



Greening steel production – technologies and policies

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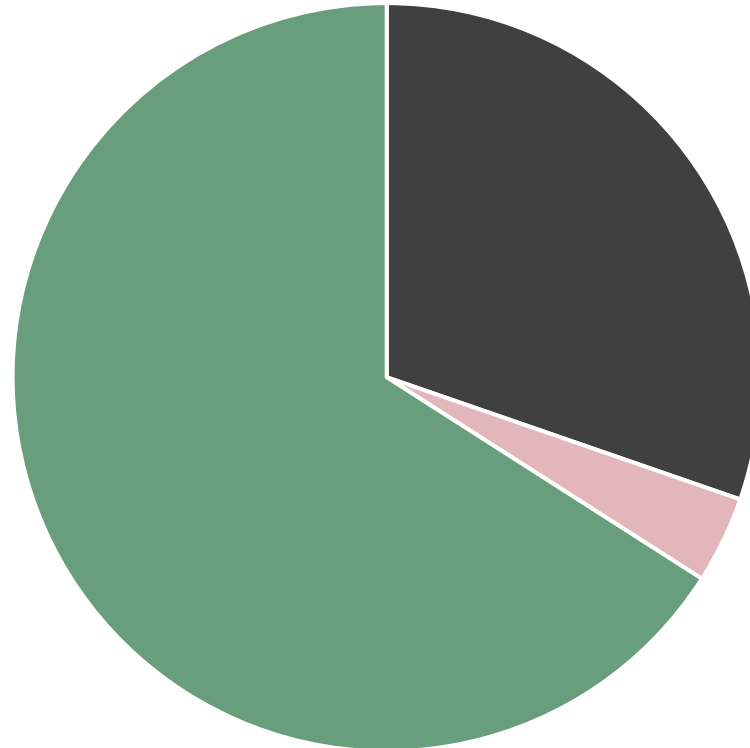
Greening High-Temperature Manufacturing: Toward an RD&D Agenda

Outline

- US steel production 2019
- Alternatives to coal
- The challenge
- Technologies
 - Hydrogen Direct Reduction
 - Electrolysis
 - Plasmasmelting
- Conclusions

US steel production 2019

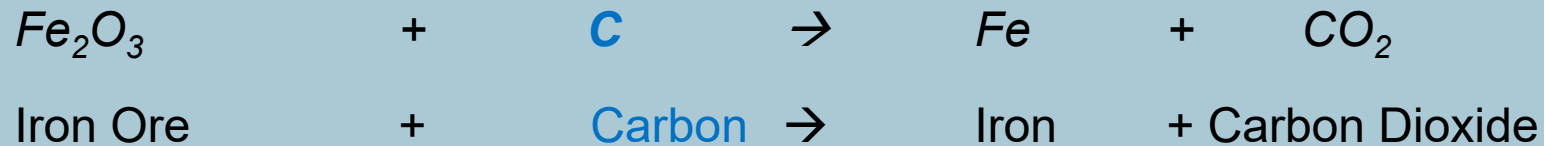
88 million tons



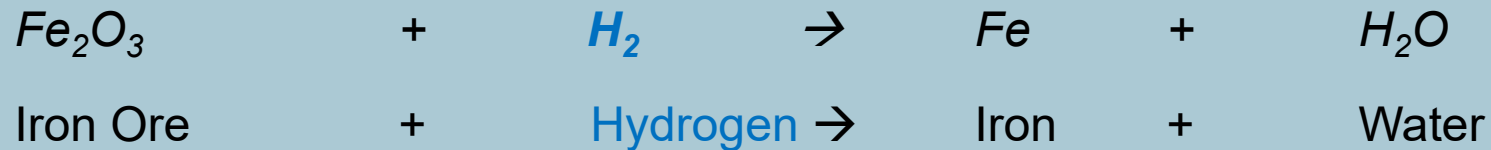
- coal based (coal & iron ore)
- natural gas based (natural gas & iron ore)
- scrap based (scrap & electricity)

Steel sector's CO₂ emissions – it's not only about heat, it is also about chemical reactions

Coal based steelmaking:



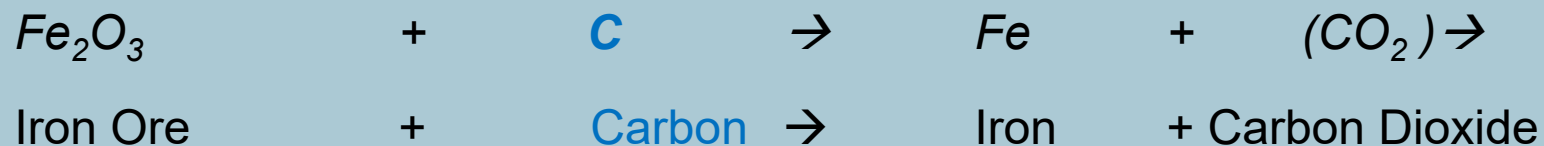
Hydrogen based steelmaking:



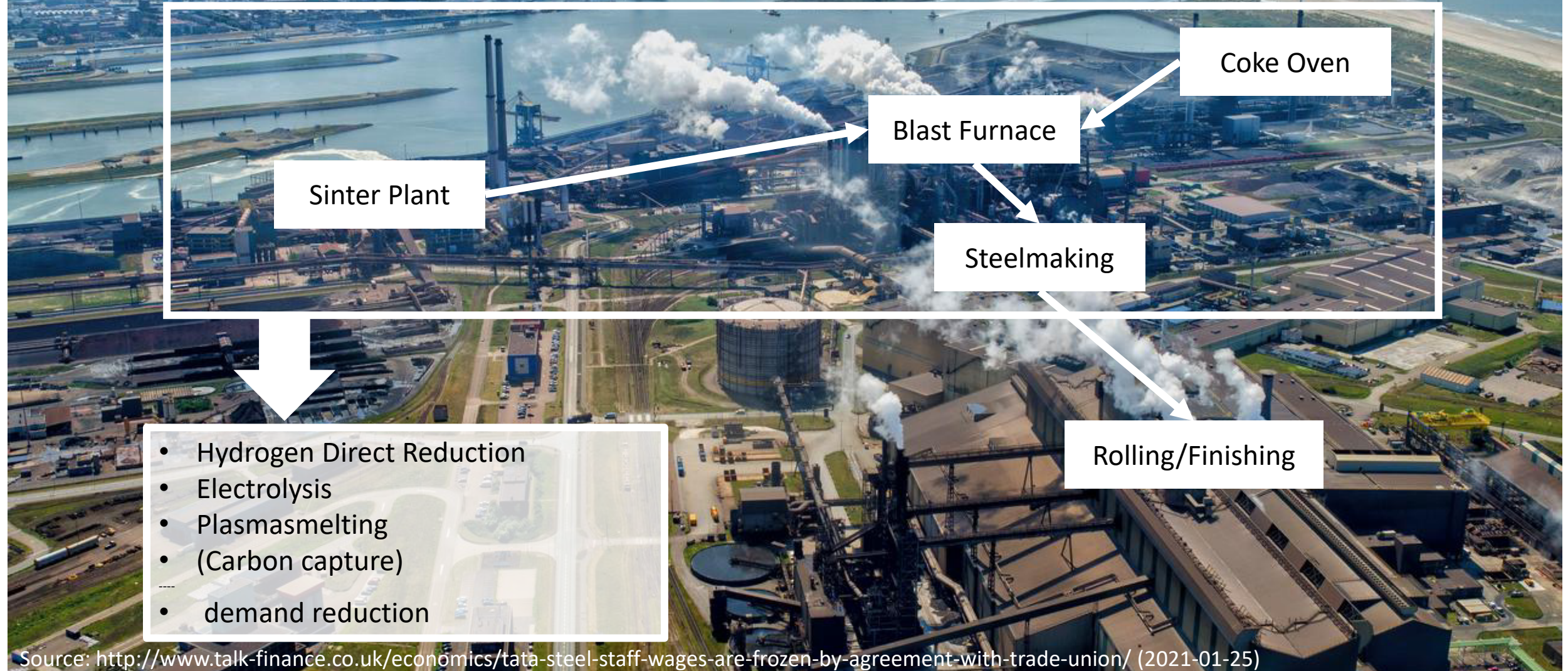
Electricity based steelmaking:



Coal based steelmaking + carbon capture:



Coal based steel production site (example)

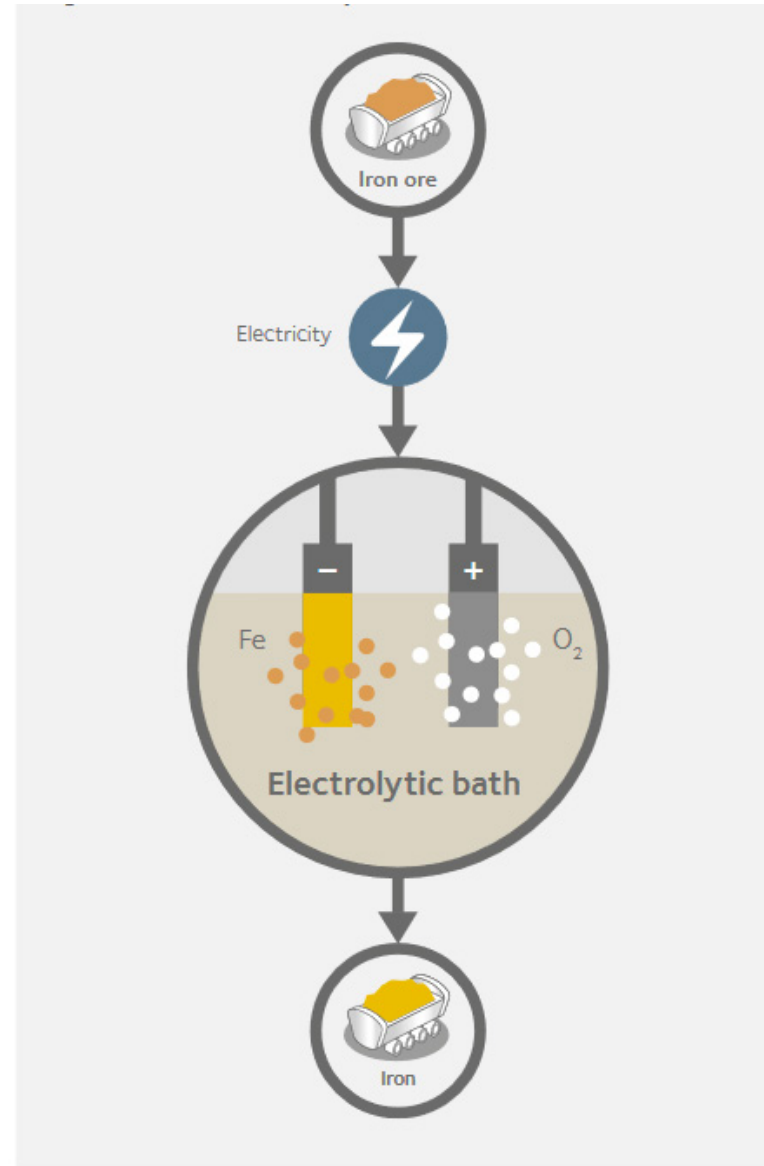


Gas-based direct reduction

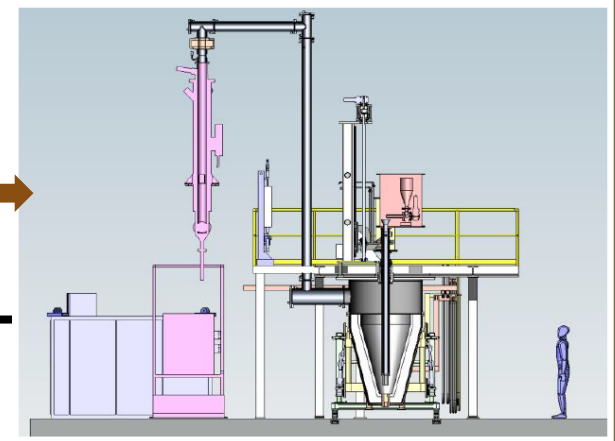
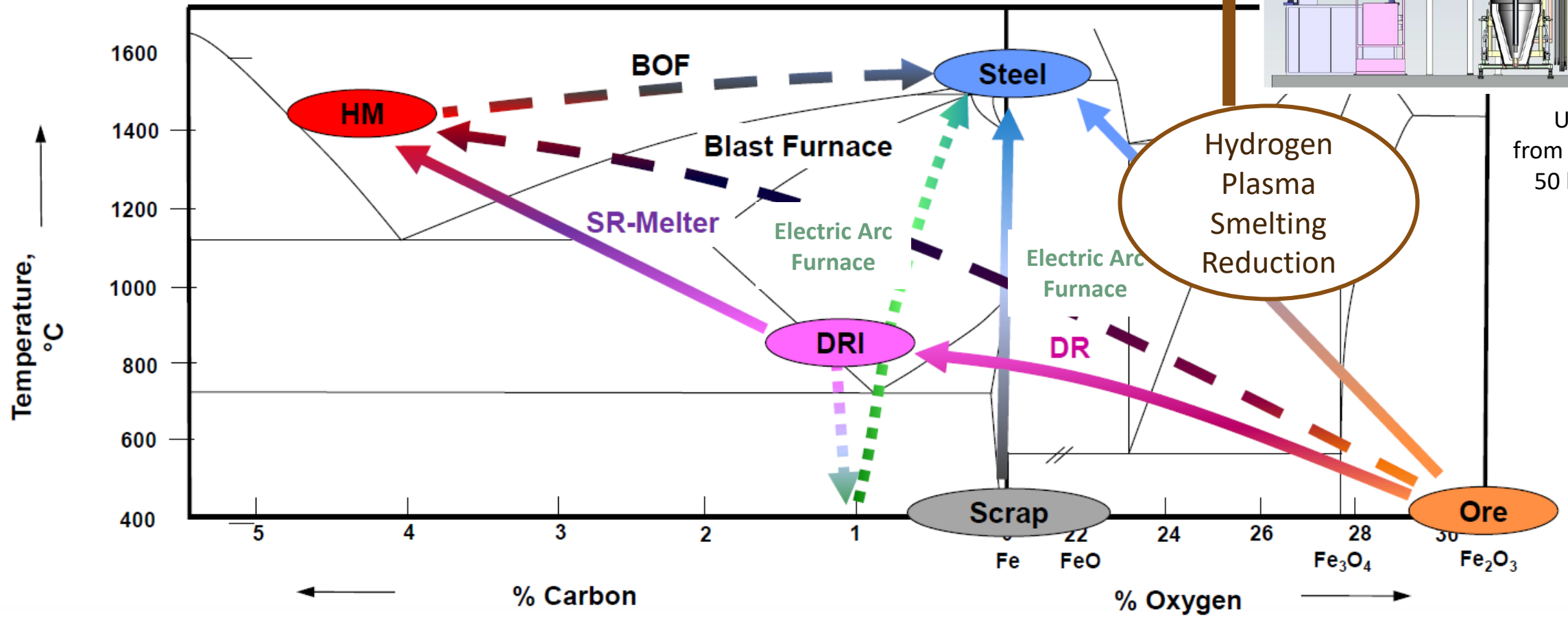
- commercial, 82 Mt globally in 2019
- can be switched to hydrogen with minor changes (flexible use as well)
- in Europe: HYBRIT (Pilot), SALCOS (Pilot), ThyssenKrupp, Dillinger, ArcelorMittal (grey hydrogen)
- in Asia: HBIS Group 0.6 Mt plant ordered Nov 2020; Baosteel Carbon Neutrality Goal 2050 (?)



Electricity based steelmaking at ArcelorMittal (Siderwin)



Plasmasmelting Reduction



Upscaling
from 100 g to
50 kg batch
process

Conclusions

- Hydrogen direct reduction for close to zero emissions steelmaking is (almost) commercially available
- Steelmaking plants that use natural gas can be run with hydrogen as well (with minor adjustments)
- Other low CO₂ steelmaking technologies are at early stage of development.
- Carbon capture as a low-CO₂ technologies may be reserved for sectors harder to abate (air transport, chemicals) or to achieve negative emissions to compensation agriculture and land-use
- Material efficiency!
- Major barriers: operational costs & availability of low-CO₂ hydrogen
- Policies that adress operational costs: e.g. lead markets, quotas, carbon contracts for difference, carbon border adjustments

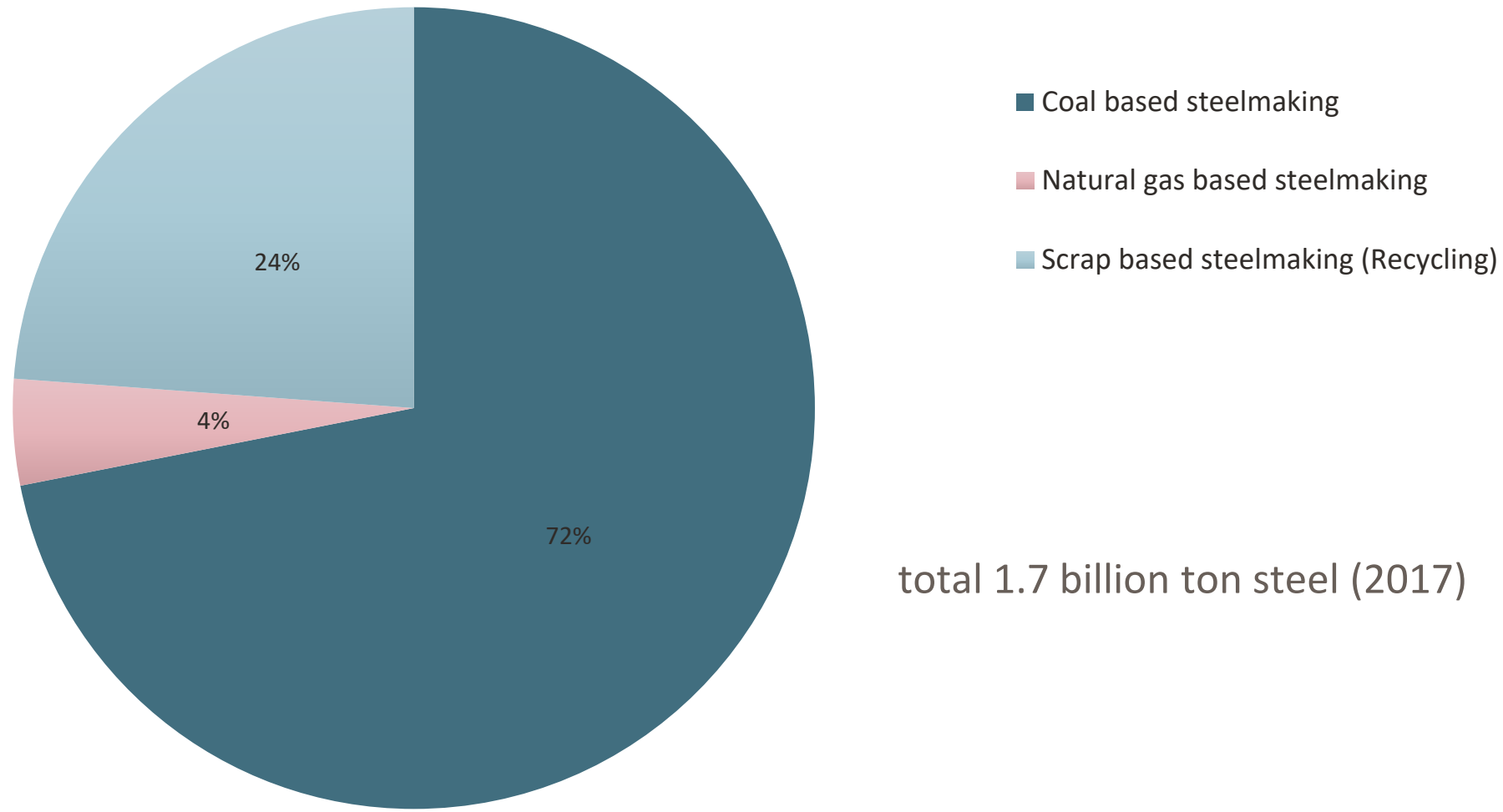
Thanks for listening!

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Back up

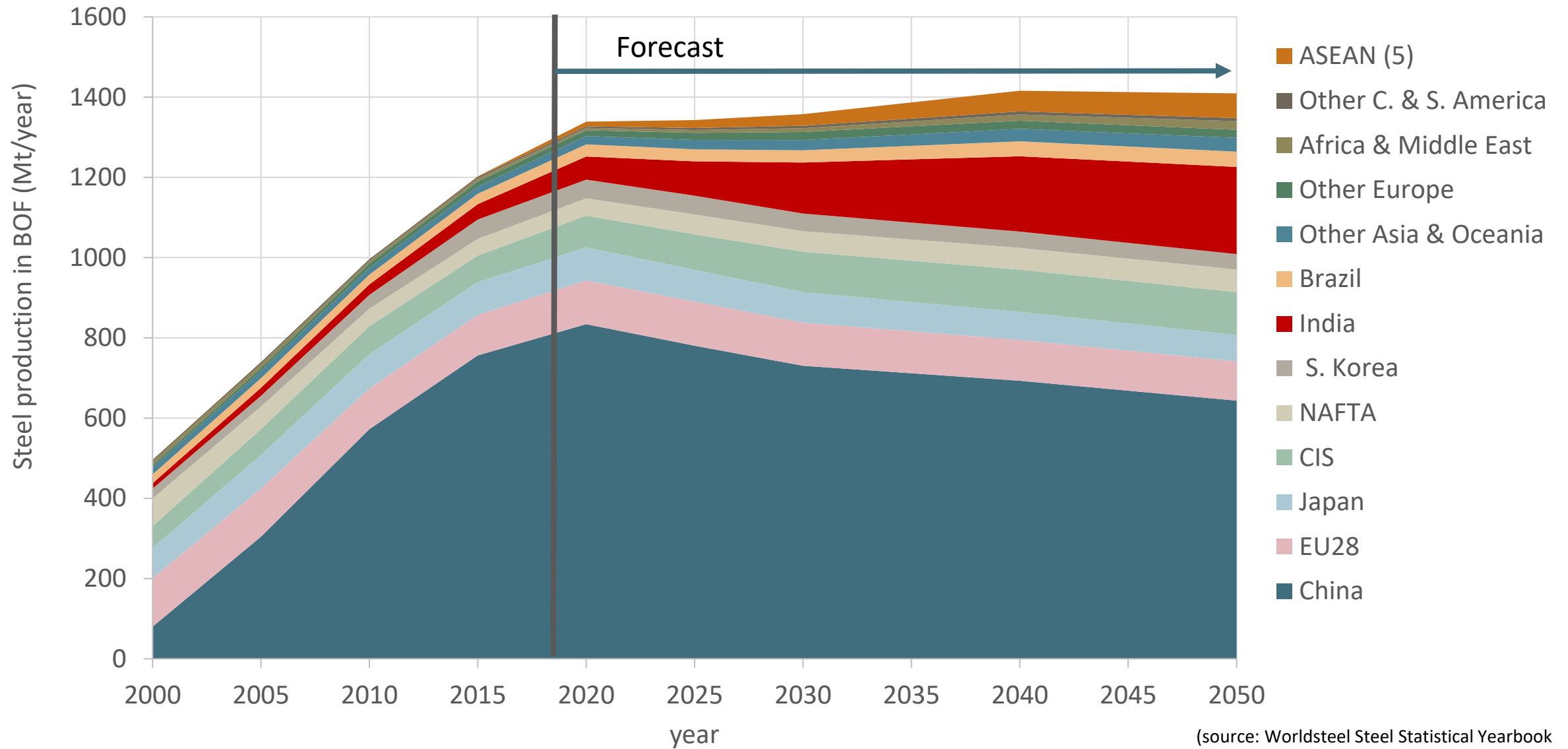
Why coal matters – Global steel production today



total 1.7 billion ton steel (2017)

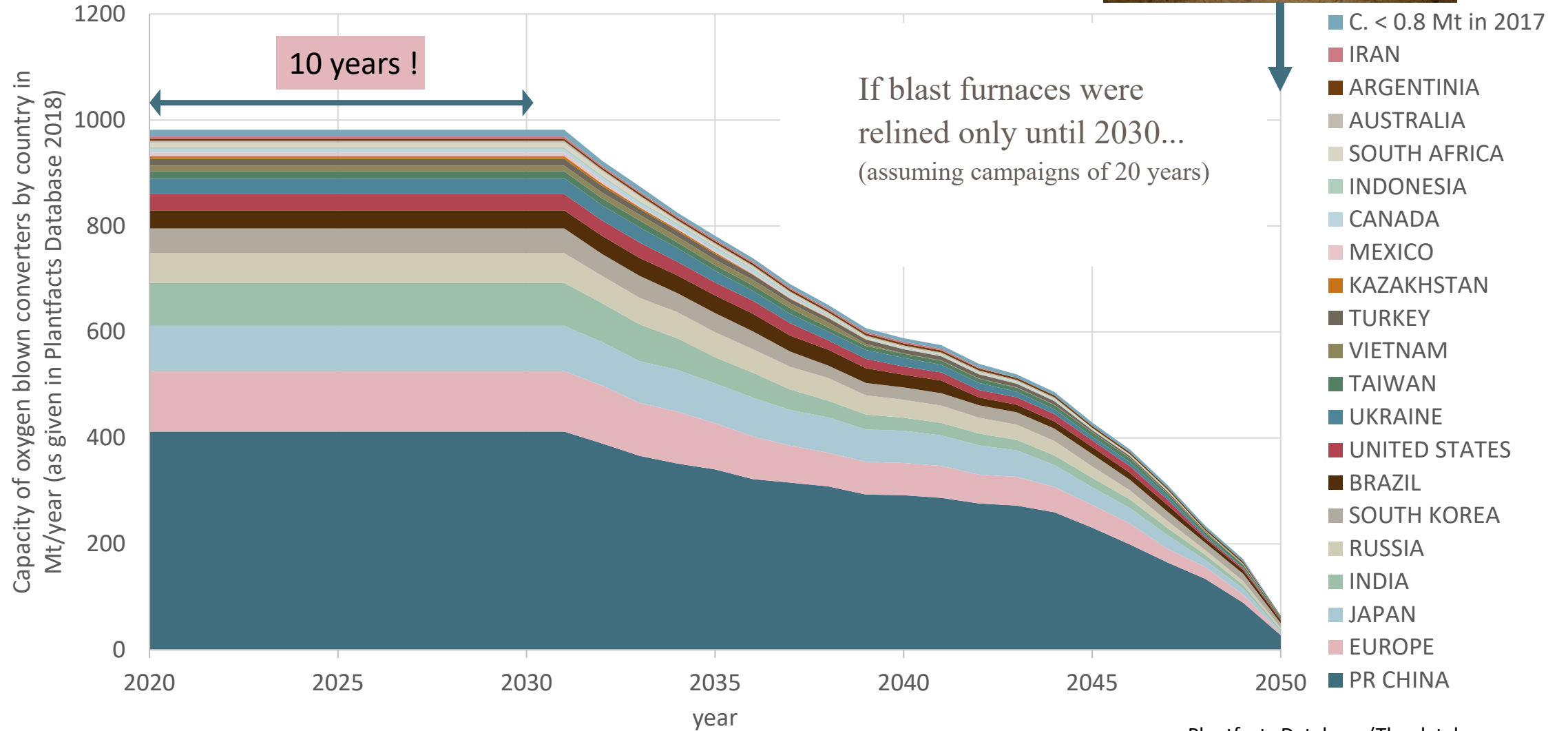
sources: Worldsteel, Midrex [neglecting coal based steelmaking in rotary kilns (15 Mio t, 2017)]

What is going to happen - Primary steel production (2000-2015) & Forecast (2020-2050)



(source: Worldsteel Steel Statistical Yearbook (2002, 2007, 2012, 2017) and Worldsteel (2019)).

What should happen?



source: Plantfacts Database (The database lacks several 100 Mts for China)