage options

Thank you for your attention.

For further information contact:

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