

# Net-zero emission opportunities for the Iron and Steel industry at a global scale

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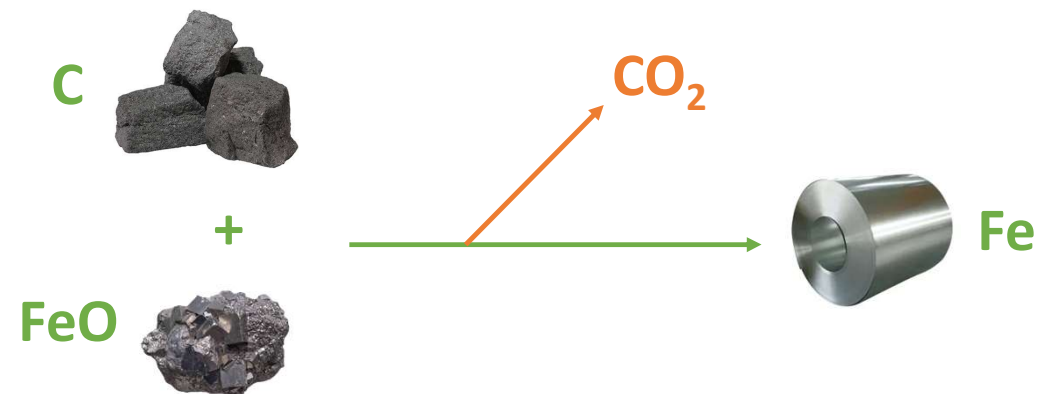


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# The challenges of the iron & steel industry

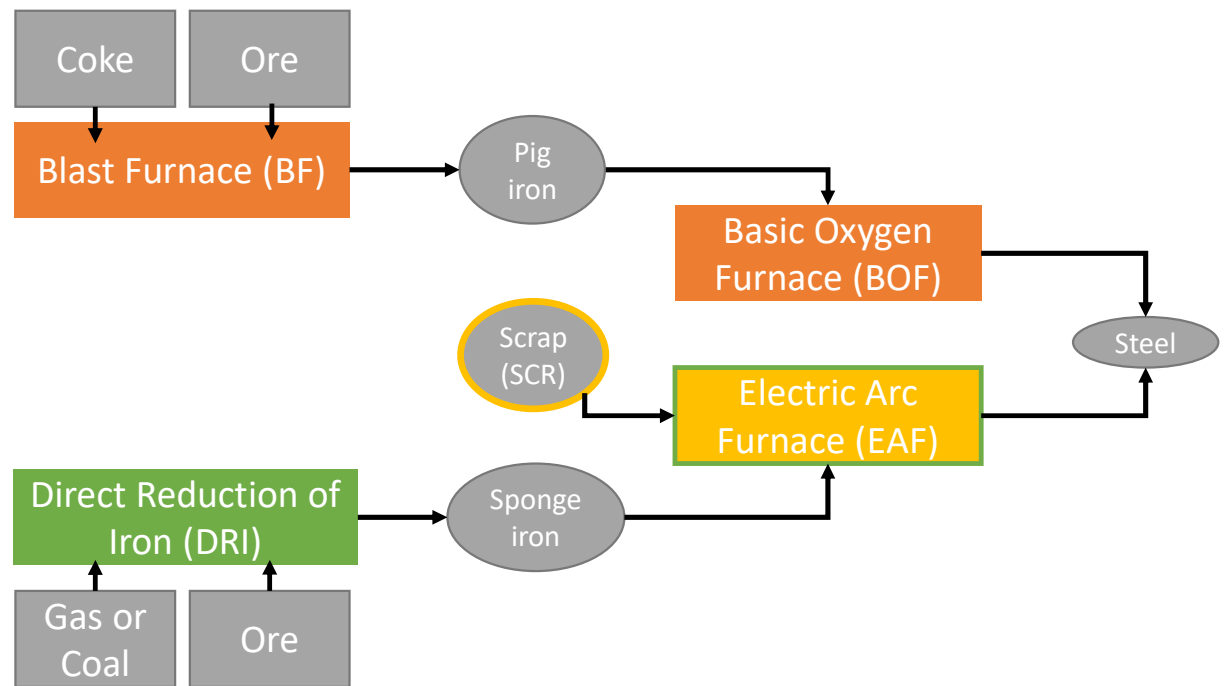
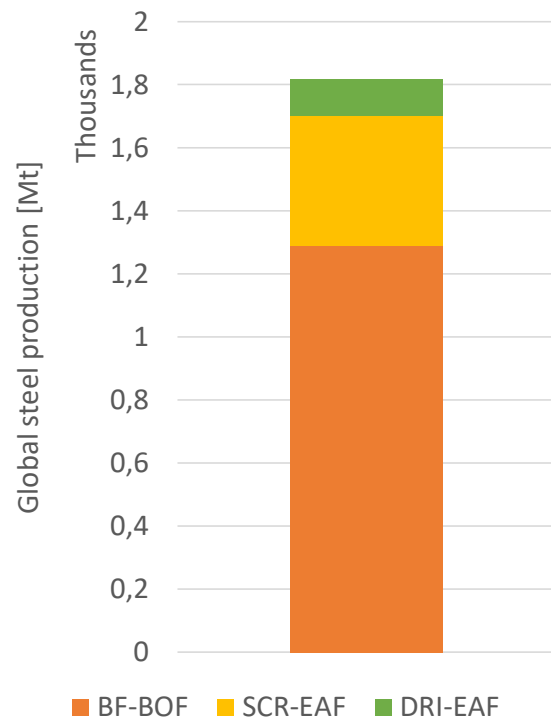
The iron & steel industry consists of deoxygenating the iron ore.

{ High temperature process  
CO<sub>2</sub> process emissions

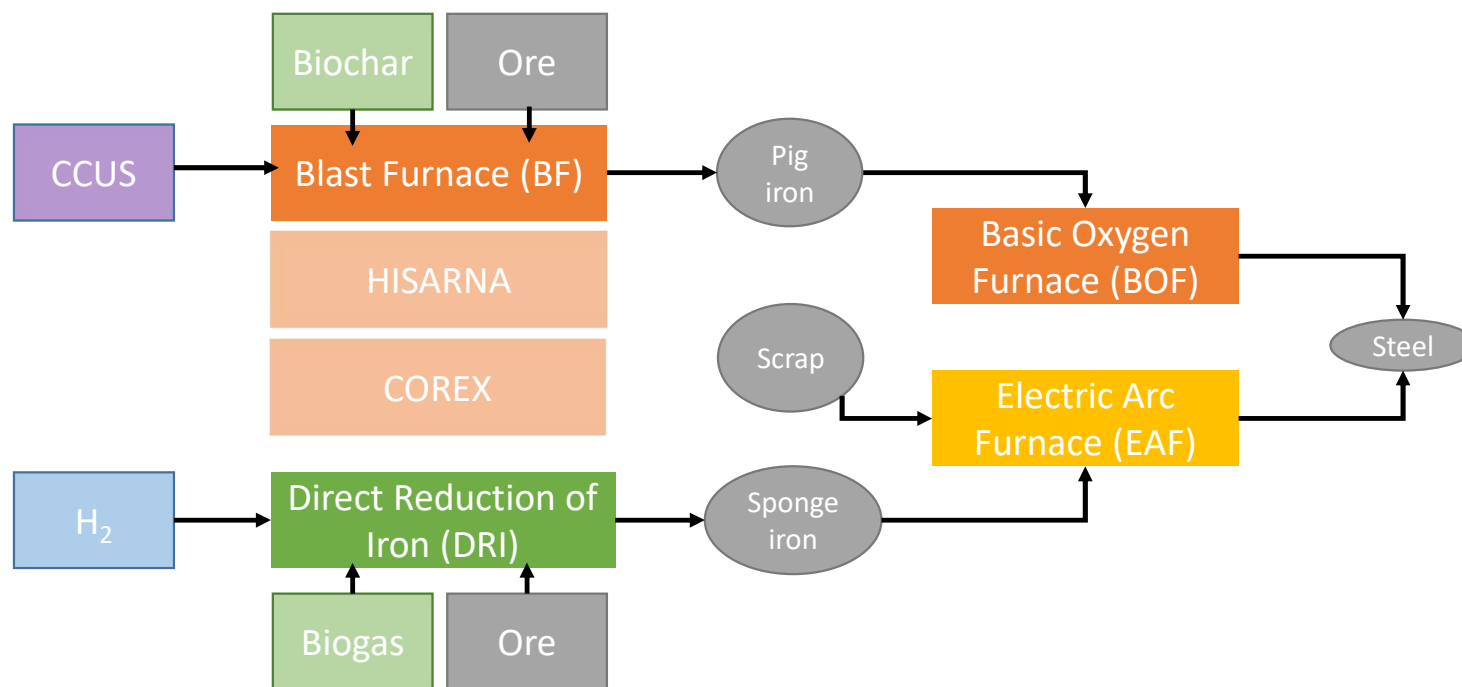


→ 7% of global CO<sub>2</sub> emissions

# Current status of steel production



# Alternative production means



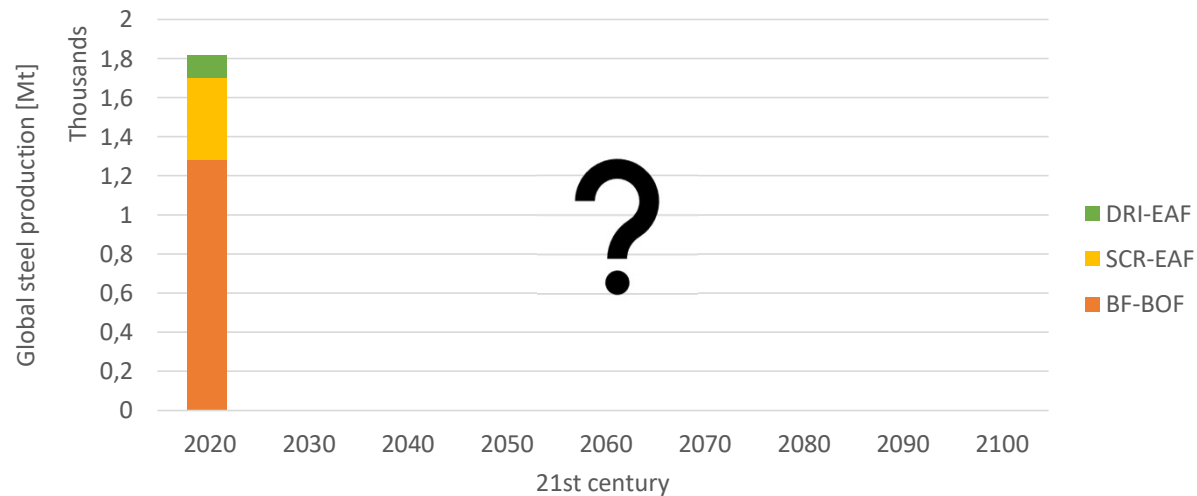
# Alternative production means

Iron producing routes	CO <sub>2</sub> emissions (kt)	Levelized cost of steel (\$/t)	CO <sub>2</sub> avoidance cost (\$/CO <sub>2</sub> avoided)
BF-BOF	1653	590	
BF-BOF CCS	401	694	83
BF-BOF TGR	1861	777	
BF-BOF CCS TGR	774	852	69
COREX	2907	665	
COREX CCS	1231	727	37
HISARNA	1355	628	
HISARNA CCS	256	724	87
MIDREX	785	584	
MIDREX CCS	412	615	83
ULCORED	586	557	
ULCORED CCS	224	588	84
ULCOWIN	289	706	
ULCOLYSIS	28	696	
DRI-H2	101	791	
DRI-H2 INT	280	742	
SCR-EAF	149	630	

Process	Availability date	Fossil fuel use	Bioproduct substitution	Maximum substitution potential	Reference
Coke oven	2018	Coal	Charcoal	0%-5%	(Mousa et al. 2016)
Pelletization	2018	Coal	Charcoal	0%-100%	
Sintering	2018	Coke	Charcoal	0%-40%	(Nwachukwu, Wang, and Wetterlund 2021)
Blast Furnace / with CCS (including the Top Gas recycling option)	2018	Coke	Charcoal	0%-6%	(Suopajärvi, Pongrácz, and Fabritius 2013; Suopajärvi et al. 2017)
		Coal	Charcoal	0%-100%	
		Natural gas	Biomethane	0%-100%	
Direct Reduction of Iron (MIDREX) / with CCS	2018 / 2025	Natural gas	Biomethane	0%-100%	(Tanzer, Blok, and Ramírez 2020)
COREX / with CCS	2020	Coal	Charcoal	0%-100%	(Norgate et al. 2012)
		Coke	Charcoal	0%-45%	
HISARNA / with CCS	2030	Coal	Charcoal	0%-100%	
ULCORED / with CCS	2030	Coal	Charcoal	0%-100%	(Tanzer, Blok, and Ramírez 2020)
		Natural gas	Biomethane	0%-100%	
ULCOWIN	2050	Natural gas	Biomethane	0%-100%	(Tanzer, Blok, and Ramírez 2020)
		Coal	Charcoal	0%-100%	
CUPOLA	2018	Natural gas	Biomethane	0%-100%	(Yang, Meerman, and Faaij 2021)
		Coal	Charcoal	0%-100%	
EAF	2018	Natural gas	Biomethane	0%-100%	(Yang, Meerman, and Faaij 2021)
DRI-H2 integrated steel plant	2030	Coal	Charcoal	0%-100%	(Tanzer, Blok, and Ramírez 2020)
		Natural gas	Biomethane	0%-100%	
Final production of steel	2018	Natural gas	Biomethane	0%-100%	(Tanzer, Blok, and Ramírez 2020)

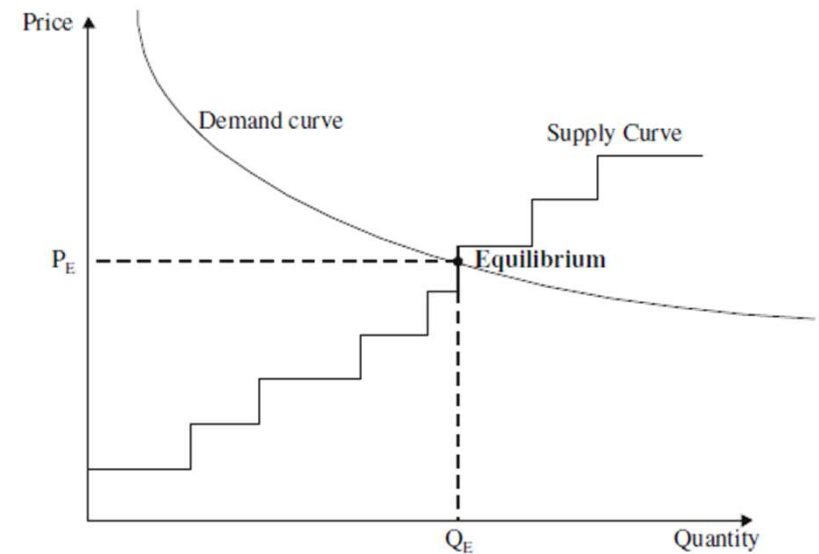
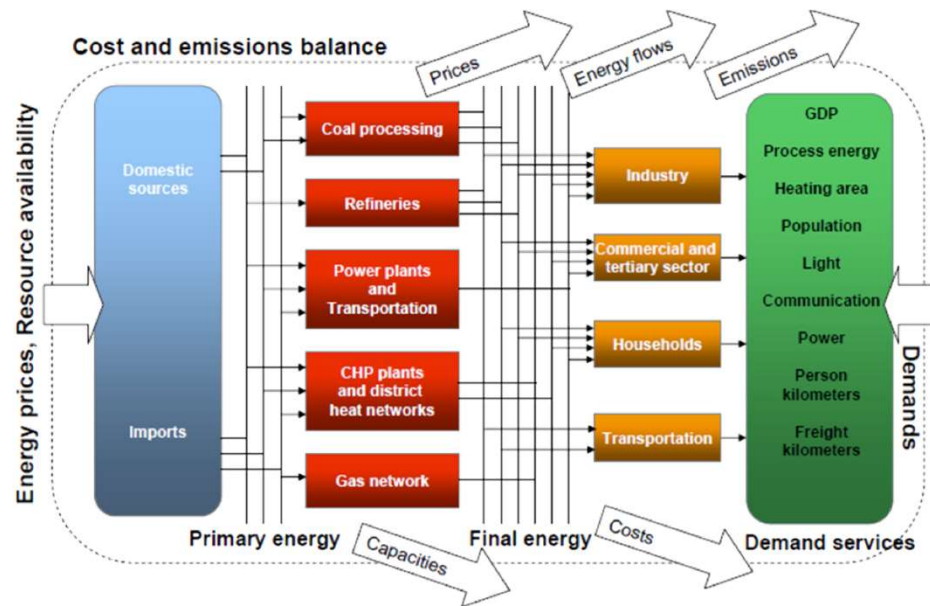
# Research question

→ In the race to get net-zero, what opportunities for the iron & steel industry to redesign its production?



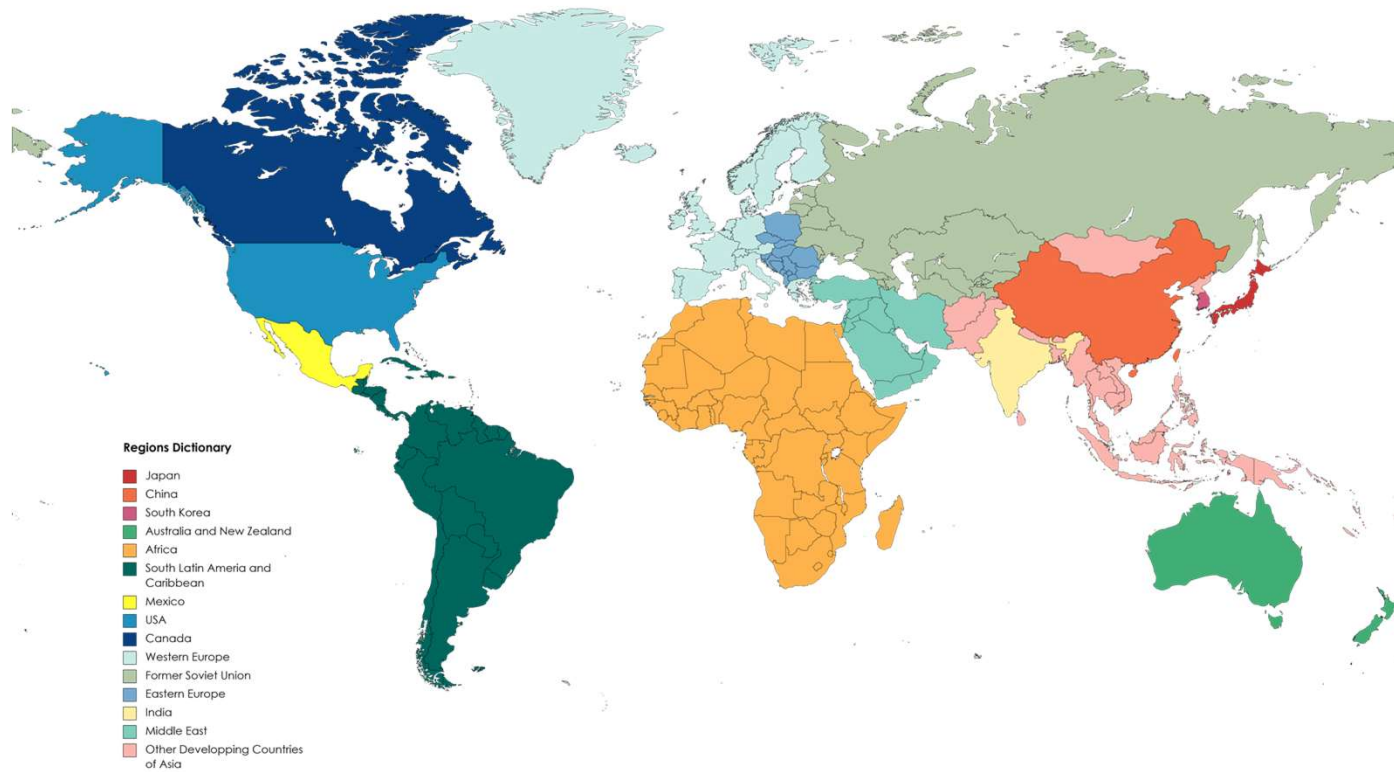
# Tool: the TIAM-FR model

→ Long-term bottom-up cost-minimization model





# Tool: the TIAM-FR model

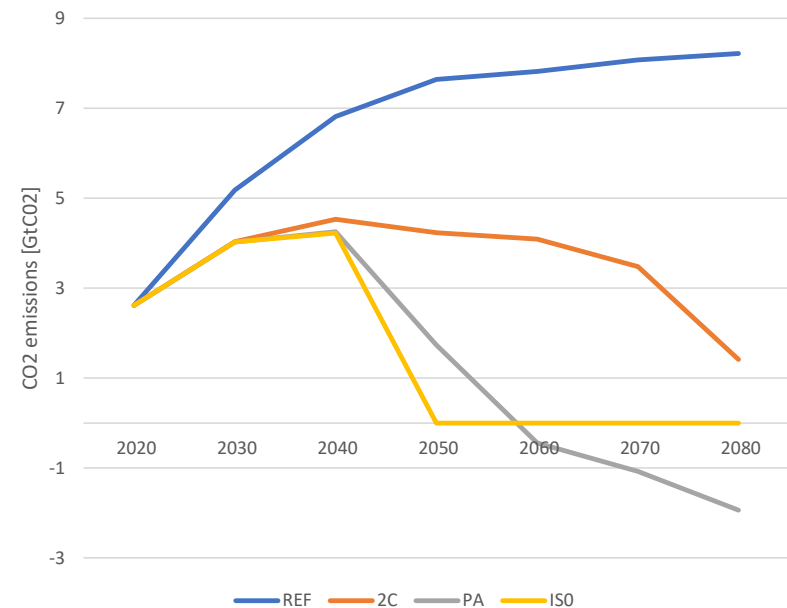


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# Scenarios

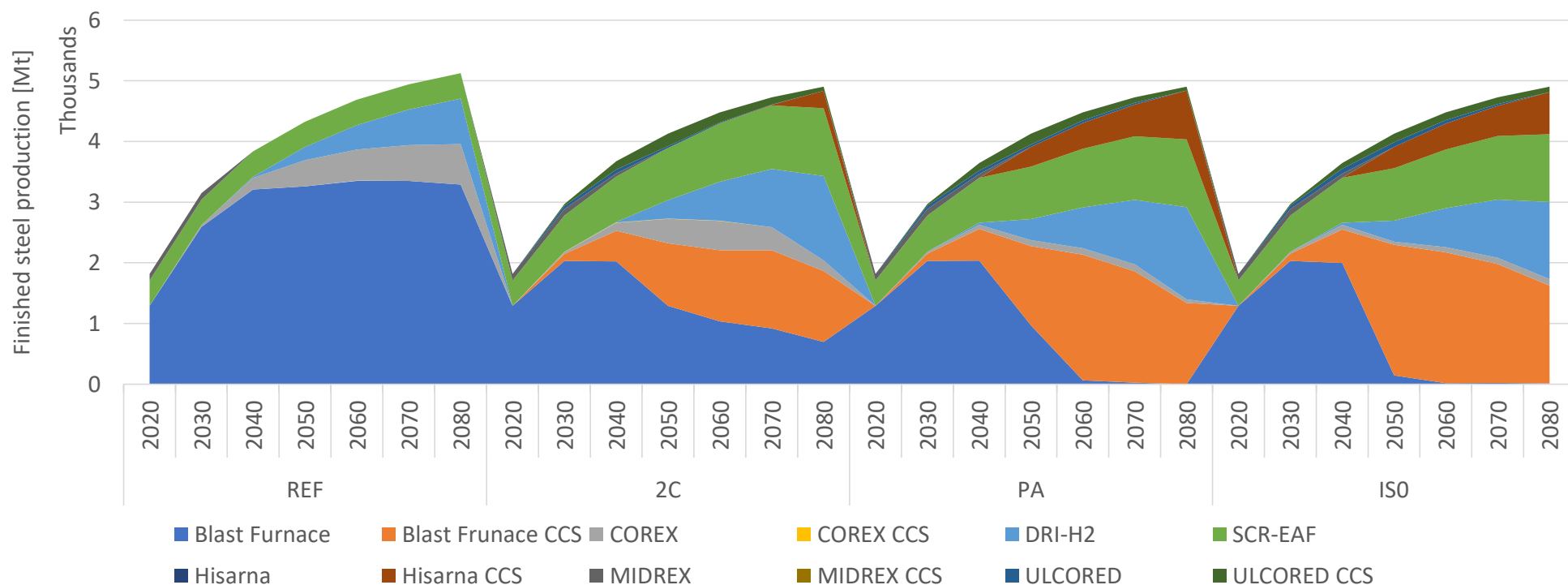
4 scenarios to explore the future of the iron & steel industry:

1. **REF**: no climate policy
2. **2C**: the world stays below 2°C temperature elevation by 2100
3. **PA**: the world is in line with the ambitions of the Paris Agreement
4. **ISO**: the Paris Agreement with a net-zero target for the iron & steel industry



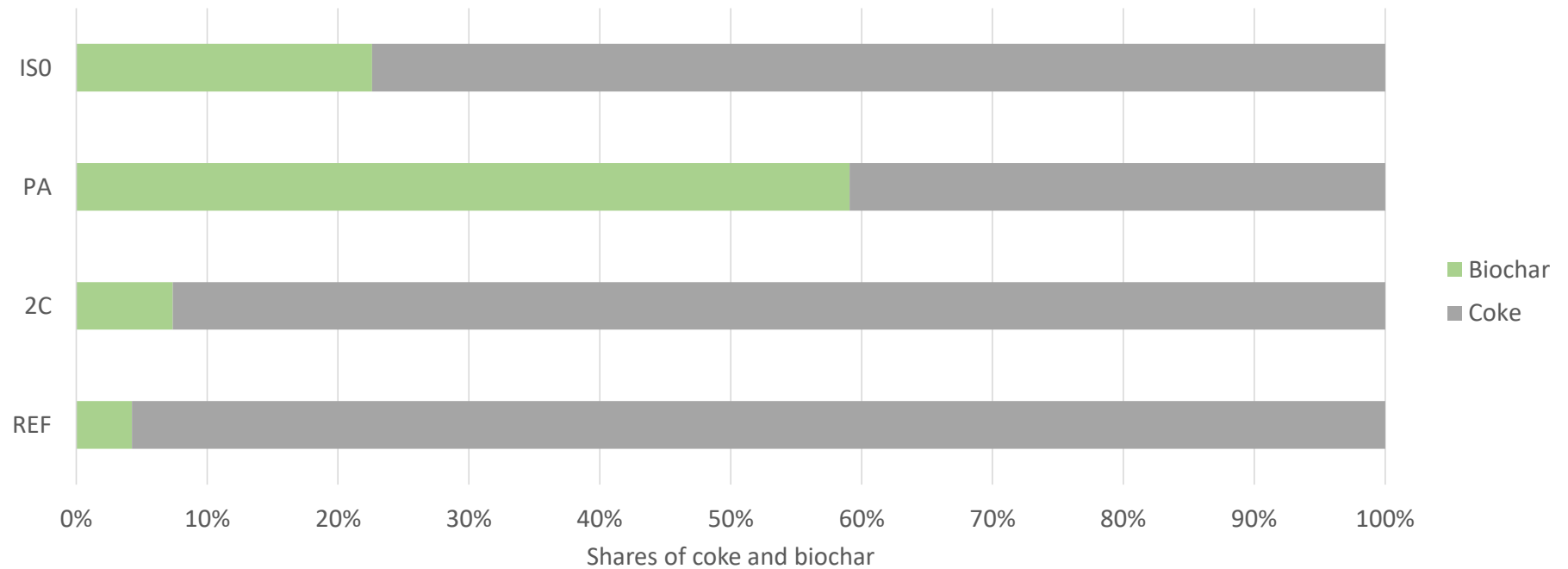
# Main results

Evolution of production technologies over the 21st century in the 4 scenarios



# Main results

Overall shares of coke and biochar used in the iron & steel industry in the 4 scenarios



# Conclusion



→ *In the race to get net-zero, what opportunities for the iron & steel industry to revamp its production?*

→ The iron and steel industry can achieve its decarbonation under 3 main conditions

1. Massively deploy CCS technologies
2. Massively use biochar
3. Global cooperation

Thank you!

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