철강 산업의 기후변화대응

철강 부문의 2050 탄소중립 기회와 도전

2021년 11월 25일 (목) 오후 4:00 – 6:30

안녕하세요, '철강 산업의 기후변화대응 – 철강 부문의 2050 탄소중립 기회와 도전'를 주제로 진행되는 온라인 세미나에 여러분을 초대합니다. 전 세계 온실가스 배출량의 약 7%를 차지하는 철강 산업의 탈탄소에 대한 필요성이 증가함에 따라, 기후솔루션에서는 관련 정책 및 산업을 대표하는 다양한 그룹의 연사와 패널을 초청하여 다음의 내용으로 세미나를 개최하고자 합니다. 이번 세미나에서는 2021년 상반기 KAIST와 SFOC가 공동 수행한 GCAM 통합 평가 모델 연구를 기반으로 철강 부문의 2050 탄소배출 넷제로 달성을 위한 철강 산업의 변화 방향과 도전 과제에 대해 논의할 예정이며, 프랑스 싱크탱크인 IDDRI에서도 최근 수행한 철강 넷제로 스터디 결과에 대해 함께 공유할 예정입니다.

토론 세션에서는 국내외 정부 관계자와 철강 산업계의 탈탄소 동향과 전략을 공유하는 시간을 통해 국제 협력 방안을 모색하고자 하니, 많은 분들의 관심과 참여 부탁드립니다.

참가 신청하기 ▲

주최 | 김성환 국회의원, (사)기후솔루션 **후원 |** 유럽연합

Supported by:

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프로그램 / Program

16:00 - 16:15	**축사** • **김성환** | 국회의원 • **Daniel Wolvén** | 주한 스웨덴 대사 • **Benoit Lory** | 주한 유럽연합 대표부 공사참사관 (경제통상)
16:15 - 17:00	**발표** • **Chris Bataille** | IDDRI 선임연구원 **- 전세계 철강부문의 2050 탄소중립 경로** • **김주진** | 기후솔루션 대표 **- 한국 철강산업의 기후변화 대응 현황** • **엄지용** | KAIST 교수 **- 한국 철강부문의 2050 탄소중립 경로** • **Anders Hektor** | 주한 스웨덴대사관 과학혁신참사관 **- 스웨덴 기업 및 연구기관의 그린 스틸 논의 현황**
17:00 - 17:10	**질의응답**
17:10 - 18:00	**지정토론** 좌장 **유승직** | 숙명여자대학교 기후환경에너지학과 교수 토론 1 **김경식** | 고철연구소 소장, (전) 현대제철 기획실장 토론 2 **서흥원** | 환경부 온실가스종합정보센터 센터장 토론 3 **이경훈** | 산업통상자원부 철강세라믹과 과장 토론 4 **Samuel Lowe** | 호주 정부 배출저감기술 특별 자문위원장
18:00 - 18:15	**질의응답 및 패널 추가발언**
18:15 - 18:20	**맺음말** **김주진** | 기후솔루션 대표

문의 김근하 연구원 geunha.kim@forourclimate.org

주최 | 김성환 국회의원, (사)기후솔루션 **후원 |** 유럽연합

Facility level, global pathways to net-zero GHG steel: South Korea

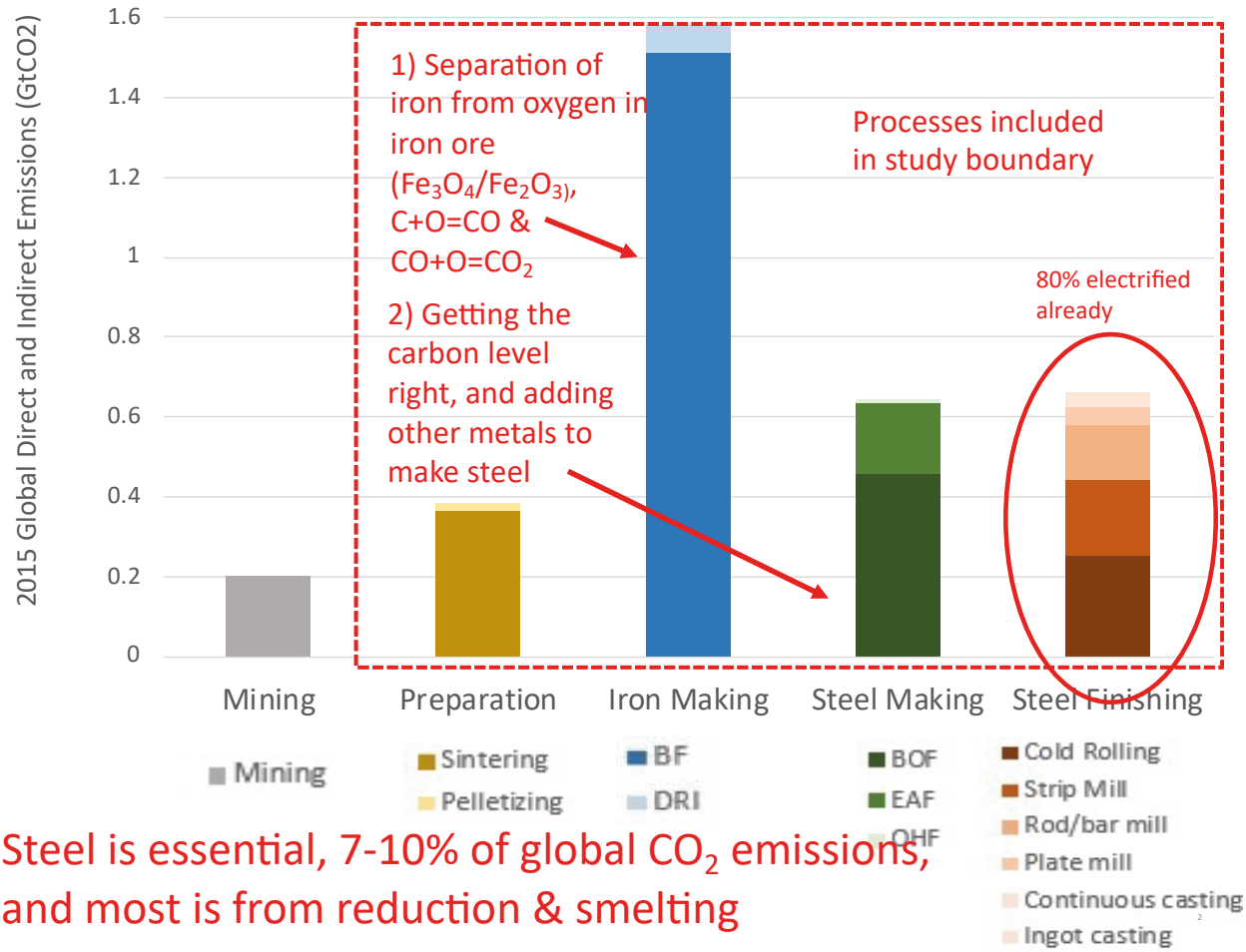
Dr. Chris Bataille, Seton Stiebert P.Eng, & Dr. Francis Li

Institut du Développement Durable et des Relations Internationales (IDDRI.org)

November 24th 2021

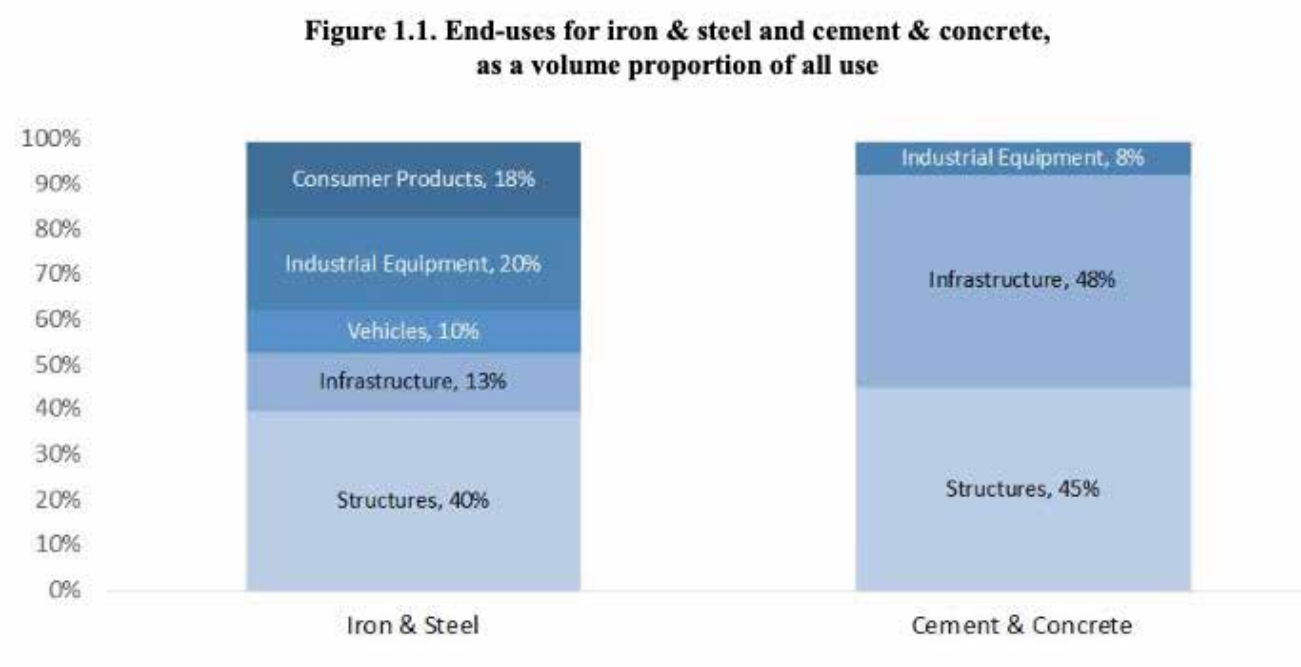
DEEP DECARBONIZATION PATHWAYS

IDDRI



Steel is essential, 7-10% of global CO_2 emissions, and most is from reduction & smelting

Infrastructure and structures are 53% of steel demand - vehicles and industrial equipment are another 10% & 20% (A South Korean export)



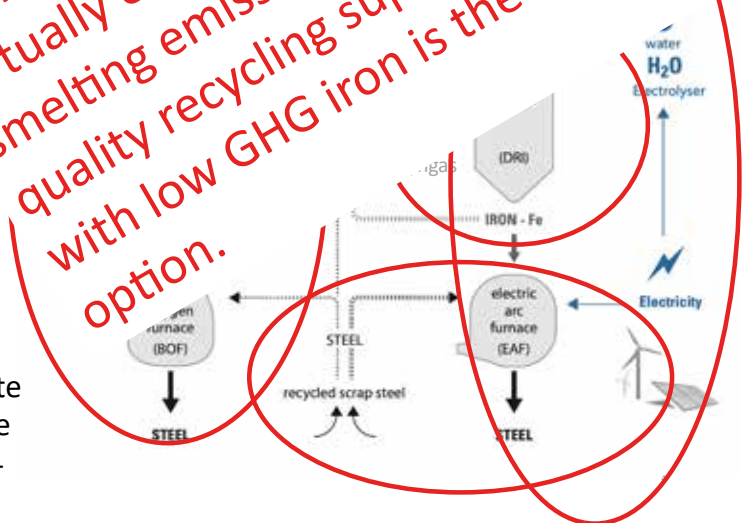
Source: Bataille, C. 2019. Low and zero emissions in the steel and cement industries: Barriers, technologies and policies. OECD Green Growth and Sustainable Development Forum.

How to eliminate reduction & smelting emissions

- Less demand, more material efficiency
- More recycling. Depends on supply of reasonable quality scrap and a network to gather it + DRI sweetening (TRL 9)
- BF-BOF with 90%+ Carbon capture and storage, possibly with biomass TRL 5* (2030?)
- Advanced smelting with CCS (shown, TRL 7 … but dormant?)
- Syngas (H_2+CO) based DRI EAF wi concentrated flow CCS TRL 9*. Replaceable with 100% hydrogen
- Green hydrogen DRI EAF TRL 5-7+ & moving fast (2028-'30)
- Molten oxide or aqueous oxide electrolysis TRL 4 (2035+? BM says late 2020s) Wild card given transformative anode development needs and ++on-demand power draw

* Hyd ng

We have at least 9 options to virtually eliminate reduction and smelting emissions. More higher quality recycling supplemented with low GHG iron is the first best option.



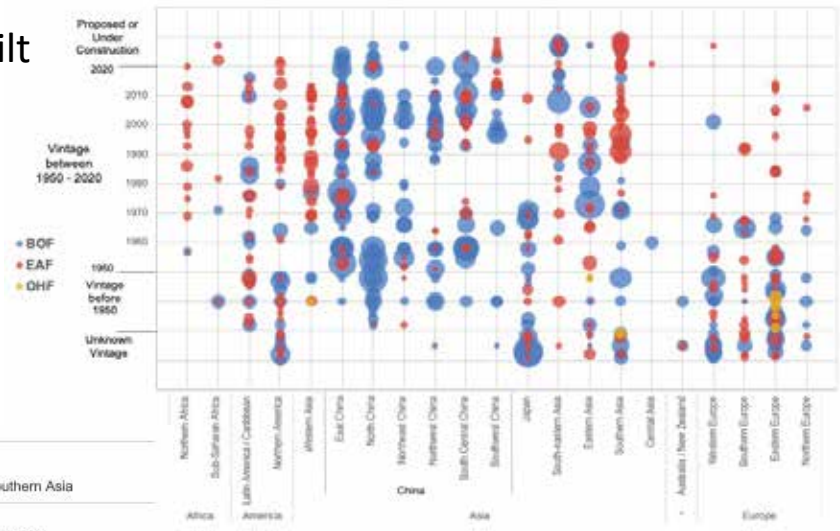
How did we forecast production and emissions?

- **Initial database**: We begin with a global dataset of exis… …t in 2019 provided by the Global Energy Monitor, ar… sources to build up a full set. These last 25+ …
- **Demand**, based on patterns in long te… …ol based on a global evolution towa… …a in 2080
- **Recycled production** is pr… …s limited by scrap availability. Based or… …bility is forecasted at ~1.2 Gt in 2050 … …ssumes for 133 countries that forec… …crap EAF production by 2050 (61 coun… …production become producers)

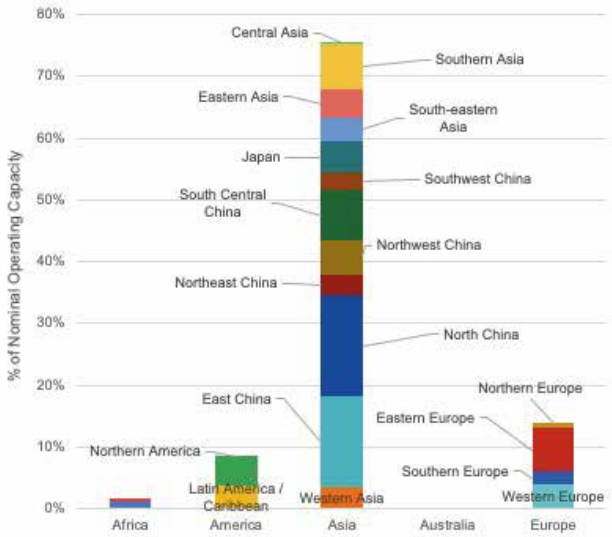
…with the premise that steel makers would …g sites if possible, we use the following algorithm

We simulated facility level stock turnover based on a 2019 global facility database, forecasts for demand, recyclable scrap, new technologies, and local access to clean electricity & CCS geology

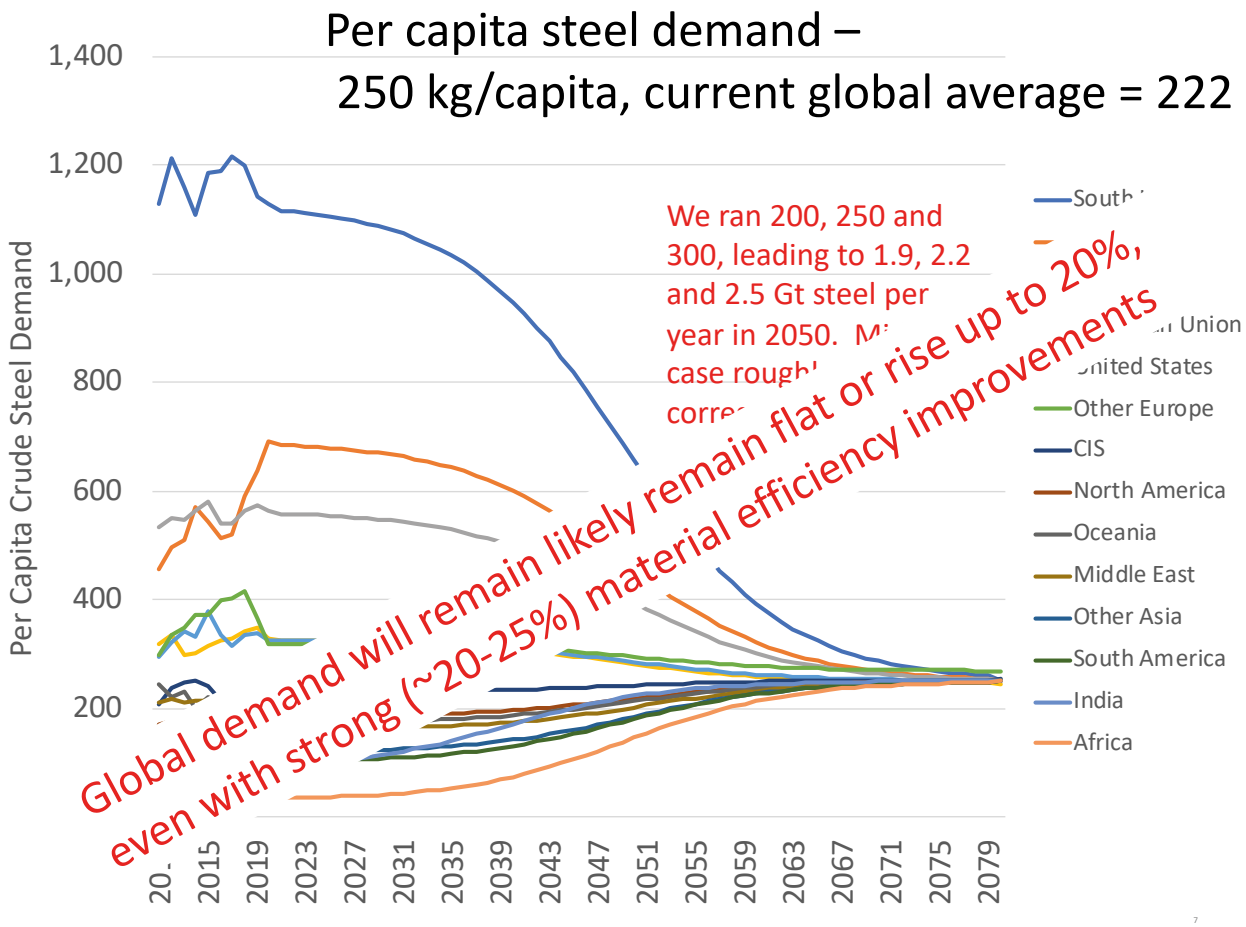
When & where it was built

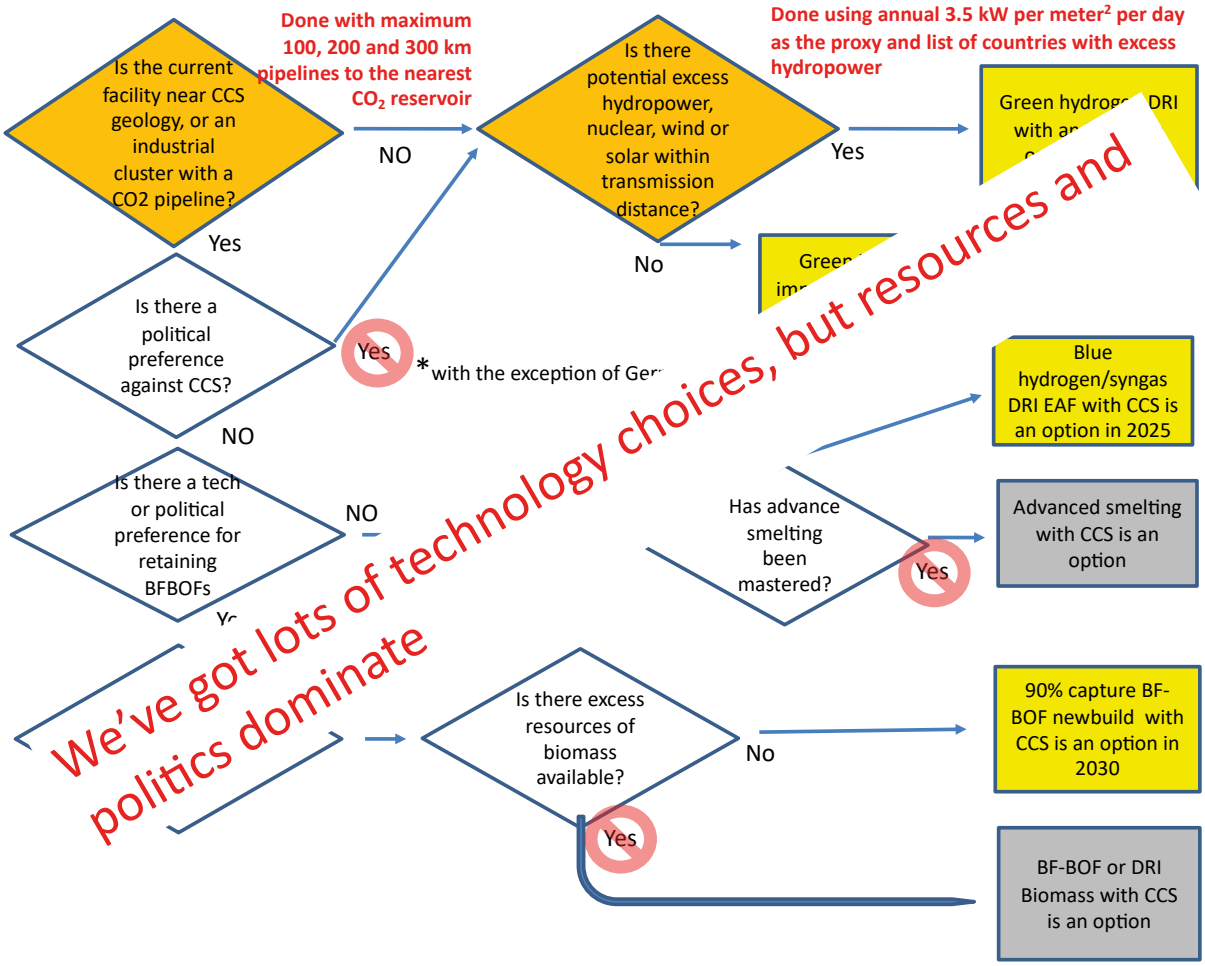


Steel capacity



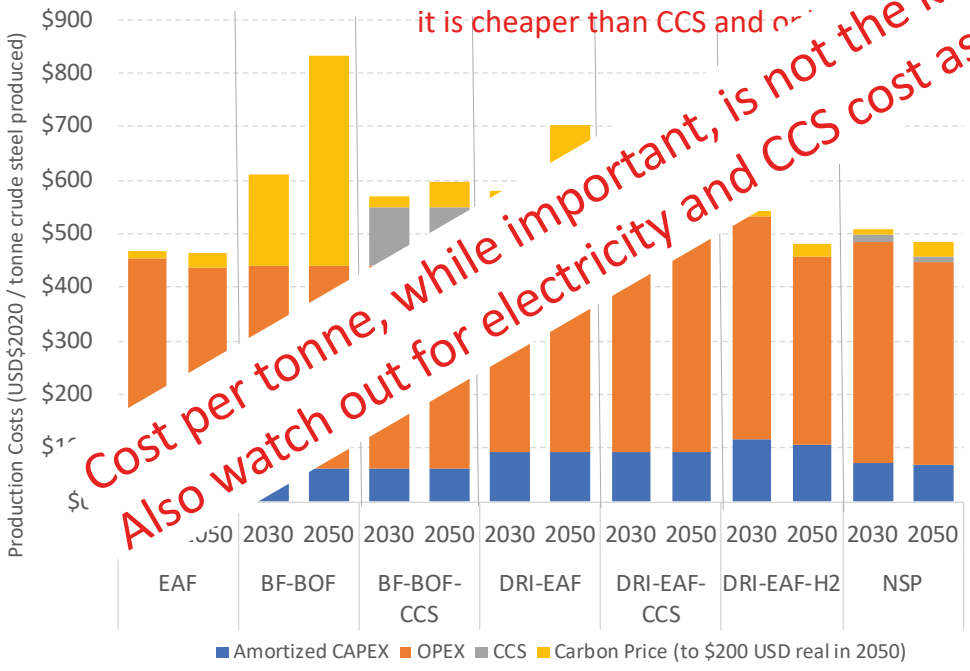
Upshot from our 2019 database building; the vast majority of steel capacity is in Asia, and especially China. And much of it was built 1995-2015, especially 2000-2010. On a 25 year furnace relining schedule, it's up for renewal 2025-2035.


Per capita steel demand –
250 kg/capita, current global average = 222
Per Capita Crude Steel Demand
1,400
1,200
1,000
800
600
400
200
2015
2019
2023
2027
2031
2035
2039
2043
2047
2051
2055
2059
2063
2067
2071
2075
2079
We ran 200, 250 and 300, leading to 1.9, 2.2 and 2.5 Gt steel per year in 2050.
Global demand will remain likely remain flat or rise up to 20%, even with strong (~20-25%) material efficiency improvements
Union
United States
Other Europe
CIS
North America
Oceania
Middle East
Other Asia
South America
India
Africa


Is the current facility near CCS geology, or an industrial cluster with a CO2 pipeline?
Done with maximum 100, 200 and 300 km pipelines to the nearest CO_2 reservoir
NO
Yes
Is there potential excess hydropower, nuclear, wind or solar within transmission distance?
Done using annual 3.5 kW per meter² per day as the proxy and list of countries with excess hydropower
Yes
No
Green hydrog DRI with ar
Green im
Is there a political preference against CCS?
Yes
*with the exception of Ger
NO
Is there a tech or political preference for retaining BFBOFs
NO
Yes
Has advance smelting been mastered?
Yes
Blue hydrogen/syngas DRI EAF with CCS is an option in 2025
Advanced smelting with CCS is an option
We've got lots of technology choices, but resources and politics dominate
Is there excess resources of biomass available?
No
Yes
90% capture BF-BOF newbuild with CCS is an option in 2030
BF-BOF or DRI Biomass with CCS is an option

But what about cost per tonne? It very much depends on assumed electricity & CCS costs, and carbon pricing le

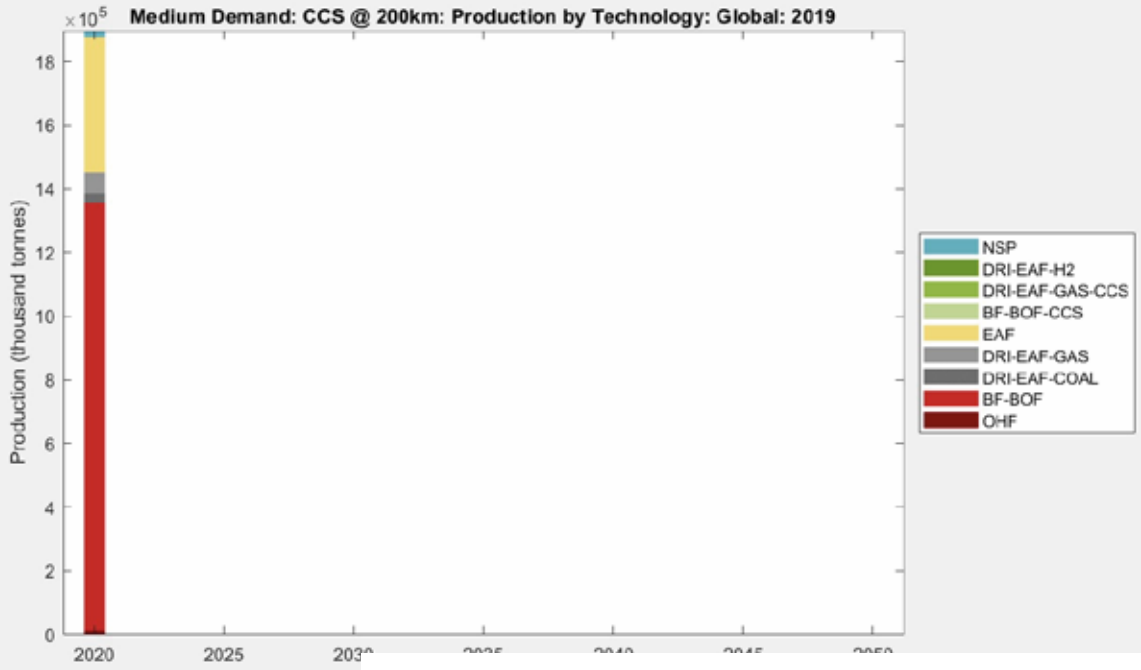
Our estimates are based on clean electricity at $ ling to $0.015. We see initial 20% cost increas EAF, assuming dedicated access to new s by 2050 it is cheaper than CCS and o BFBOFs today.



Cost per tonne, while important, is not the key driver. Also watch out for electricity and CCS cost assumptions

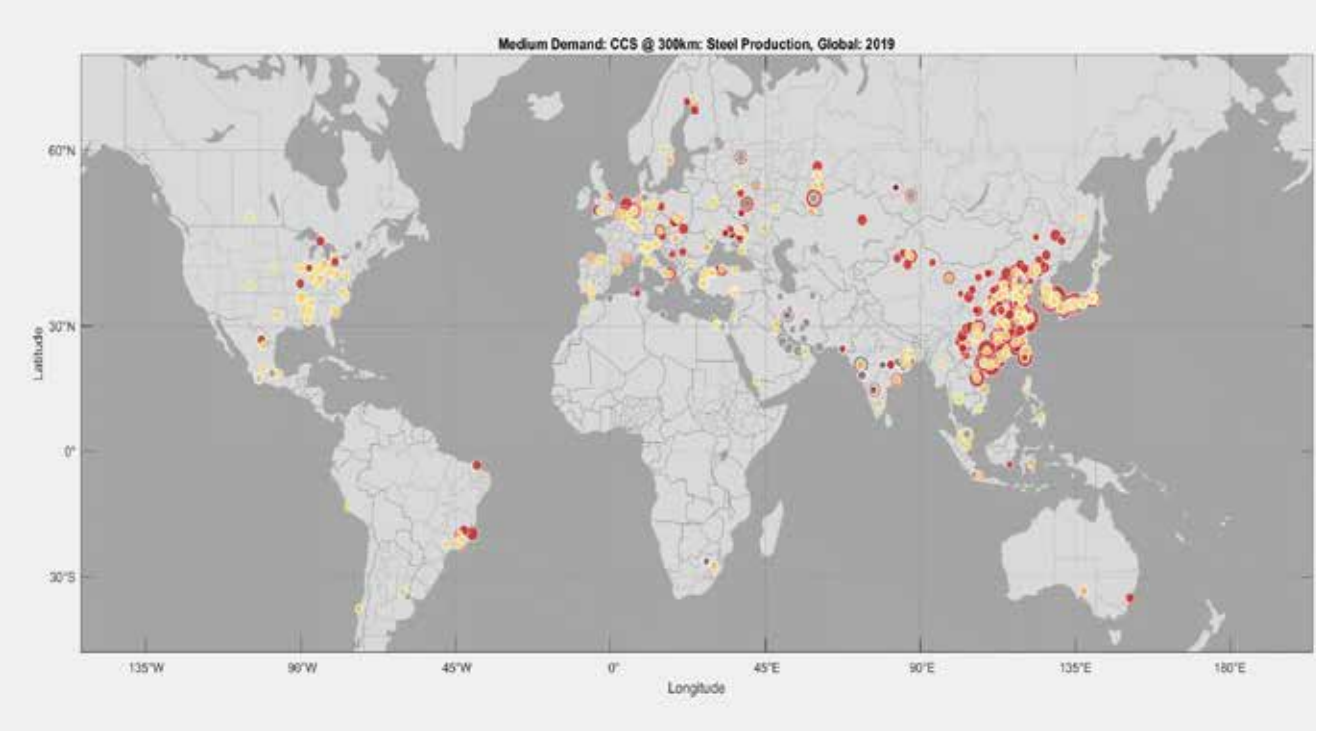
The upshot? If initially higher costs can be passed through to end-users using lead markets (with <2% extra costs), then the difference is not relevant. The technology choice will be mostly geographic & political. BFBOFs are known, but HDRI will likely eventually be cheaper including carbon costs.

Global results– medium demand, 200km of CO_2 pipelines available



DEEP DECARBONIZATION PATHWAYS

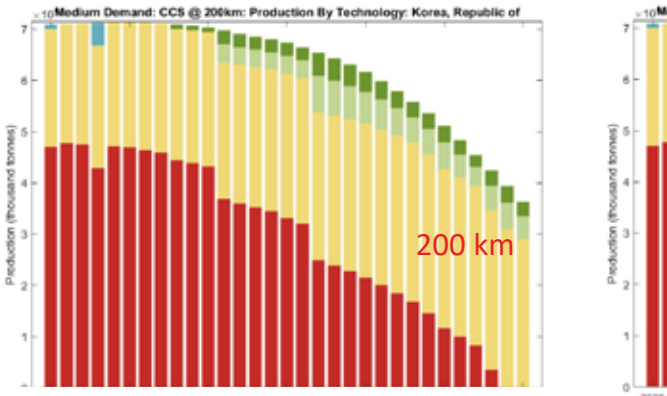
1) More recycling, 2) clean primary iron, and 3) trade are the keys

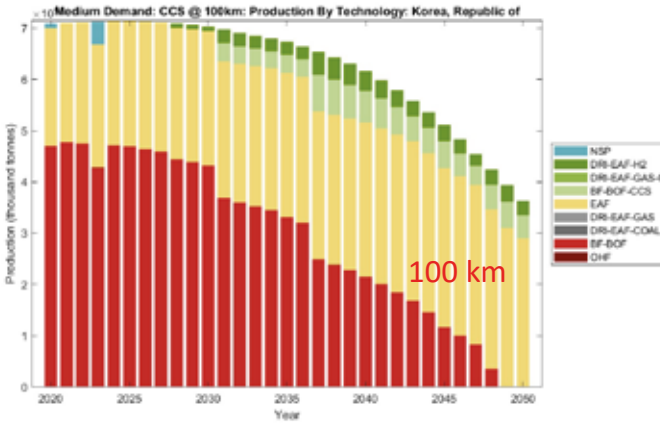


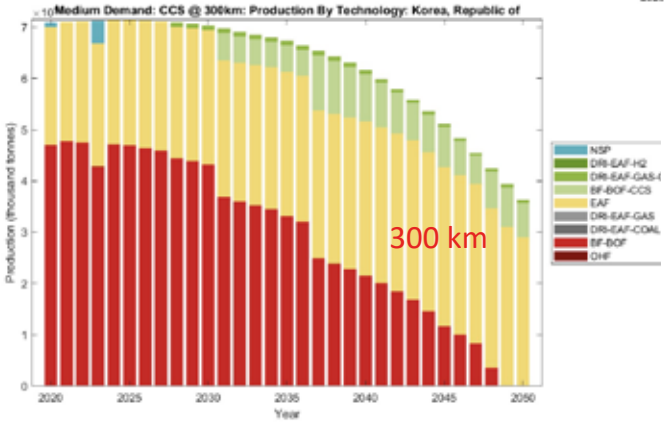
In the medium demand, 200km case, as time passes …

- Red BF-BOFs gradually disappear
- Yellow EAFs gradually double
- Various shades of light green syngas DRI EAFs with CCS, hydrogen DRI EAF and BFBOFs with CCS arrive

South Korea – low, medium & high pipeline availability

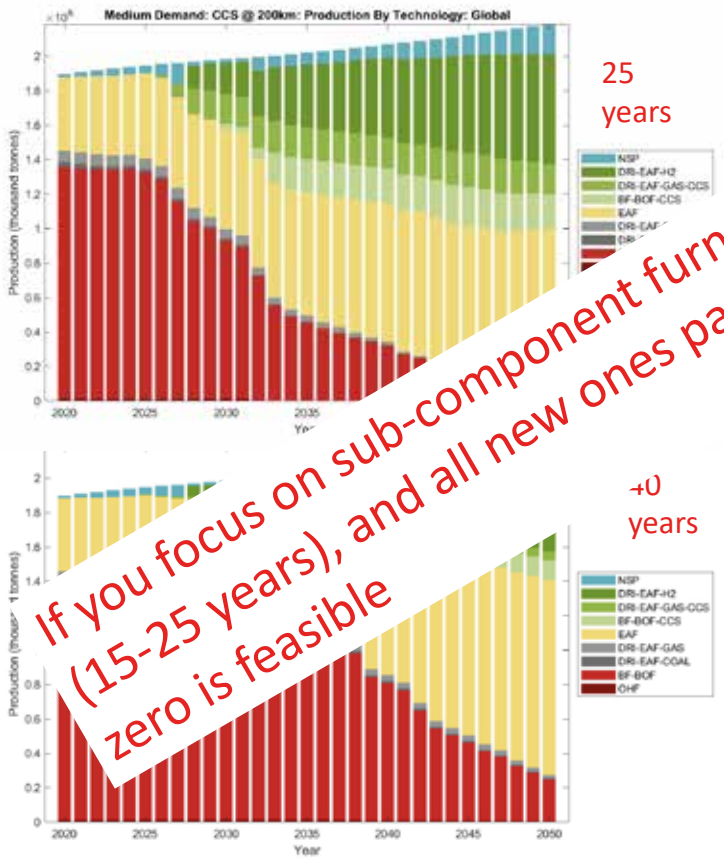






- Long run exports would be added
- Recycling is the dominant story
- Pipeline availability is critical to use of CCS (all or half), but not critical to decarbonization of steel.
- The km distances are from existing steel production sites to the centroid of known potential CO_2 disposal sites from the Oil & Gas Climate Initiative database.

The other big sensitivity – asset renewal timetable



If you focus on sub-component furnace renewal lives (15-25 years), and all new ones past 2025 are clean, net-zero is feasible

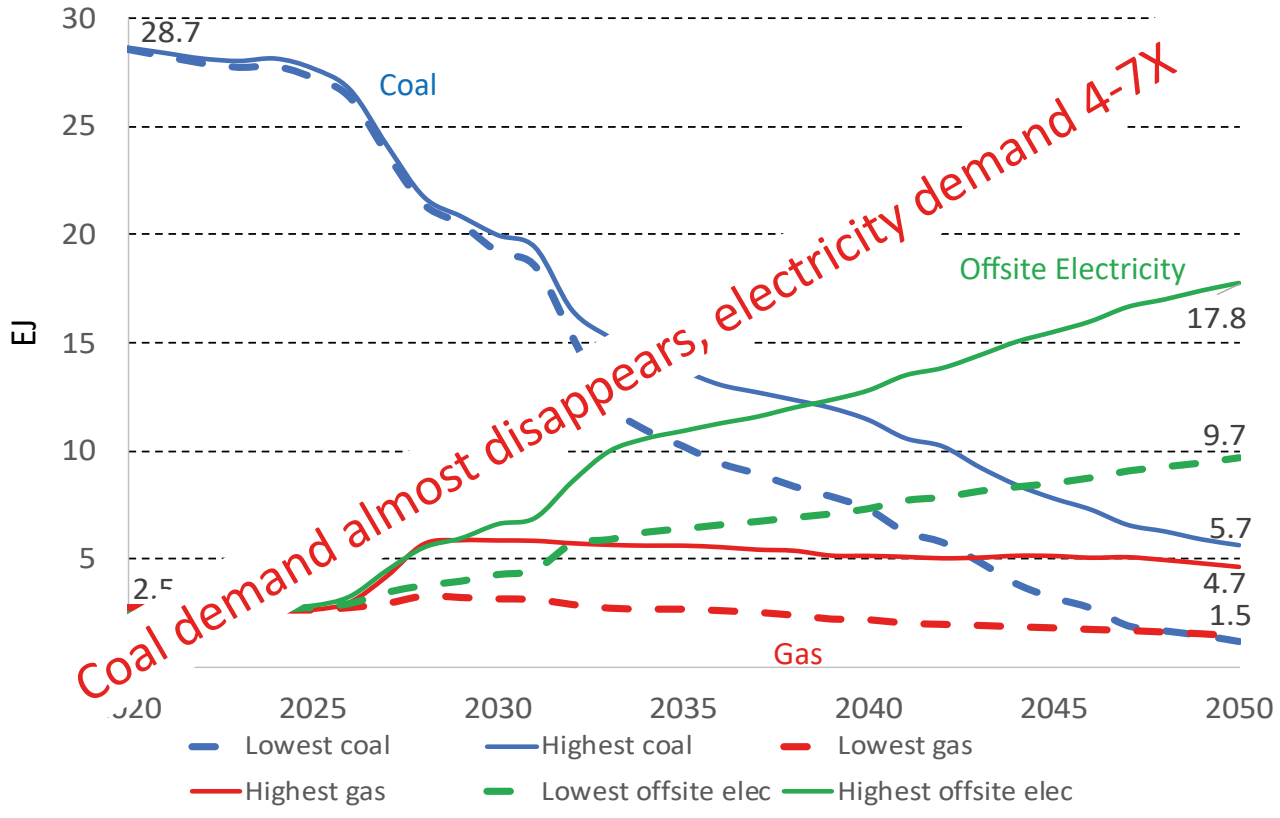
- The most emittin… sintering, re… and smeltin… re…

…ears as …e as low as 20 …e cases.

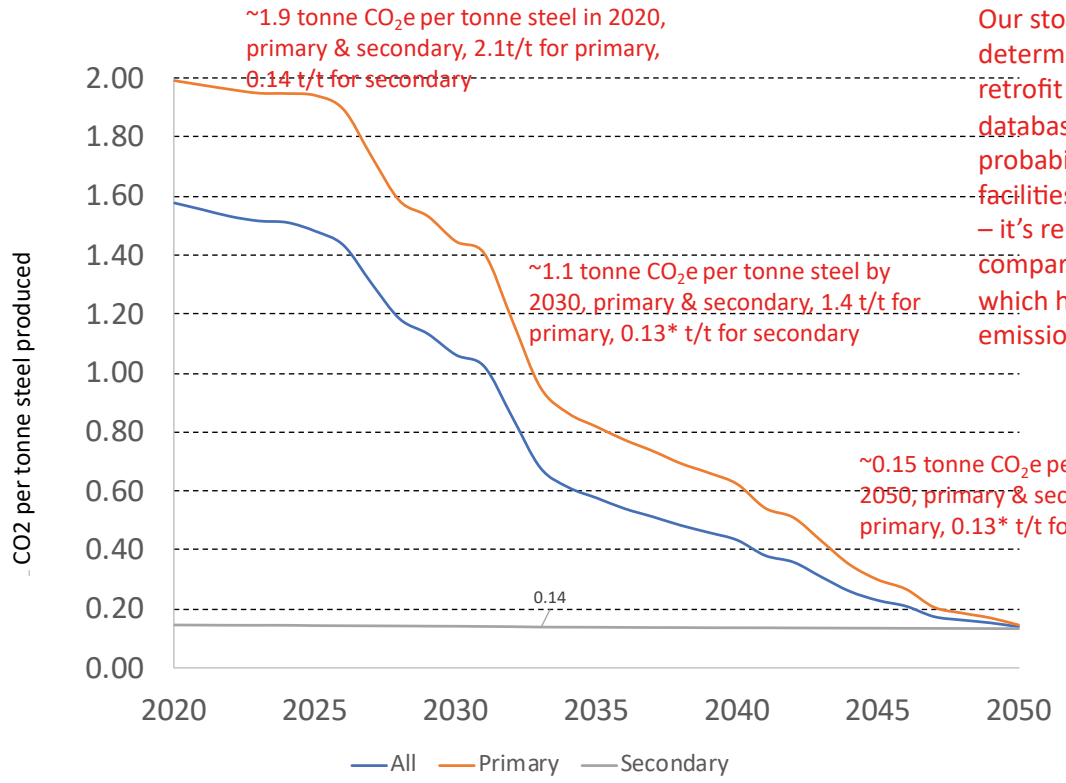
…g slower than 27-28 years …l prevent net-zero without early retirement.

Vogl et al 2021 has since suggested a mean furnace life of ~17 years, this is good news

Global steel purchased energy use (Medium demand, 200km)



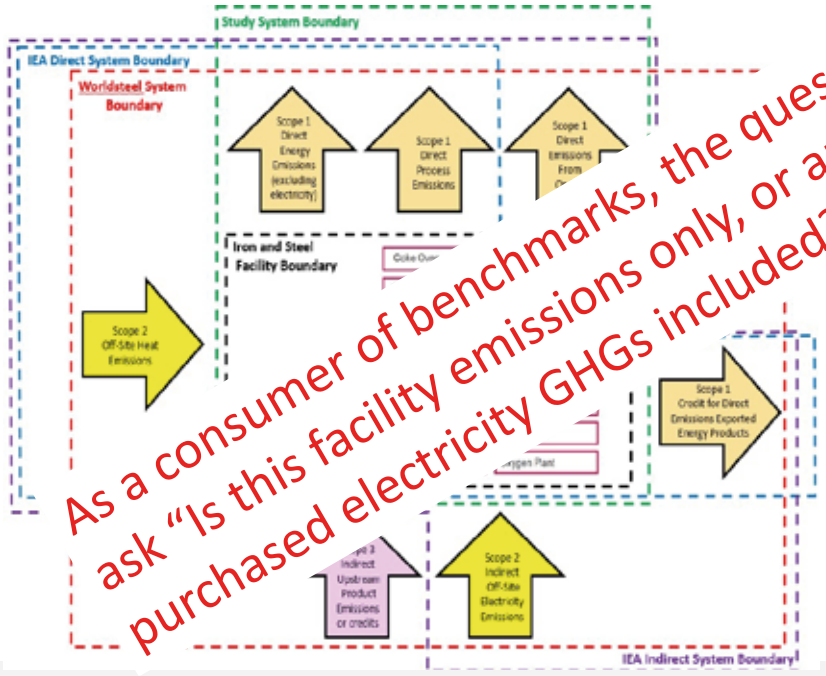
GHG intensity benchmarks
All, primary and secondary facilities



Our stock turnover was determined by a 25 year retrofit cycle, the GEM database age data, and probabilistic estimate for facilities of unknown age – it's relatively fast compared to the IEA, which has more remnant emissions.

*Work to be done increasing ambition for EAF GHG intensities

Study Emission Boundary



As a consumer of benchmarks, the question you need to ask "Is this facility emissions only, or are fuel sales and purchased electricity GHGs included?"

W… …l

…e the …atter?

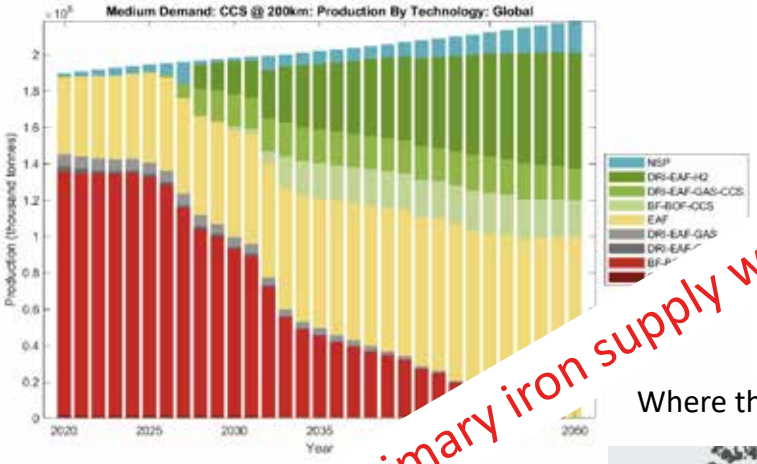
…GHGs from all …enter the facility, …out credit for sales

We don't credit for offsite electricity sales (WS does)

- We don't credit for offgas or heat sales (WS & IEA do)
- We don't include GHGs from purchased electricity (WS does), assuming system electricity GHGs are supposed to go to zero.
- Our system is designed for primary process replacement and elec->zero GHGs.

Global production by large producing region

The global picture, and the export opportunity



- About 200 Mt per year (~ South Korea's annu… production) of … uction could or… …e there is acc… …re, inexpensive …tricity, or access to …eology.
  The big potential exporters are Australia, Brazil, Russia, South Africa, Canada …

10+% of green primary iron supply will move or be traded

Where the iron ore is …

DEEP DECARBONIZATION PATHWAYS

Other possibilities – Thinking bigger about reorganizing supply chains

- We currently make primary iron and steel near coal and iron ore and move it where it's needed; with hydrogen DRI we can make it near iron ore, cheap clean electricity (green), or cheap methane and CCS (blue), and move green iron where it is needed.
- Electric arc furnaces can stay where they are, near markets and supply chains.
- BF-BOFs can be preloaded with up to 30% green iron and cofired with hydrogen until the end of their kiln lives
- Eventually primary steel could all be run through DRI and EAFs, with iron being reduced and traded globally
- Eventually, when there is lots of clean electricity and power capacity, modular molten oxide furnaces can take over to supplement recycling, which should eventually dominate.
- Places like China & South Korea could import reduced iron from Australia, South Africa, etc. and eventually run almost only electric arc furnaces for primary steel.

DEEP DECARBONIZATION PATHWAYS

Summary *"We can do it, but time is of the essence"*

- Decarbonisation of global steel manufacturing by 2050 is technologically feasible using high TRL technologies.
- This requires all new facilities & retrofits are near zero emission by latest the early 2030s. If this is delayed early retirements will become necessary.
- China has a key role to play because of the BF-BOF capacity built ~1995-2015, 54% of global. This capacity is coming due for retrofit.
- Global innovation and commercialization programs, including private and public green procurement & lead market contracting, will be needed to make sure technologies are ready to replace all steel facilities from the late 2020s onward.
- The scale of investment is VERY large, but has been accomplished in the past
- The varying distribution of resources (i.e., scrap, carbon storage locations, renewable generation) means regions have varying opportunities, with different infrastructure needs.

DEEP DECARBONIZATION PATHWAYS

Policy & technical one pagers,
video of main presentation,
technical report, country factsheets,
detailed results for countries,
and standard groupings (EU, G-7, G20)
are downloadable available at

Netzerosteel.org

Please send questions to:

Email: info@netzerosteel.org
Twitter DM:@bataille_chris

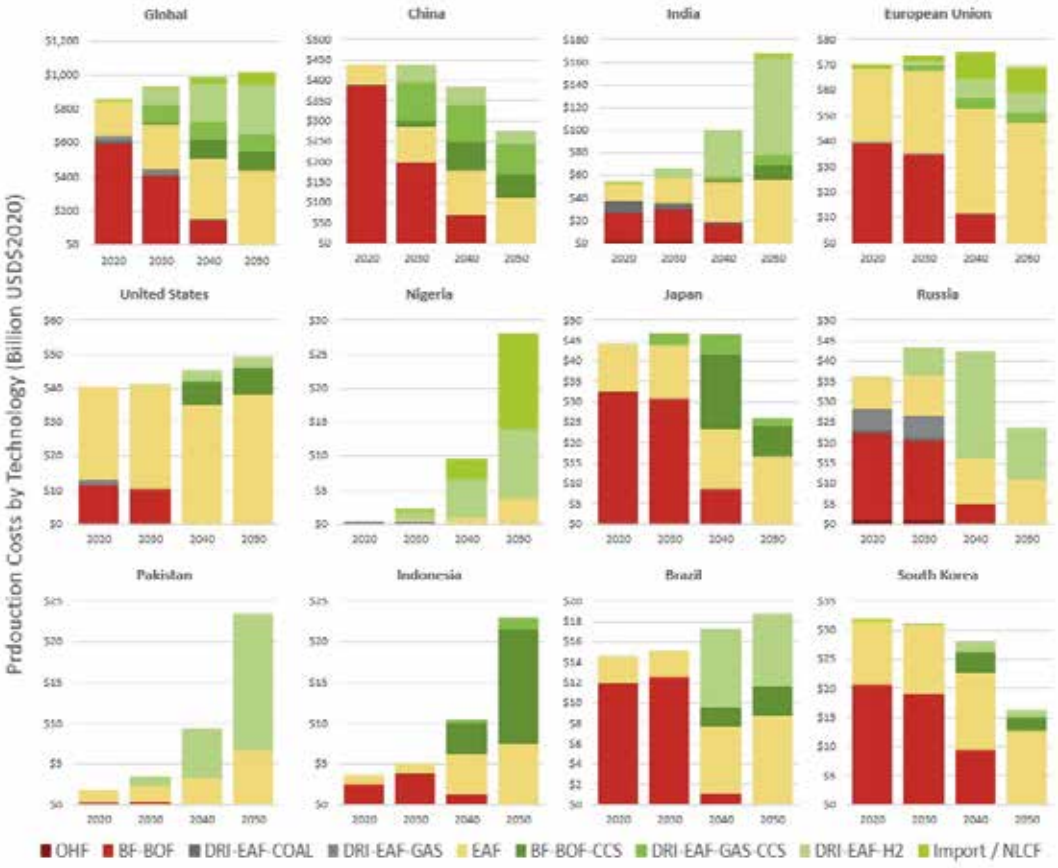
DDP-INITIATIVE.ORG

DEEP DECARBONIZATION PATHWAYS

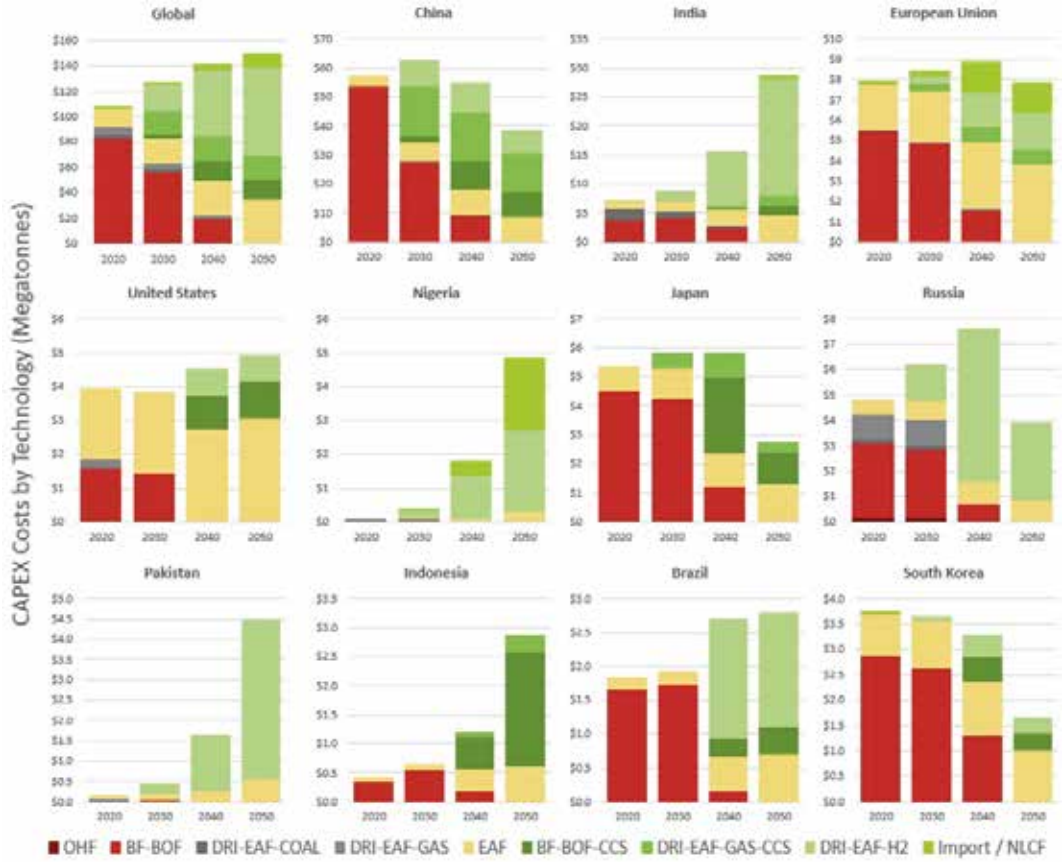
What next?

- **Goal: Maintain innovation & commercialization momentum**
  - ➢ Action: Engage with Clean Energy Ministerial/LeadIt+, national government partnerships. Argue for a dedicated technology accelerator to produce open IP.
- **Goal: Make sure companies are planning on clean replacement cycles**
  - ➢ Action: Engage with steel firms, hold them accountable.
- **Goal: Maintain lead market momentum**
  - ➢ Action: Engage with CEM LeadIT IND/UK/GER/CAN initiative, national govt public procurement and car marker/energy supplier private procurement (Volvo/Mercedes). Leverage on BMW/Tesla/Volvo/Ford?
  - ➢ **Architectural, civil engineering and construction firms.**
- **Goal: Trade & Broad uptake post lead markets**
  - ➢ Action: Measurement systems to allow border GHG standards, CBAM, etc. Broaden EU/US partnership. Steel content standards? The EU CBAM is already transforming Turkish and Russian plans. Where is the

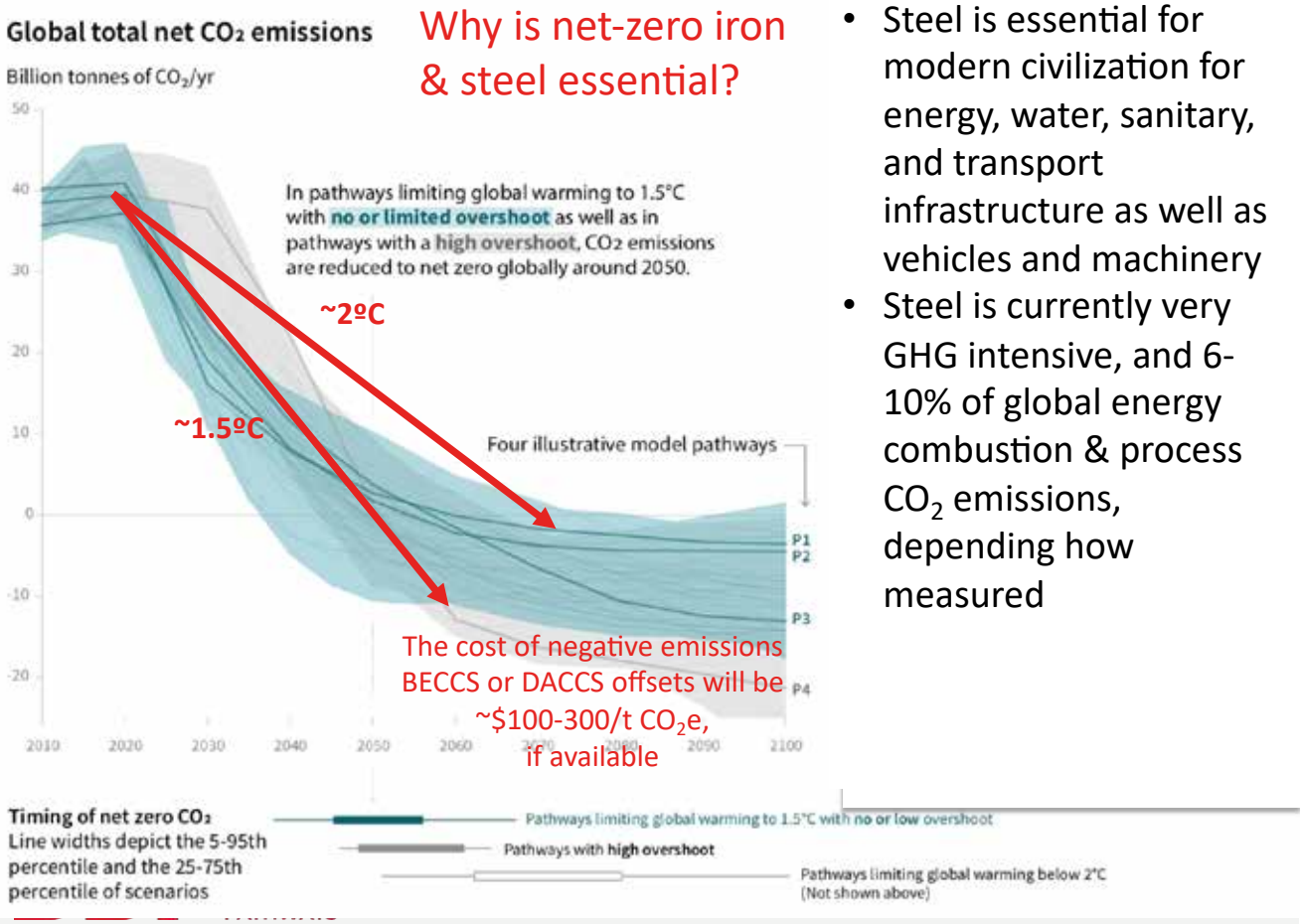
Global production costs by technology by large region



Global CAPEX by technology by large region



Why is net-zero iron & steel essential?

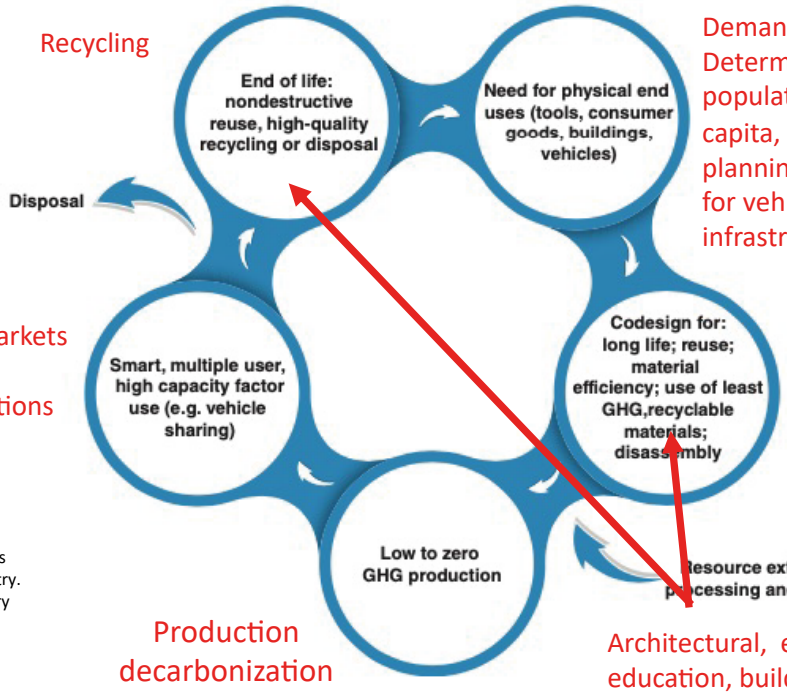


- Steel is essential for modern civilization for energy, water, sanitary, and transport infrastructure as well as vehicles and machinery
- Steel is currently very GHG intensive, and 6-10% of global energy combustion & process CO_2 emissions, depending how measured

Existing Iron & Steel Facilities Included in Model (Additional slide for questions)

- Start with GEM Database facilities (only facilities > 1 MT of capacity)
  - 2.0 Gt of crude steel capacity in 2019, 67 countries, 622 facilities
  - Estimate of 1.6 Gt of 2019 production / 86% of global
- Cross referenced with GIDS Database, country level production identified by the Worldsteel Association and OECD national capacity database to identify remaining 14% of global production:
  - 27 additional countries (94 total) with reported production and/or capacity
  - Estimate of 213 additional facilities (mostly smaller EAF) - based on average regional operating characteristics of facilities and spatially allocated near existing production or in major country industry centres.
- Additional 39 countries are also seeded in the model for future production based on scrap availability and national demand for steel.

So where are we trying to get to?
Steel in a global net zero GHG circular economy



Recycling

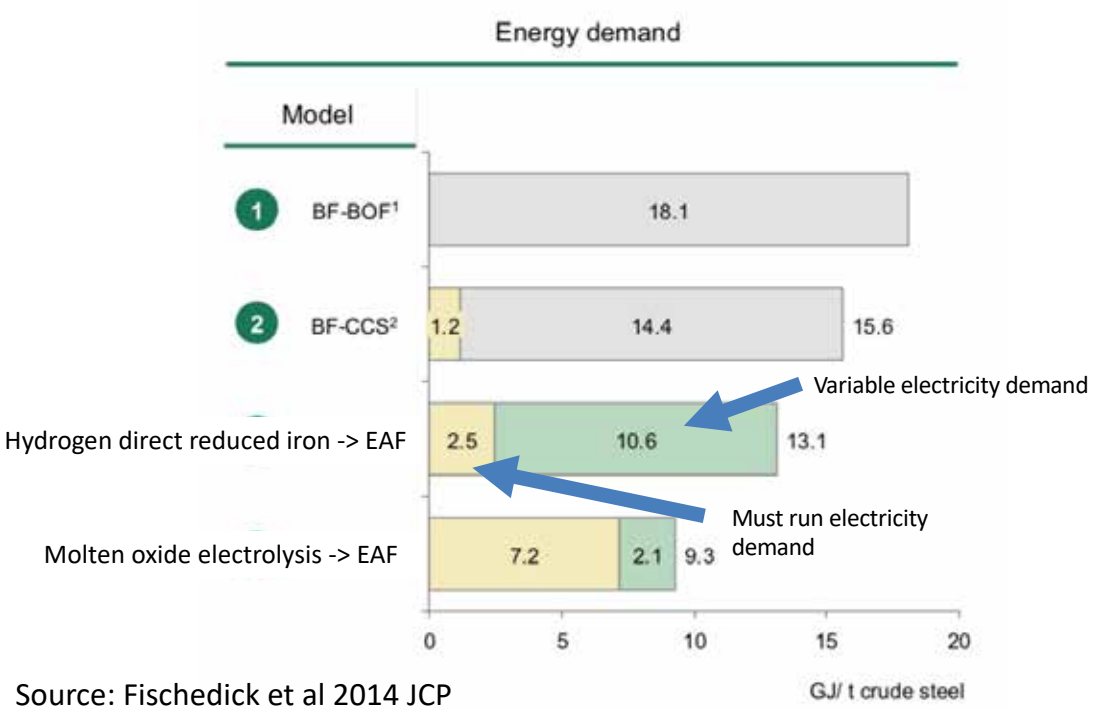
Demand! Determinants: population, income per capita, regs, urban planning, culture, need for vehicles, buildings, infrastructure

Use markets and institutions

Source: Bataille, C., 2019. Physical and policy pathways to net-zero emissions industry. WIRES Wiley Interdisciplinary Reviews 1–20. doi:10.1002/wcc.633

Production decarbonization

Architectural, engineering and trades education, buildings codes



Source: Fischedick et al 2014 JCP

Korea Steel Sector GHG Emissions Overview

November 25, 2021

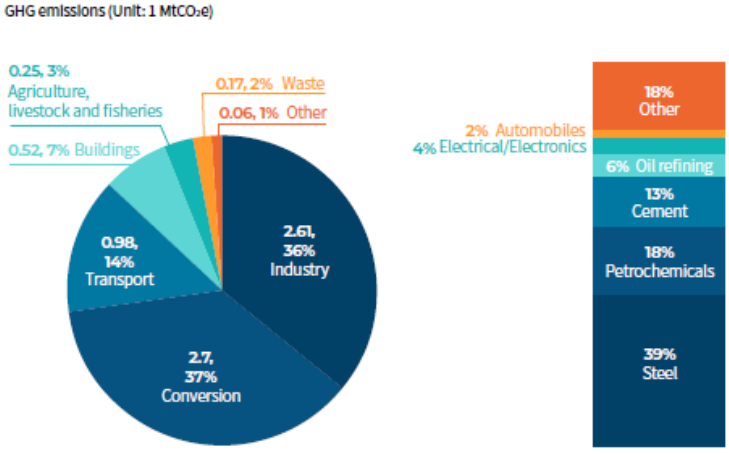
SFOC
Solutions for Our Climate

Solutions for Our Climate

Joojin Kim

New SFOC report on Korean steel sector's climate challenges

Nearly 40% of industry sector emissions, 13% of national emissions



[Figure 1] GHG Emissions by Sector and Steel's Share
Source: Office for Government Policy Coordination 2021

Steel sector emission intensity trends

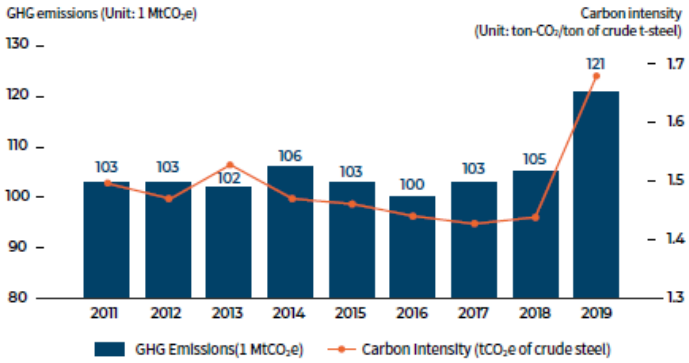
Emissions rising relatively more compared to other manufacturing sectors

[Table 1] GHG Emissions from Korean Manufacturing Sectors: Shares and Trends

Classification	2010	2012	2014	2016	2018	Share in 2018	10-Year Decrease/ Increase
Steel	76,841	89,290	104,610	93,360	95,288	51.0%	+24.0%
Nonferrous metals	2,344	2,361	2,416	2,674	2,979	1.6%	+27.1%
Chemicals	34,936	40,124	42,602	39,167	45,953	24.6%	+31.5%
Pulp	1,805	1,183	772	646	662	0.4%	-63.3%
Food & Beverages	2,400	2,082	1,842	1,850	1,955	1.0%	-18.5%
Others	43,673	44,568	40,867	43,730	39,759	21.3%	-9.0%
Total	**162,000**	**179,608**	**193,110**	**181,428**	**186,596**	**100.0%**	**+15.2%**

Source: GIR 2020

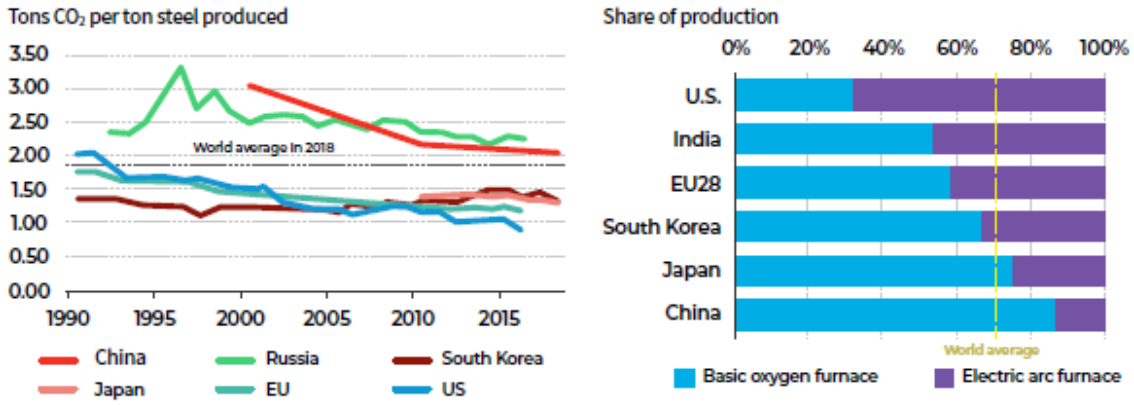
Recent jump in Korea steel sector emission intensity, due to integration of off-gas plants, whose emissions were originally accounted for in different corporate vehicles



[Figure 2] GHG Emissions and Carbon Intensity of the Steel Industry
Based on 2020 data from the GIR and Steel&Metal News

Relatively high emission intensity due to high portion of BF-BOF

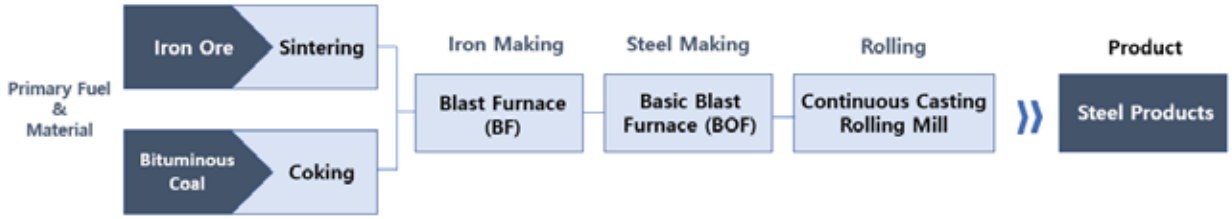
Korea manufactures 4% of world's steel

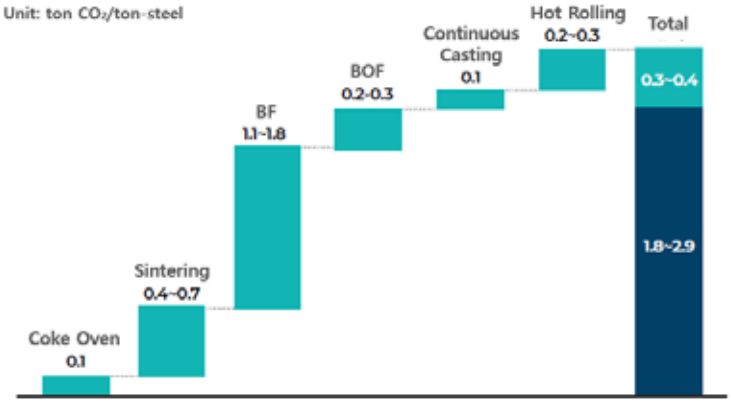


[Figure 3] Carbon Intensity Trends in Major Steel Producers
Source: Bloomberg New Energy Finance 2021

Brief summary of BF – BOF process

Blast Furnace + Basic Oxygen Furnace





Greenhouse Gas Emission of BF-BOF Route

Source: Nippon Steel 2021

To see is to believe

GHG emissions per steel company

POSCO and Hyundai Steel account for approx. 92% of steel sector emissions

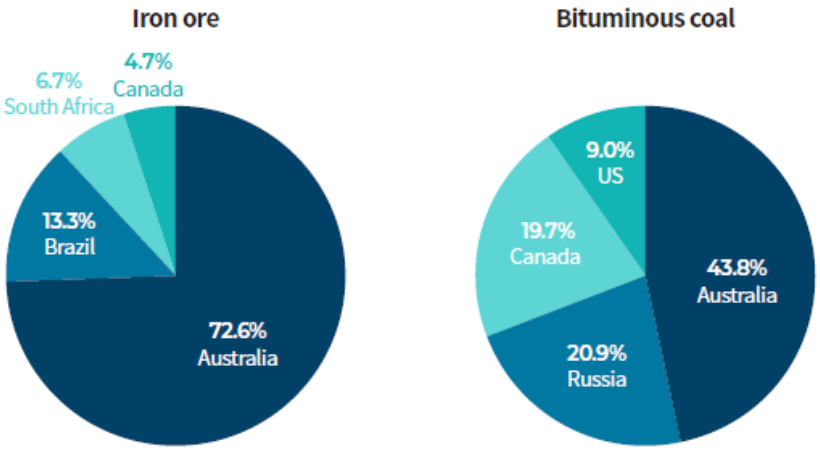
[Table 2] GHG Emissions from South Korean Steel Producers (Unit: 1,000 tCO_2e)

Steel Company	2017	2018	2019	Share In 2019	Remarks
POSCO	71,340	73,121	80,598	66.8%	Blast-converter/electric
Hyundai Steel	21,513	22,514	30,147	25.0%	Blast-converter/ electric
Dongkuk Steel	1,994	1,952	1,879	1.6%	Electric
SěAH Besteel	1,395	1,421	1,228	1.0%	Electric
DB Metal	851	950	778	0.6%	Electric (alloy steels)
SěAH CSS	535	546	511	0.4%	Electric (special steels)
SIMPAC	408	22	463	0.4%	Electric (alloy steels)
KISCO	515	488	399	0.3%	Electric
Daehan Steel	586	412	374	0.3%	Electric
YK Steel	354	352	360	0.3%	Electric
Others (75companies)	3,688	3,745	3,861	3.2%	
Total	**103,180**	**105,526**	**120,597**	**100.0%**	

Source: GIR

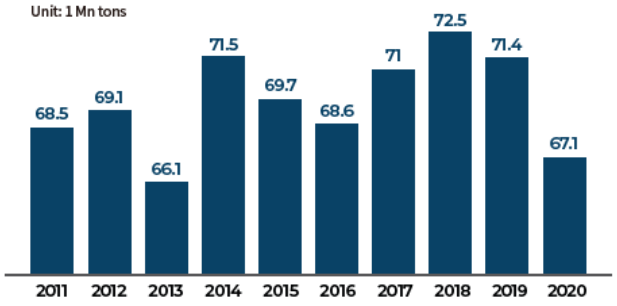
Where does the coal and iron ore for Korea's steel industry come from?

A lot from Australia



[Figure 6] Major Exporters of Iron Ore and Bituminous Coal to South Korea
Source: KOSA, requoted from KDB 2020

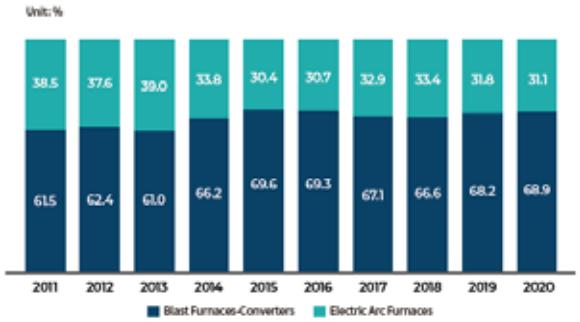
Korea Steel Sector trends



[Figure 9] Crude Steel Output from 2011 to 2020 in South Korea
Source: KOSA 2020

Steel production trends - downturn in 2020

Ratio of BF-BOF increasing



[Figure 10] Steel Output over 2011-2020: Blast Furnaces-Basic Oxygen Furnaces vs. Electric Arc Furnaces
Source: KOSA 2021b

Steel material demand per industry

[Table 6] Shares of Different Customer Industries (Units: %; pp)

Classification	2010	2019	Rise/Fall (pp)
Construction	27.3	30.6	+3.3
Automobiles	22.5	27.7	+5.2
Shipbuilding	24.9	19.7	-5.2
Electrical/Electronics	4.2	5.6	+1.4
Fabricated Metal	8.4	5.3	-3.1
General Machinery	3.4	3.1	-0.3
Others	9.2	8.1	-1.1
Total	100.0	100.0	-

Source: Steel&Metal News 2020

- **Demand in construction and automobile industry has been increasing, while demand in shipbuilding industry has been declining**

Sales per POSCO products

Cold rolled plates constitute high portion of POSCO sales

[Table 7] Revenue and Production Shares of Key Product Categories of POSCO in 2019
(Units: 1,000 tons; KRW 100 Mn; %)

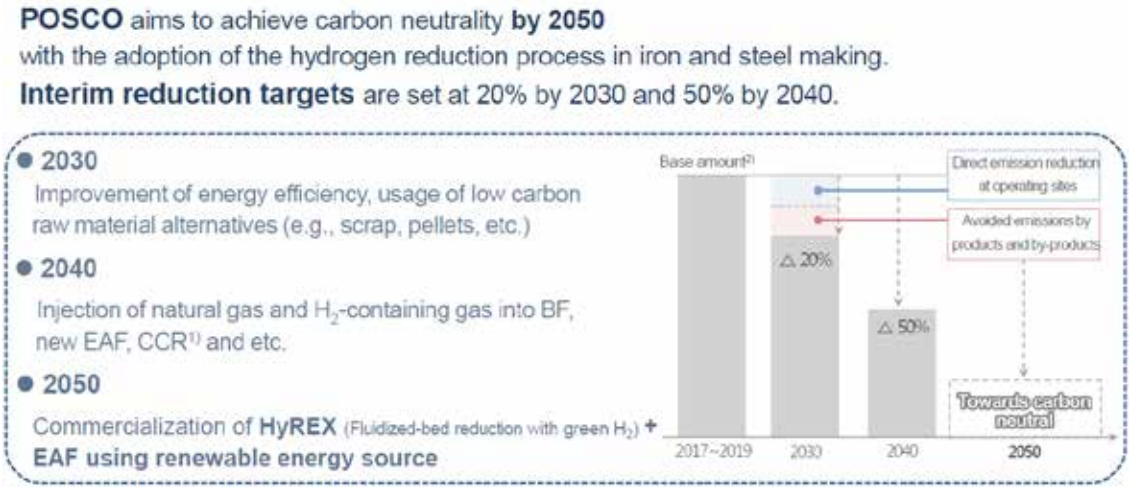
Classification	Revenue (Share)	Production (Share)	Primary Uses
HR Steel	83,669 (16.8)	8,739 (19.0)	Wires; structural steel for shipbuilding, machinery, construction, and automobiles
CR Steel	165,374 (33.2)	7,191 (16.1)	Automobiles, electronic products
Stainless Steel	101,347 (20.4)	3,850 (8.4)	Automobile exhaust pipes, kitchenware, electronic products, construction materials, electric vehicle battery cases, LNG storage tanks
Others	147,694 (29.6)	26,020 (56.5)	Heavy plates: structural steel for shipbuilding, construction, heavy equipment, marine & wind power; storage tanks and oil pipelines Wire rods: automobiles, construction of buildings and bridges Galvanized steel: civil engineering, construction, automobiles, and home appliances
Total	498,084 (100.0)	46,025 (100.0)	-

Source: POSCO 2021b

- **POSCO is the world's largest seller of automotive steel sheets, commanding about ten percent of the global market**
- **POSCO supplies automotive steel sheets to carmakers including BMW, Benz, Volkswagen, Renault Nissan, Hyundai Motors, Kia Corporation, Toyota, Honda, Fiat, Ford, and Peugeot Citroen (CEO Score Daily 2021)**

POSCO's Carbon Neutrality Vision

Which appears to lack details compared to competitor companies



Half of 2030 reductions to take place by direct reduction (e.g., energy efficiency improvement, using low carbon raw materials), and the remaining half by "avoided emissions" (providing energy-efficient steel product, recycling by-products)

Conclusions

- Government should establish **environmentally-friendly steel products certification systems / environmental criteria** for steel product procurement
  - Governments of California and other major states apply environmental criteria to steel products and have put in place systems that require bidders to satisfy these standards.
- Government **should ensure sufficient renewable energy based power** generation, which can support green hydrogen based steel production efforts
- POSCO and other Korean still companies will need to have **more concrete carbon neutrality plans**
- **Support** for the accelerated development of commercially viable carbon-free steelmaking technologies, including innovative DRI technology should be provided

Decarbonization pathways of Korea's steel sector for 2050 national carbon neutrality

2021.11.25

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KAIST Graduate School of Green Growth
KAIST Business & Technology Management

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Introduction

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Overview of the Project

- This joint project explores the decarbonization pathways for Korea's steel sector that is compatible with the nation's 2050 carbon neutrality target.
- To span a possible range of the sector's future CO_2 emissions plausibly and consistently, we develop multiple scenarios based on the Korean integrated assessment model, GCAM-KAIST2.0.

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Introduction to GCAM (Global Change Analysis Model)

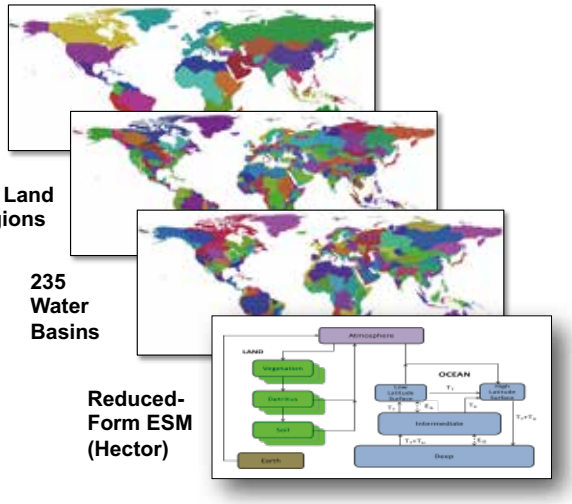
Pacific Northwest NATIONAL LABORATORY

Global Coverage

32 Energy & Economy Regions

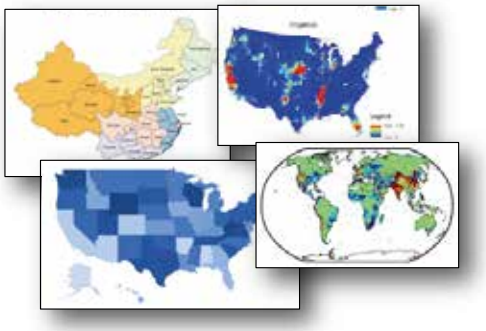
384 Land Regions

235 Water Basins



Reduced-Form ESM (Hector)

Flexible Scale



Market Equilibrium Solution

Community Model

http://jgcri.github.io/gcam-doc/toc.html

Flexible Time Scale

GCAM Core runs at 5 years; capability to run at one year; ancillary models run at finer scale

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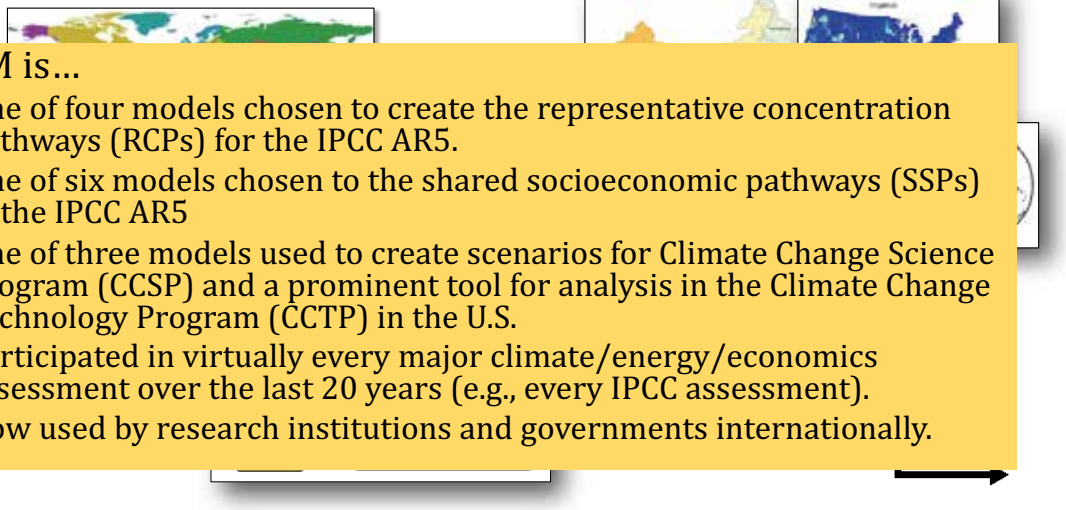
Introduction to GCAM (Global Change Analysis Model)

Pacific Northwest NATIONAL LABORATORY

Global Coverage

Flexible Scale



- GCAM is…
  - One of four models chosen to create the representative concentration pathways (RCPs) for the IPCC AR5.
  - One of six models chosen to the shared socioeconomic pathways (SSPs) in the IPCC AR5
  - One of three models used to create scenarios for Climate Change Science Program (CCSP) and a prominent tool for analysis in the Climate Change Technology Program (CCTP) in the U.S.
  - Participated in virtually every major climate/energy/economics assessment over the last 20 years (e.g., every IPCC assessment).
  - Now used by research institutions and governments internationally.

Community Model

http://jgcri.github.io/gcam-doc/toc.html

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GCAM Core runs at 5 years; capability to run at one year; ancillary models run at finer scale

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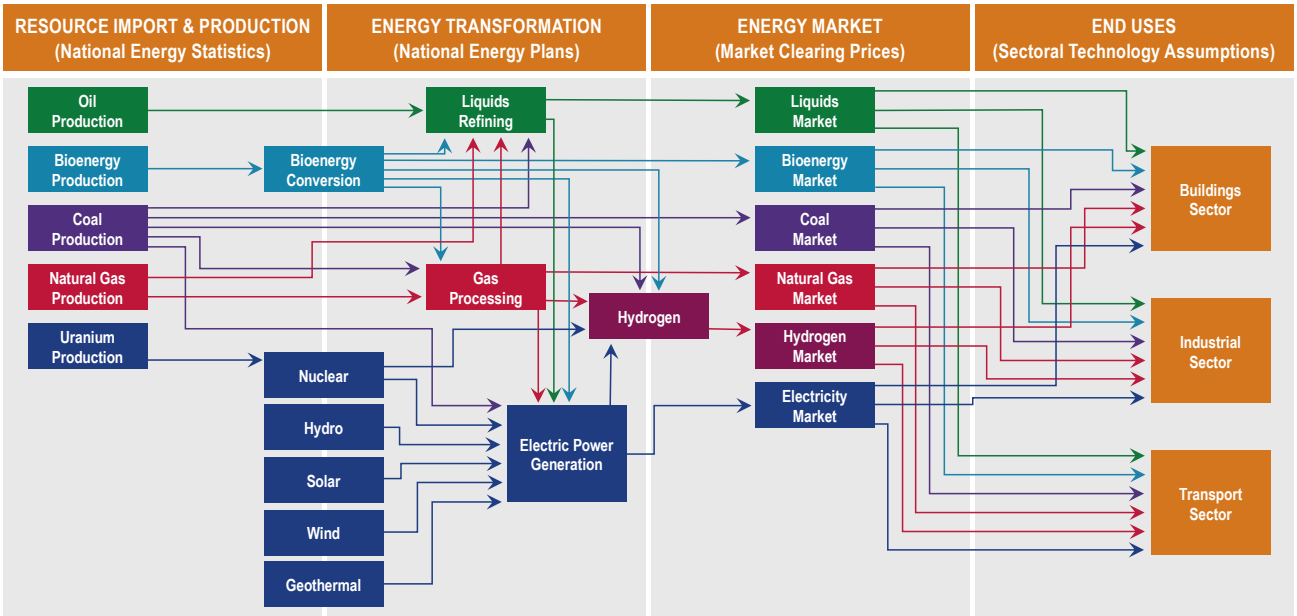
Overview of GCAM-KAIST2.0



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Overview of Scenarios

- **CurPol**: scenario that reflects **current steel-making technologies** in Korea and the industry **forecast of steel output** through 2050. It also assumes **national energy policy measures**, including the 9th plan for electricity supply & demand, the 3rd basic plan for energy, and other sectoral instruments. However, the scenario does ***not*** **reflect Korea's 2050 carbon neutrality ambition**.
- **NZ2050**: scenario that achieves a **constant decrease in national GHG emissions to eventual net-zero emissions by 2050** with no material efficiency improvement assumed for the steel sector
- **NZ2050_Eff**: scenario that achieves a constant decrease in national GHG emissions to eventual net-zero emissions with a **22% output reduction by 2050 assumed for the steel sector** relative to NZ2050 due to material efficiency improvement*

*Building lifetime extension, optimized building design and post-use recycling, use of high-strength steel and lighter weight vehicles, improved steel making yields, etc. ("1.5°C Steel," Yu et al., 2021)

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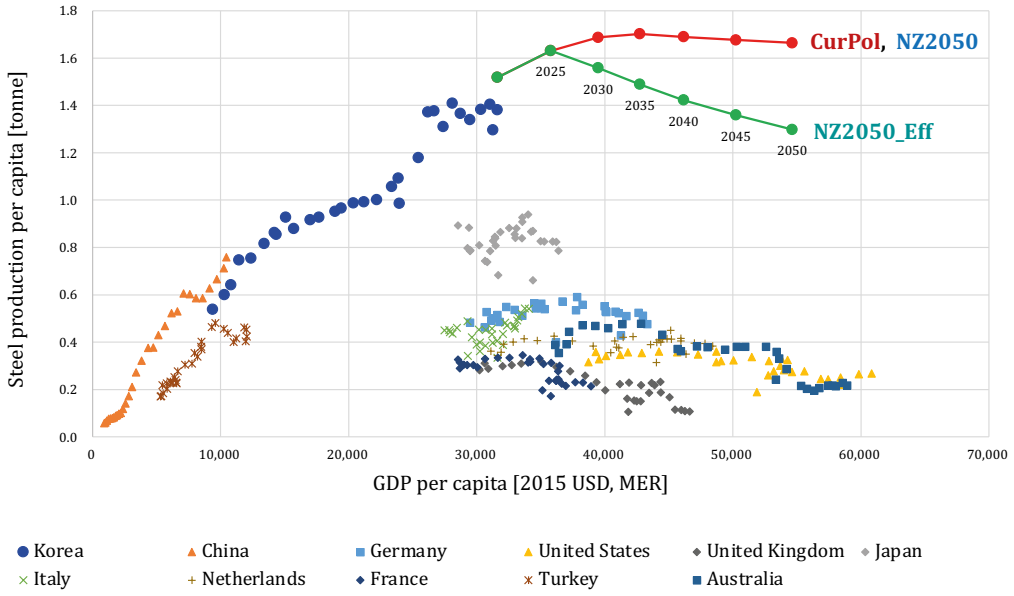
International Comparison of Steel Production (1990-2020)



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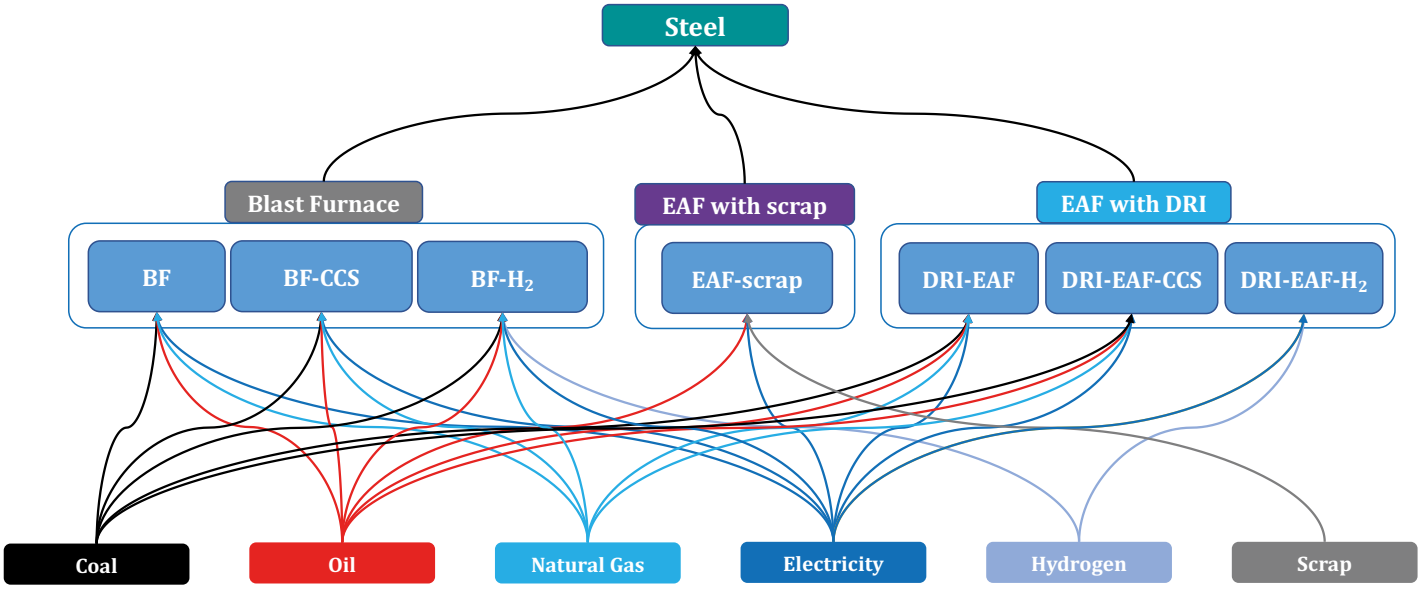
Structure of Korea's Steel Sector in GCAM-KAIST2.0



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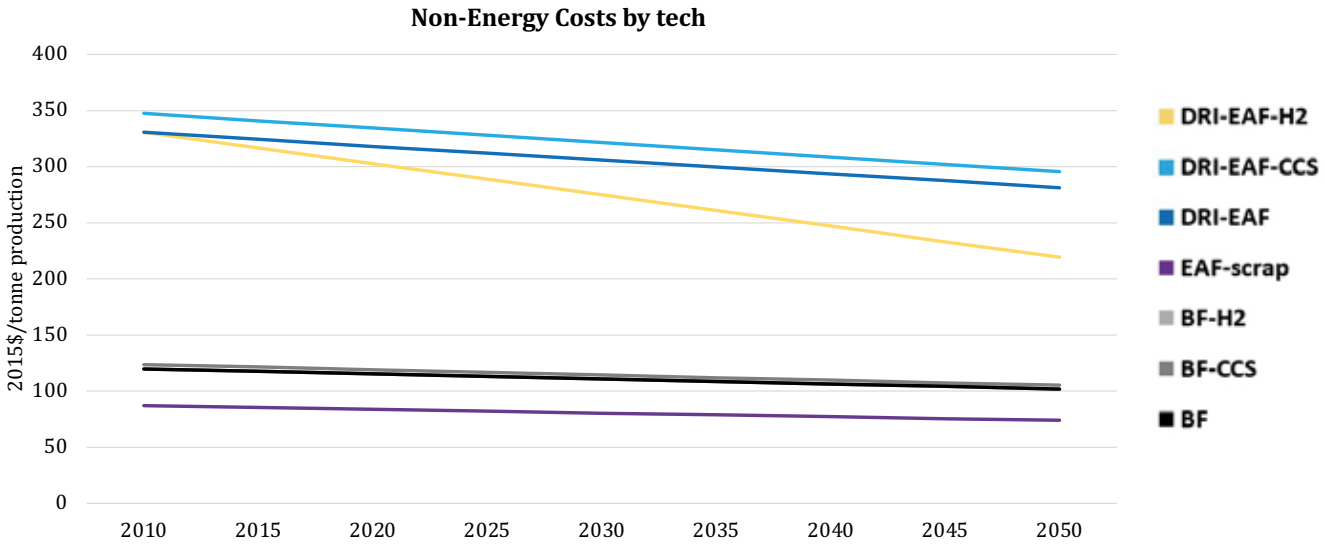
Investment costs assumed for steel production



*Technology investment costs based on E3G & PNNL report (Sha et al., 2021), which uses estimates from Ren et al. (2021) and IEA's iron and steel technology roadmap (2020)

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Results

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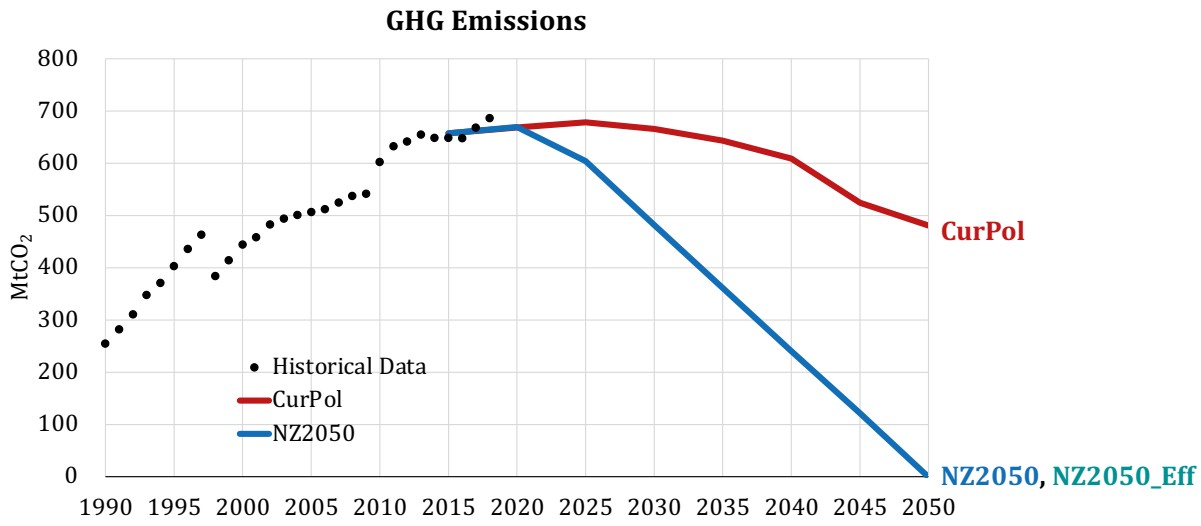
GHG Emissions of Korea



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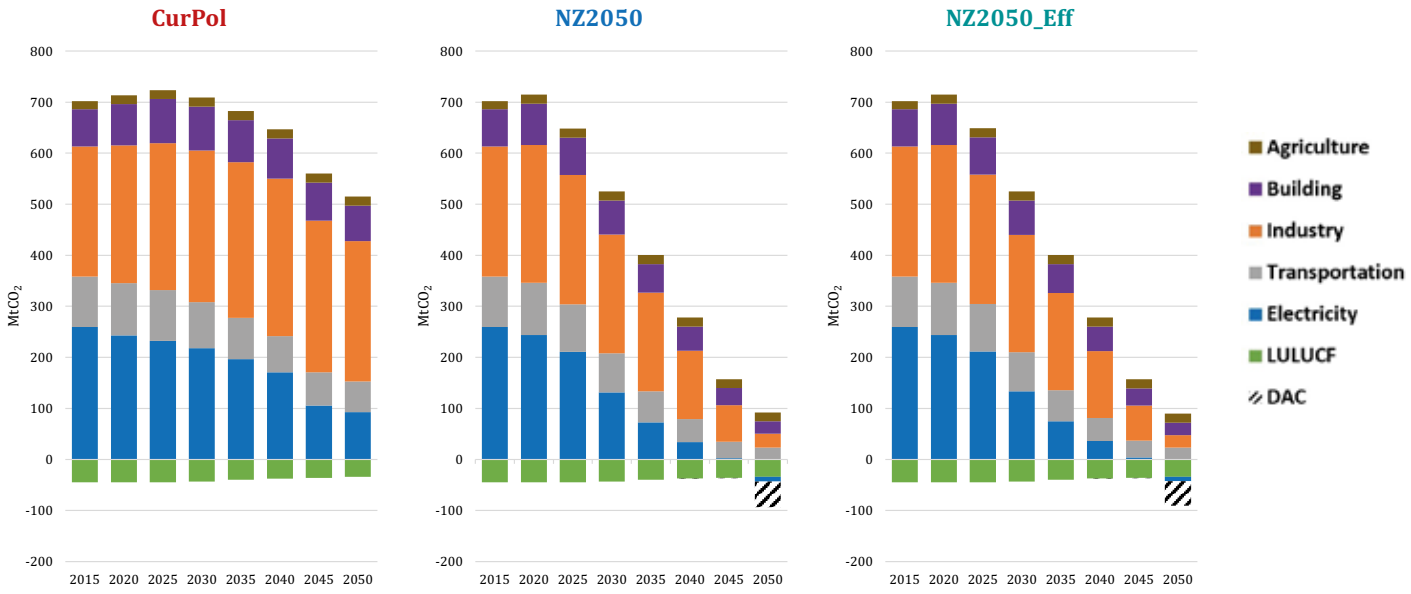
GHG Emissions by Sector



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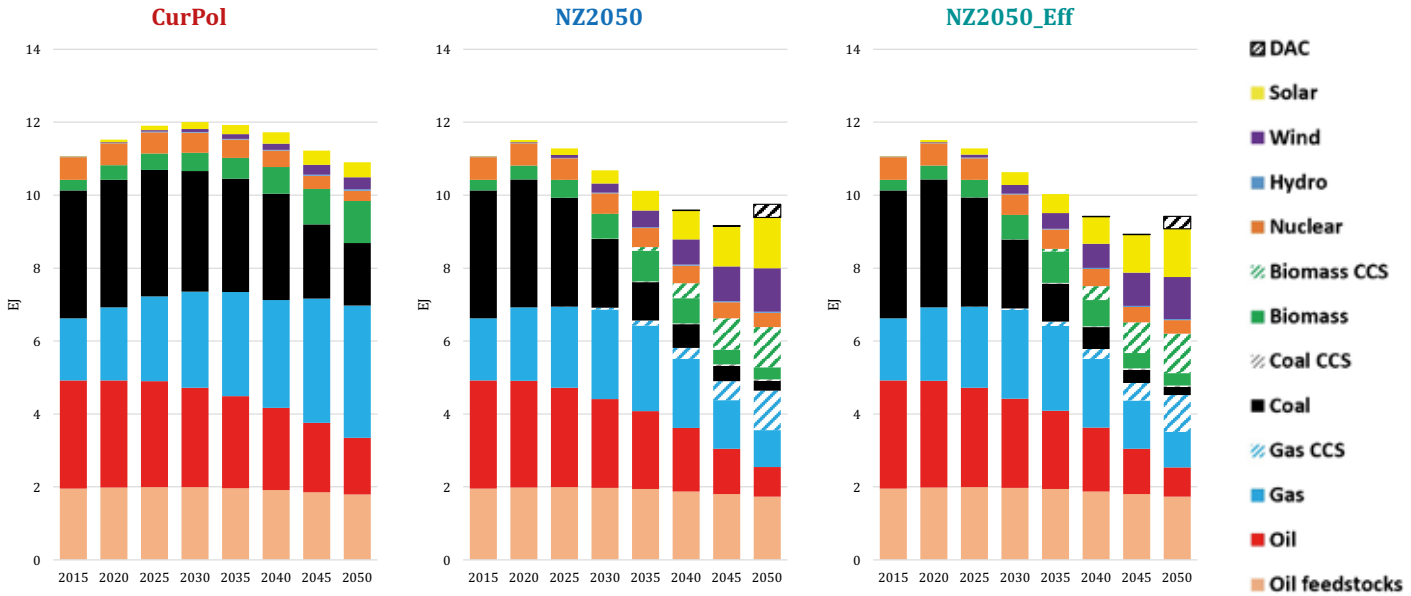
Primary Energy Consumption by Fuel



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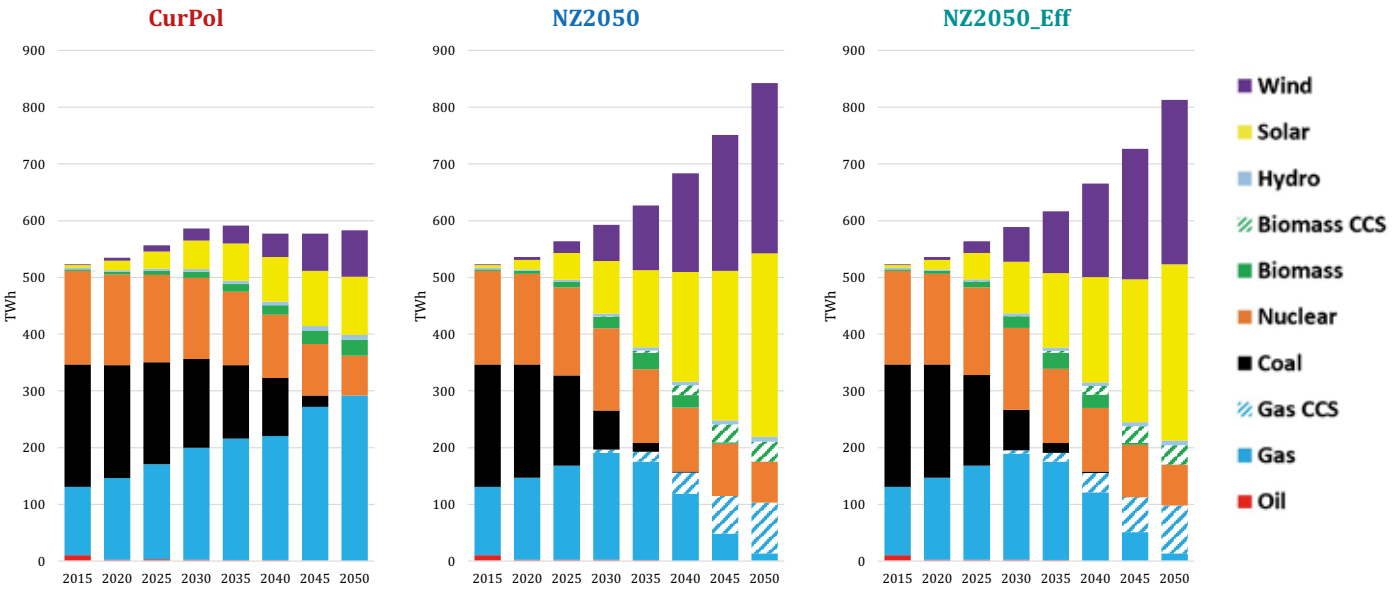
Electricity Generation by Technology



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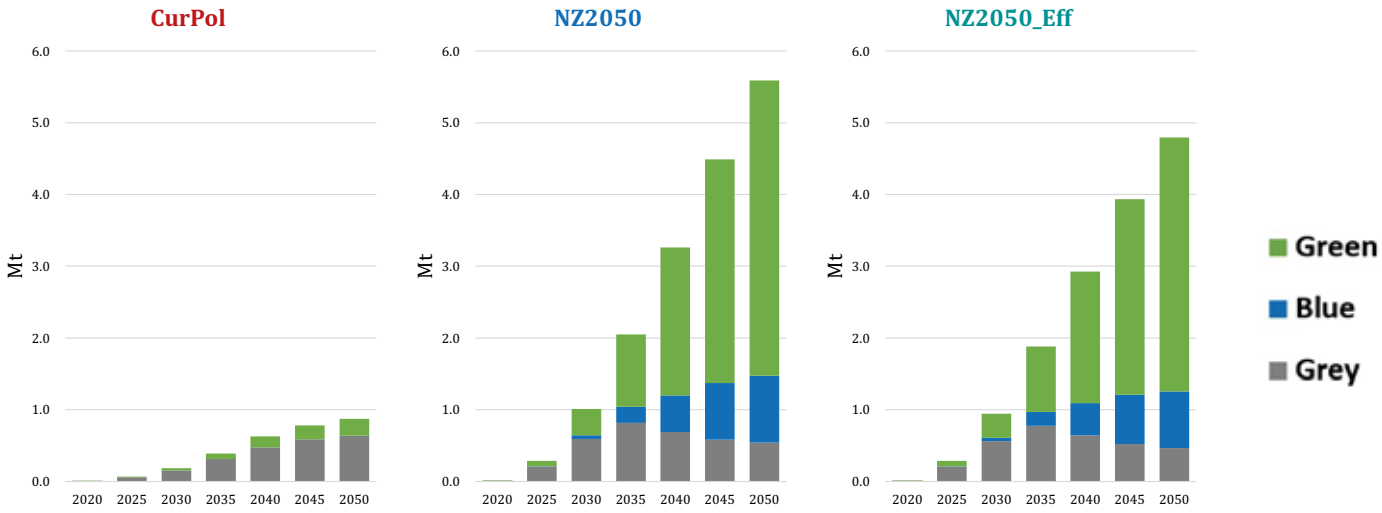
Hydrogen Production by Technology



* **Green hydrogen** includes solar and wind power based electrolysis, biomass gasification w/ and w/o CCS, and nuclear thermal splitting, **blue hydrogen** includes coal and natural gas reforming w/ CCS, and **grey hydrogen** includes natural gas steam reforming w/o CCS.

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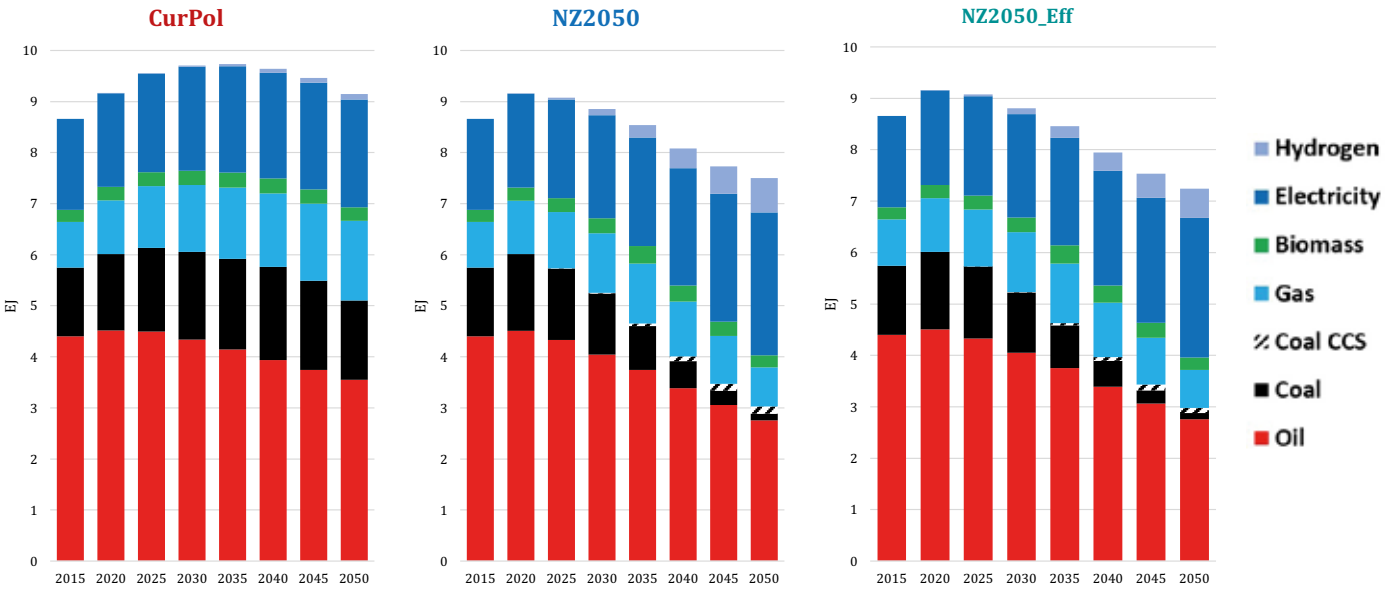
Final Energy Consumption by Fuel



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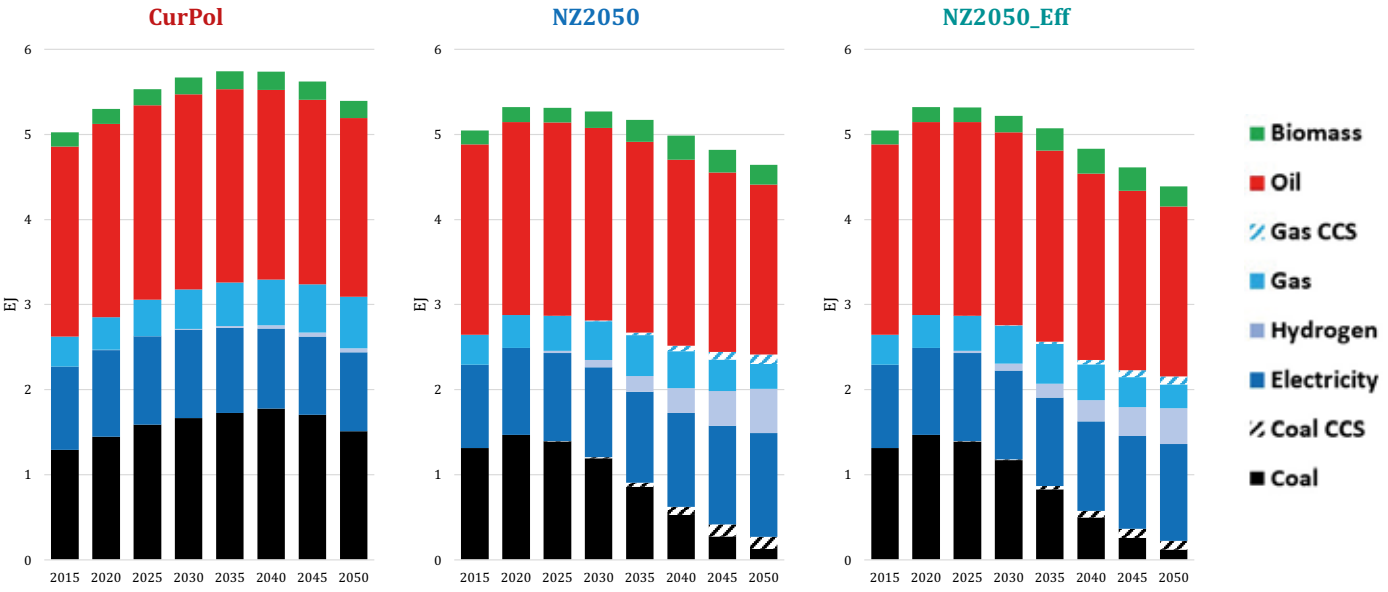
Industry Sector Energy Consumption by Fuel



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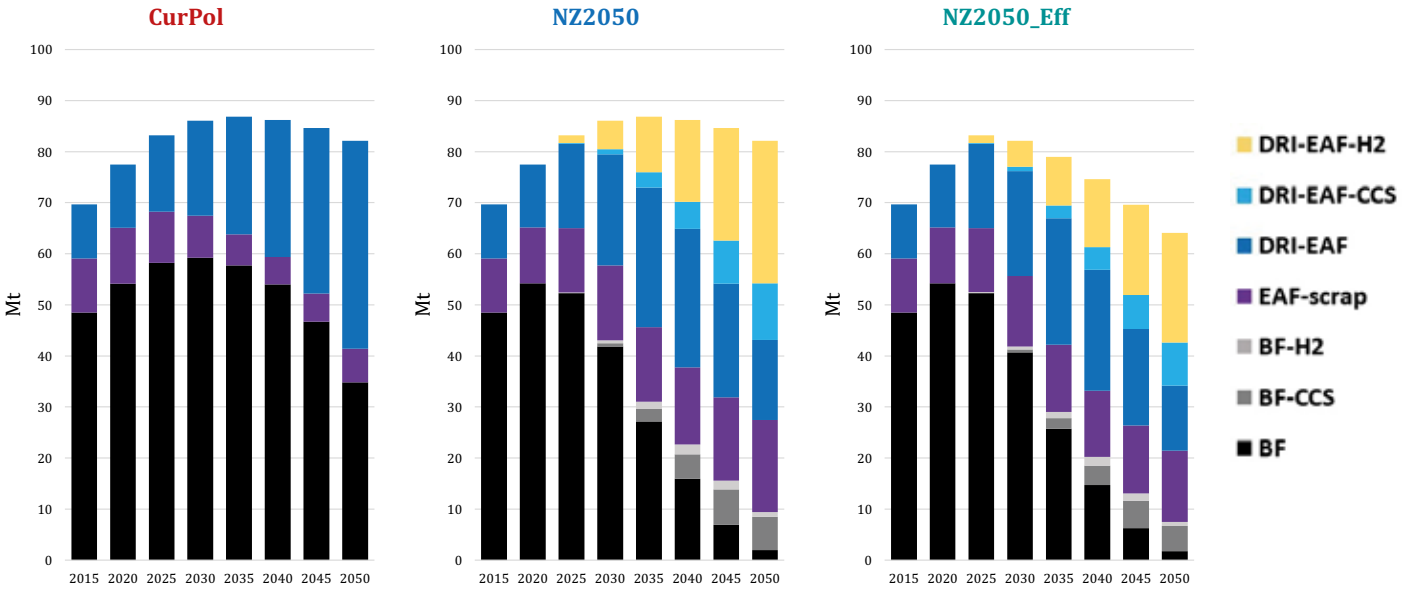
Steel Production by Technology



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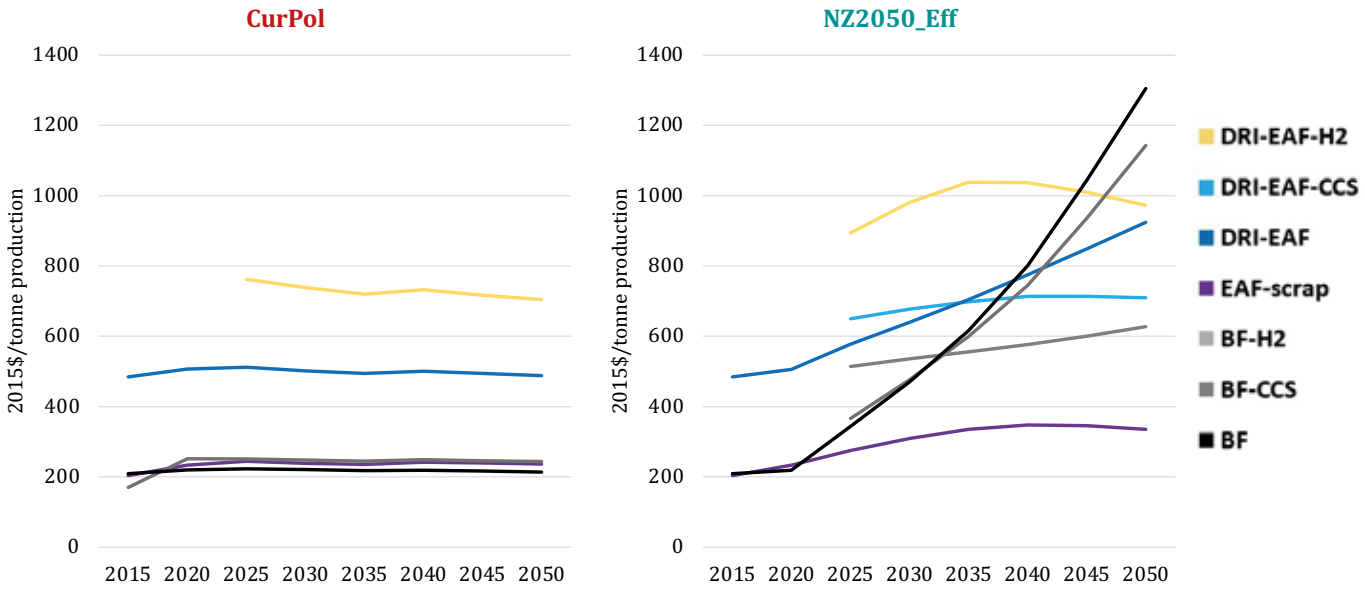
Steel Production Costs by Technology



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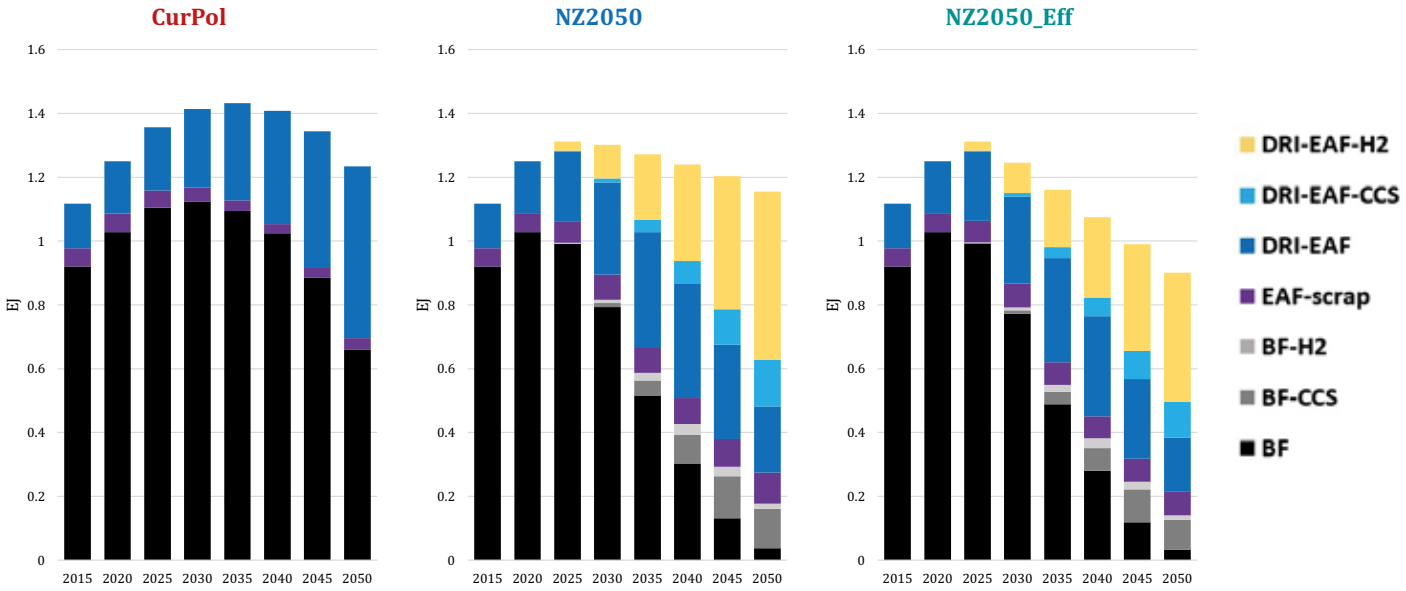
Steel Sector Energy Consumption by Technology



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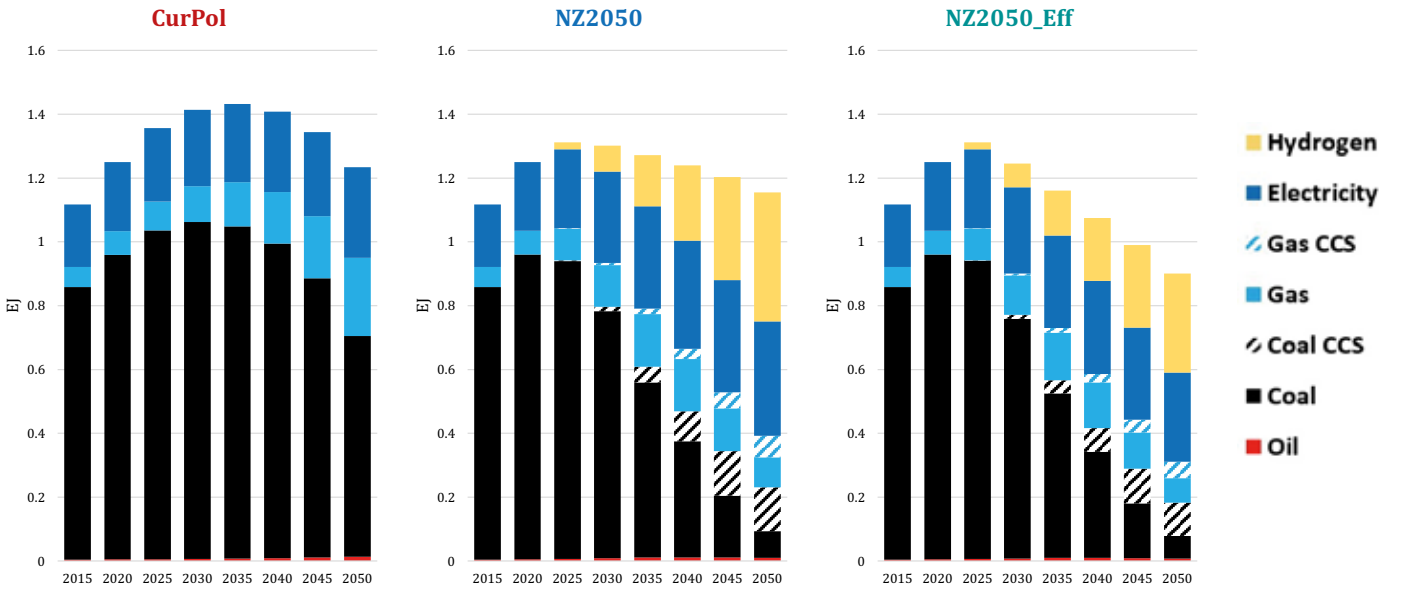
Steel Sector Energy Consumption by Fuel



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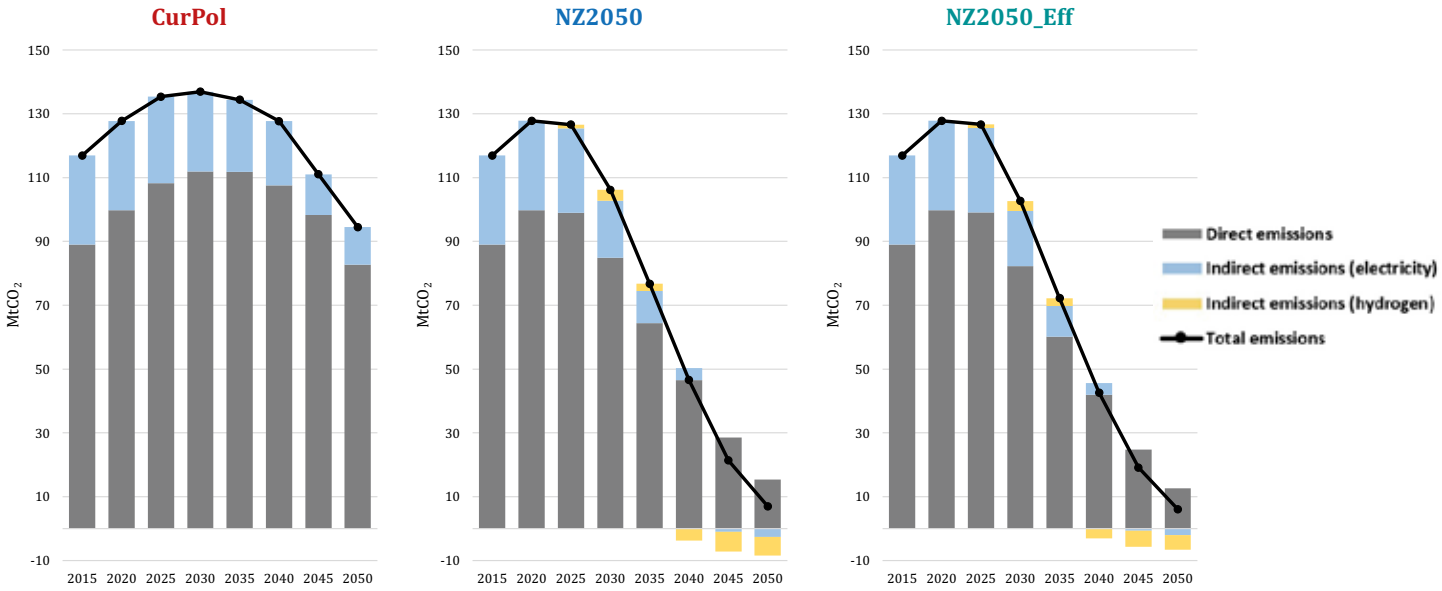
Steel Sector CO_2 Emissions



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Summary

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Main Findings

1. The promising decarbonization strategy for Korea's steel sector would be to scale up **hydrogen DRI** and **DRI w/ CCS** up to about half the production and phase out **unabated blast furnaces** by 2050.
2. Under the carbon neutrality target, lower steel output prospects do ***not*** considerably reduce the sector's emissions but help ***slow down*** the expansion of the power and hydrogen sectors.
3. The carbon neutrality target would ***not*** require the complete removal of CO_2 emissions from the steel sector by 2050. However, its associated indirect emissions from the power and hydrogen sectors would bring the steel sector's total emissions closer to zero by 2050.

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Acknowledgment

- **Hanju Lee** from KAIST for the steel sector
- **Haewon McJeon**, Ph.D. and **Sha Yu**, Ph.D. from UMD for the steel sector
- **Dawoon Jung, Kwangnam Ryu,** and **Hanwoong Kim** from KAIST for other sectors
- **Joojin Kim** and **Kyungrak Kwon** from SFOC

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Thank you!

eomjiyong@kaist.ac.kr

KAIST Working Papers on Korea's Carbon Neutrality:

Integrated assessment modeling of Korea 2050 carbon neutrality technology pathways
https://arxiv.org/abs/2111.01598
Feasibility trade-offs in decarbonization of power sector with high coal dependence: A case of Korea
https://arxiv.org/abs/2111.02872

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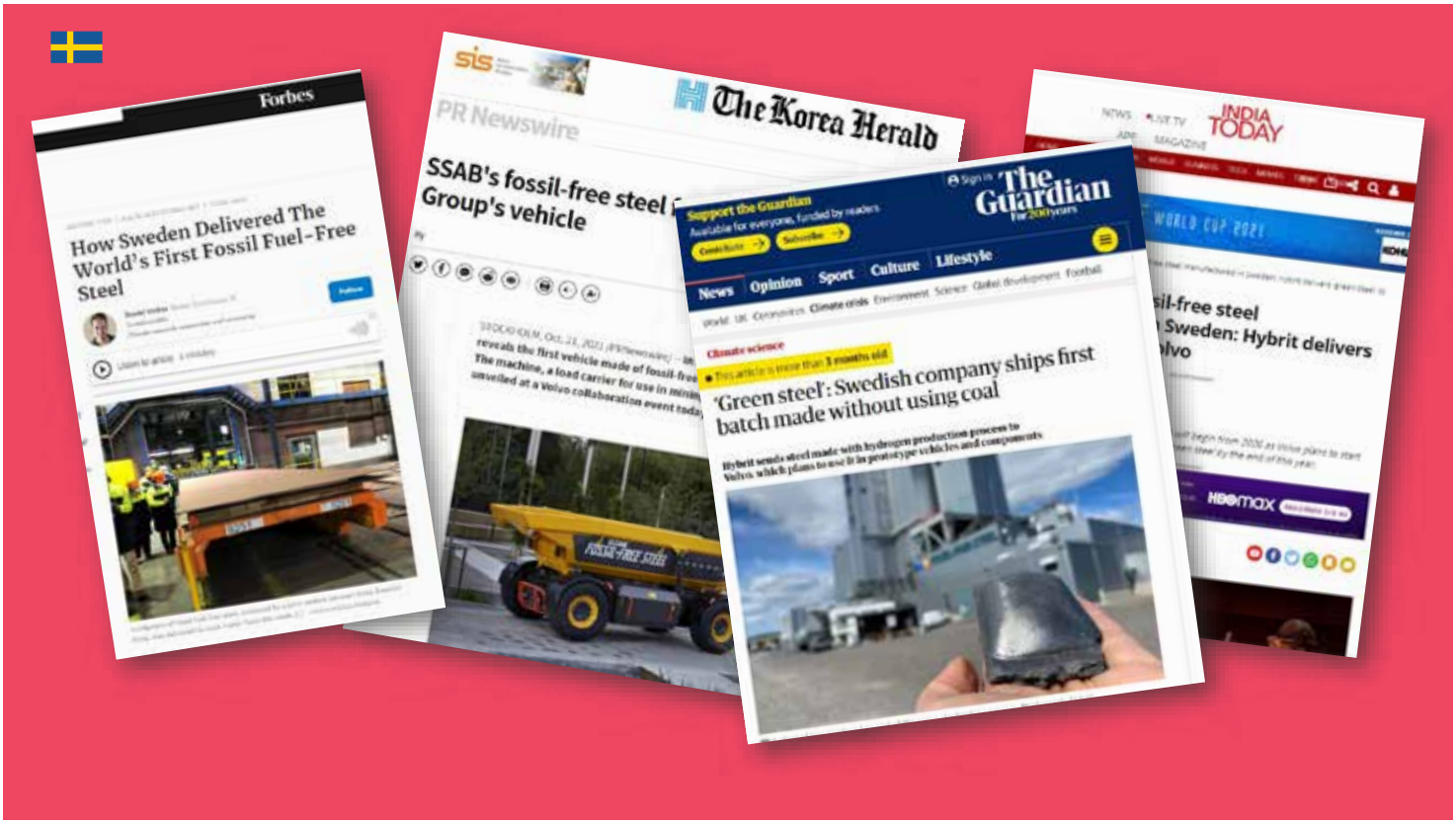
Sweden
Sverige

TRANSITION STEEL INDUSTRY IN SWEDEN TO FOSSIL FREE COMPETITIVENESS

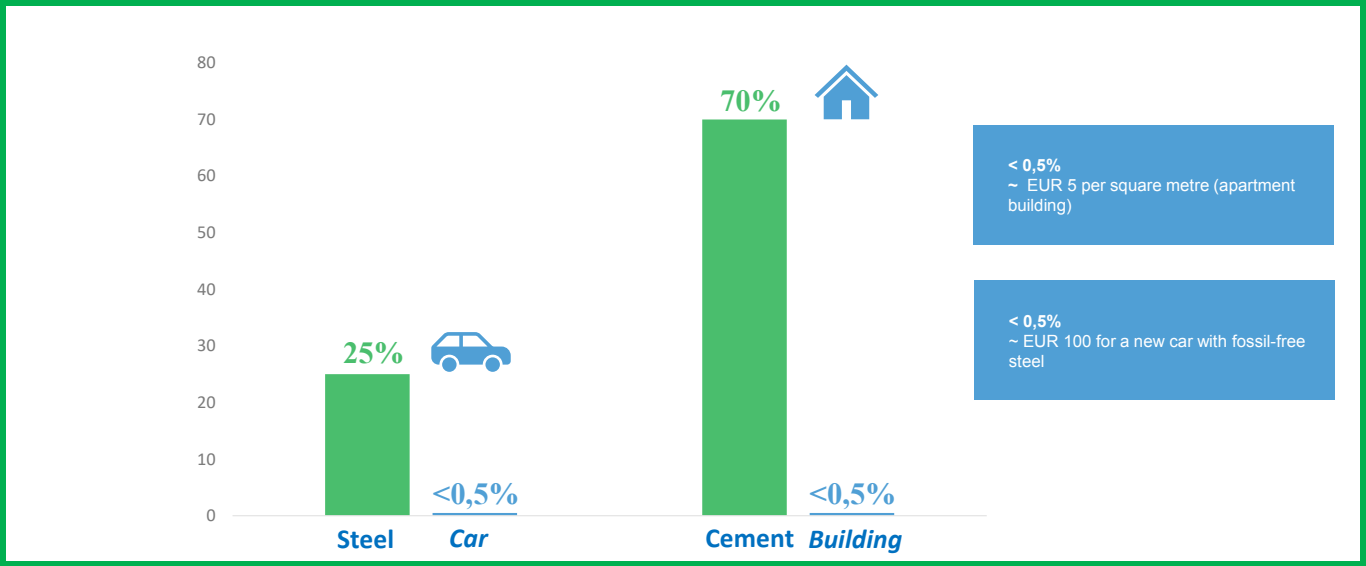
Anders Hektor
Science and Innovation Counsellor
Embassy of Sweden in Seoul



WHY SO FAST IN SWEDEN?

LIVING IN A FOSSIL-FREE SWEDEN

The increased cost of fossil-free raw materials and consumer products



Source: Rootzén and Johnsson, Energy Policy 98 (2016) 459, Climate Policy 17, 6, (2017) 781-800

Concrete 2023 Halved climate impact from house concrete	**Aviation** 2030 Fossil-free domestic aviation	**Cement** 2030 Climate neutral cement	**Agriculture** 2030 Fossil-free agriculture	**Mining and mineral** 2035 Fossil-free mining	**Steel** 2045 Fossil-free steel production	**Gas** 2045 Fossil-free energy gases
Skiing 2027 Fossil free ski resorts	**Digitalization consulting** 2030 Halved energy use	**Grocery stores** 2030 No new oil for plastic packaging	**Haulage** 2030 70% lower emissions	**Heating** 2045 Climate positive	**Shipping** 2045 Fossil-free domestic shipping	**Grocery industry** 2045 Fossil-free value chain
Rock material industry 2030 Halved GHG emissions	**Electricity** 2030 Fossil-free electrical production	**Vehicle industry** 2030 80% chargeable cars	**Construction and facilities** 2030 Halved GHG emissions	**Forrestry** 2045 Bio-economy replace fossil dependence	**Recycling** 2045 Fossil-free and increased recycling	**Petroleum and biofuel industry** 2045 Climate neutral

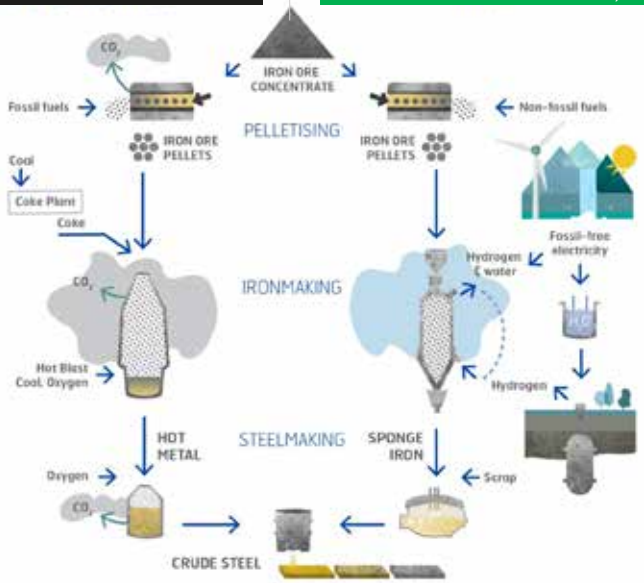
22 Roadmaps for fossil free competitiveness

The HYBRIT technology

HYBRIT
FOSSIL-FREE STEEL
SSAB LKAB VATTENFALL

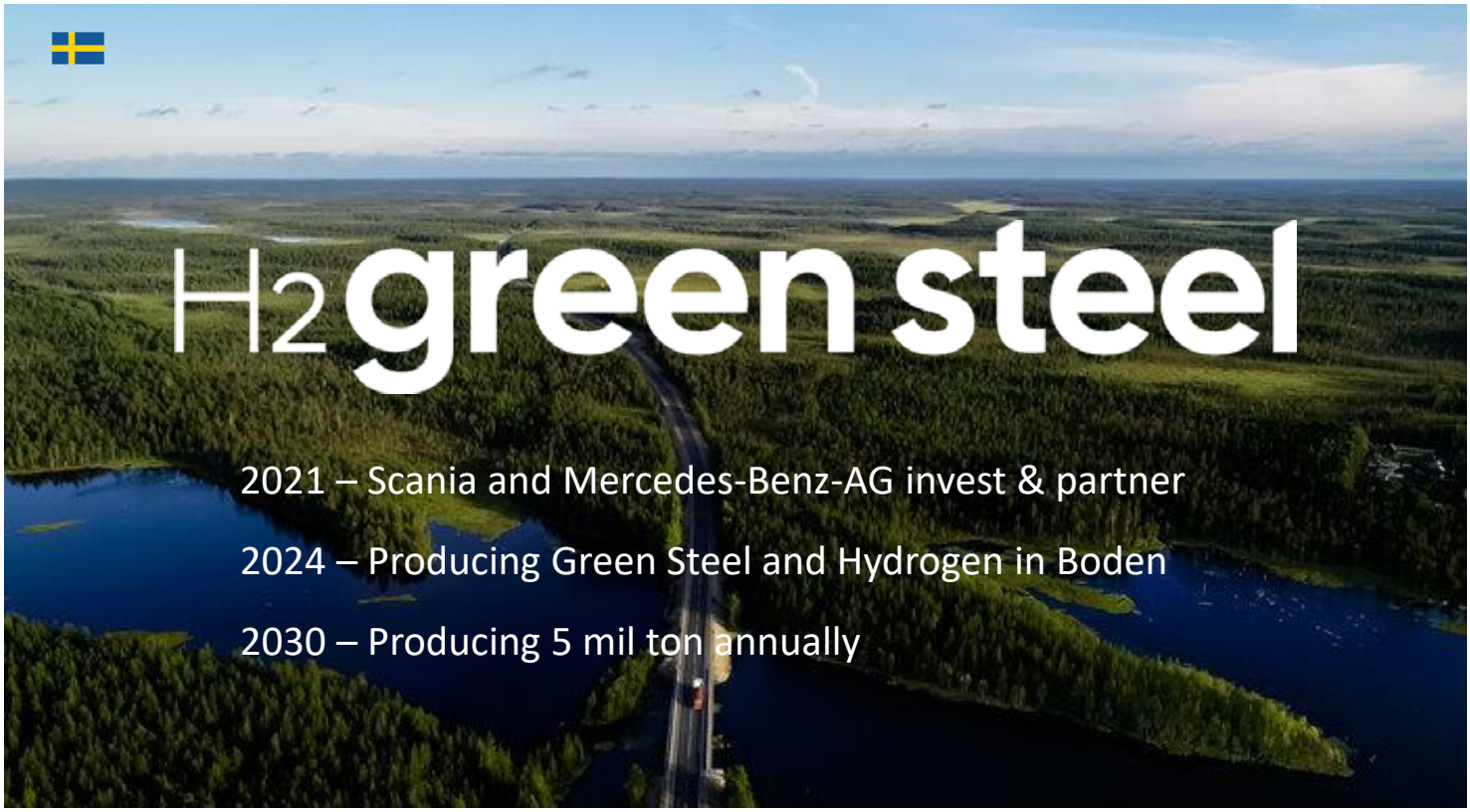
Production intensity per tonne of crude steel

BLAST FURNACE		HYBRIT – *SSAB, Vattenfall & LKAB*
1,600 kg CO_2		25 kg CO_2
81 kWh Oil		42 kWh Coal
5,510 kWh Coal		560 kWh Bio
235 kWh Electricity		3,488 kWh Electricity



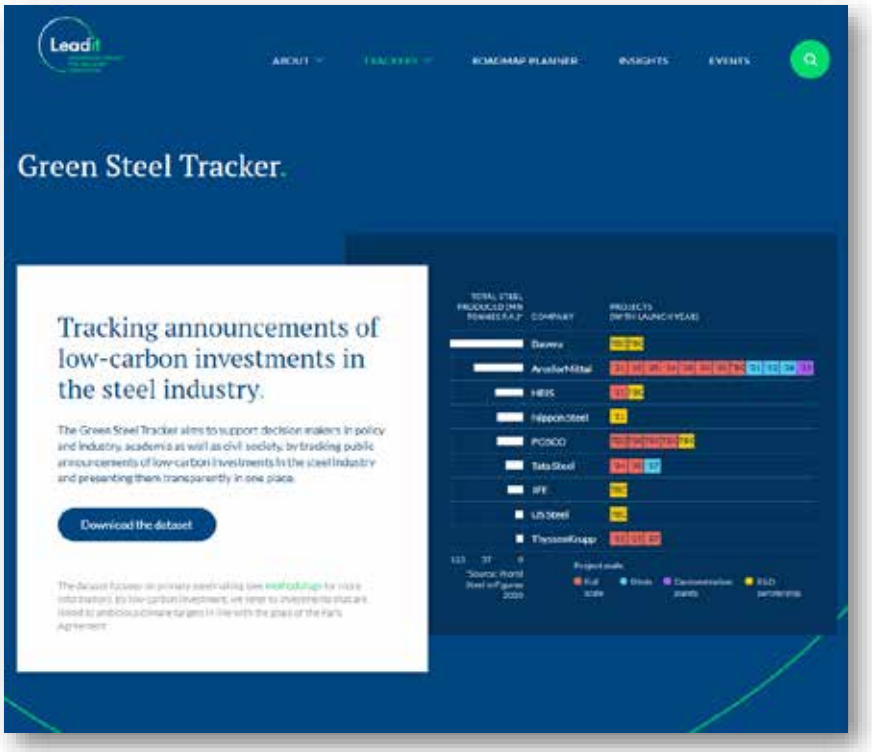
2021 – Ovako and Linde Gas testing to heat steel before rolling

2022 – Electrolyzing 17 MW Hydrogen



Enablers for shift to net-zero industry - including for HYBRITs industrial demonstration

- Long-term policy measures leading to net-zero emissions & sustainable growth, jobs, innovation
  - EU 2050 Long-term Strategy
  - EU Industrial Strategy
- Access to fossil-free electricity and build-up of critical infrastructure, including hydrogen production and storage
- Efficient permit procedures
- Financial support, including EU funding, and risk sharing
- EU ETS system should be designed from 2020 to benefit the most climate-efficient methods from quarrying in the rock to finished steel
- Continued support for competence build-up
- Development of markets for low-carbon products



https://www.industrytransition.org/green-steel-tracker/

Australian Government
Department of Industry, Science, Energy and Resources

Low Emissions Steel – Pathways and Partnerships

Solutions for our Climate - Steel Seminar

Sam Lowe

Project Director

Office of the Special Adviser on Low Emissions Technologies, Australian Government

25 November 2021

Australia is pursuing international partnerships with trade and strategic partners

- Collaboration with international partners is critical to achieving our goals. We cannot address this challenge alone.
- **$565.8 million** committed for Low Emissions Technology Partnerships.
- Australia is a trusted provider of affordable and reliable energy and commodities, and we want to grow opportunities in new low emissions technologies and trade.

Recently announced partnerships

Germany **Japan** **Singapore** **United Kingdom**

Both Australia and Korea have committed to Net Zero emissions by 2050.

Dr Alan Finkel AO
Special Adviser on Low Emissions Technology

Leading Australia's ambitious low emissions technology collaborations with trade and strategic partners

Technology Investment Roadmap: Accelerating deployment of low emission technologies

Technology Investment Roadmap

(May 2020)

An enduring framework to accelerate deployment of low emission technologies

- Support jobs, industries and export opportunities
- Achieve substantial emission reductions
- Deliver affordable, reliable energy

Annual Low Emission Technology Statements

(First LETS released September 2020)

Priority technologies & economic stretch targets

Clean Hydrogen	Production under A$2 ($H_2$ under 2)	2025-30
Ultra low-cost solar	Under A$15 per MWh	2030-35
Electricity storage	Under A$100 per MWh	2025-30
Zero emissions materials	Steel under A$900/tonne Aluminium under A$2,700/tonne	2030-35 2035-40
Carbon capture and storage	Under A$20 per tonne	2025-30
Soil organic carbon measurement	Under A$3 per ha per year	2025-30

International Partnerships

Partnerships focus on the priority technologies in the LETS.

International Partnerships on Low Emissions Technology to date in 2021

Germany

Australia-Germany Hydrogen Accord

- HyGate Program, with combined investment of approximately $130 million for RD&D along the hydrogen supply chain
- Facilitating industry partnerships on demonstration projects in Australian hydrogen hubs
- Exploring opportunities to supply hydrogen and it's derivatives from Australia to Germany

Japan

Low Emissions Technology Partnership

- Partnership to support technologies, including: clean hydrogen and ammonia; carbon capture, use and storage; lower emissions LNG; and low emissions steel and iron ore.
- Start of operations for Hydrogen Energy Supply Chain project, to produce and export liquefied clean hydrogen to Kobe, Japan.

Singapore

Low Emissions Maritime Initiative

- $30 million co-investment from Australia, Singapore and industry for pilot and demonstration projects to trial the use of low emissions technologies, including clean hydrogen and ammonia, in shipping and port operations.

United Kingdom

Australia-UK Partnership on Low Emissions Solutions

- Collaboration on research and development across six key technologies including clean hydrogen; carbon capture and use and storage; small modular reactors including advanced nuclear designs and enabling technologies; low emissions materials including green steel; and soil carbon measurement.
- As a first initiative, we will develop a joint industry challenge to increase the competitiveness of industry, recue emissions and support economic growth.

Australia – Republic of Korea Low and Zero Emissions Technology Partnership

Announced 1 November 2021 by Leaders

"…we commit to working together over the next decade and beyond to develop and support initiatives that will help drive increased adoption of low and zero emission technologies, and support our efforts to meet and beat our commitments under the Paris Agreement…"

Technology focus areas for the Partnership

Low Emissions Iron Ore & Steel	Clean Hydrogen & Ammonia	Hydrogen Fuel Cell Electric Vehicles	Hydrogen power generation	CCS

"…pursuing a low emissions steel and iron ore initiative that looks to reduce emissions across the supply chain."

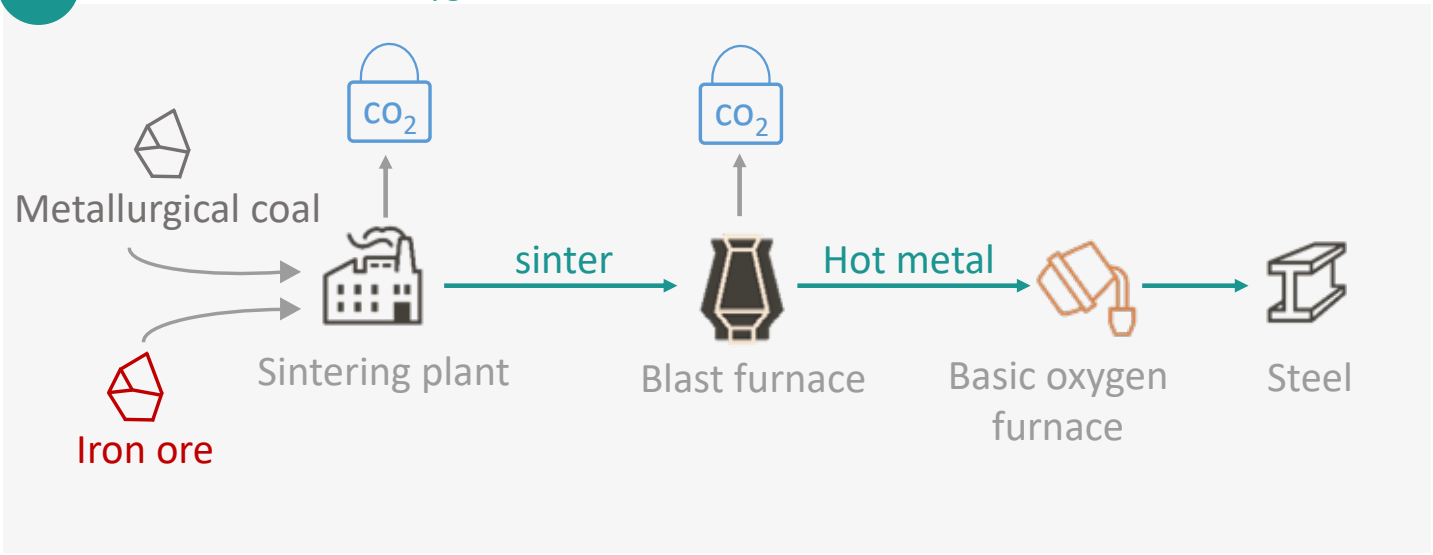
A number of possible opportunities collaboration on low emissions steel and iron ore.
Potential areas of cooperation include value-added iron ore products such as:

- Beneficiated ores to enable lower emissions steel production pathways
- Demonstration of hydrogen use in DRI and HBI export from Australia to Korea

Low emissions steel pathways

Under A$700 per tonne by 2023-30

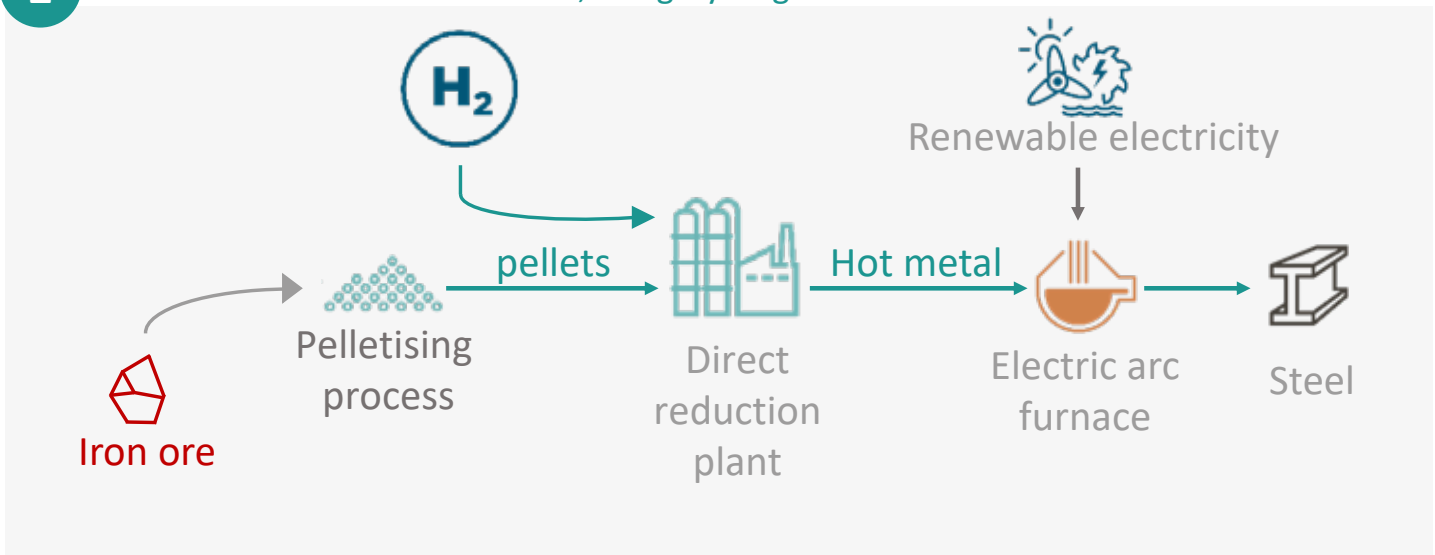
1 Blast furnace, Basic Oxygen Furnace + CCUS



Low emissions steel pathways

Under A$700 per tonne by 2023-30

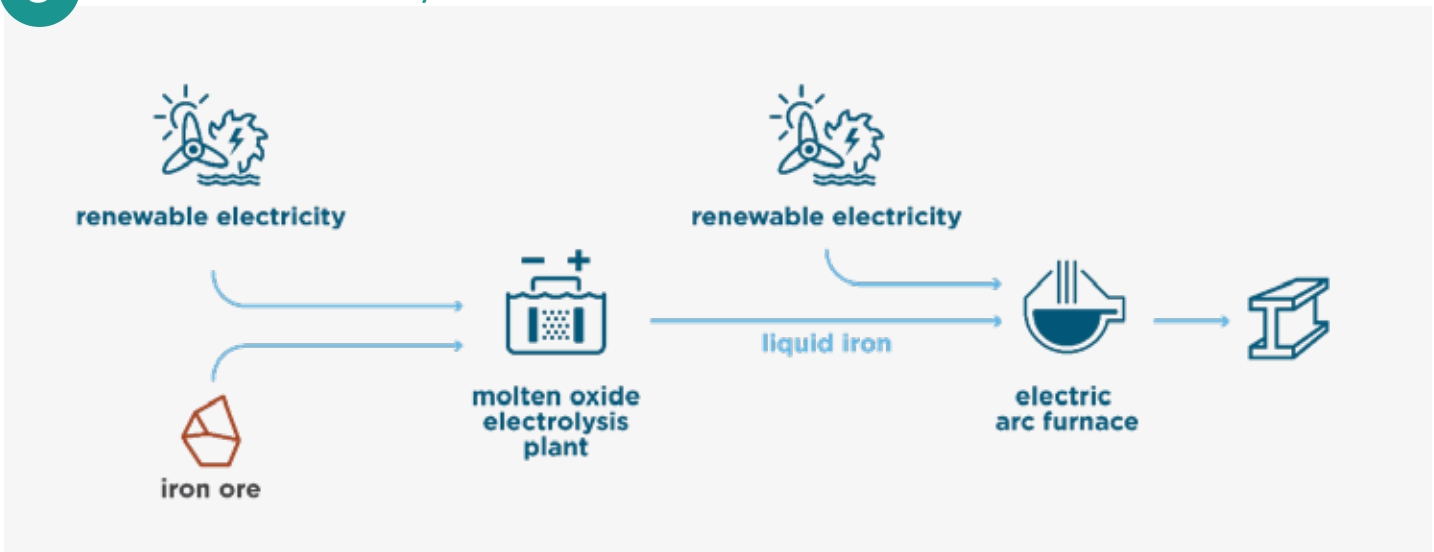
2 Direct reduction of iron with EAF, using Hydrogen



Low emissions steel pathways

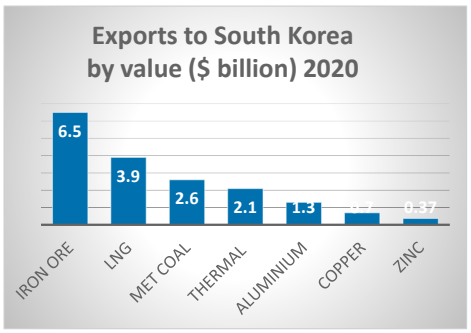
Under A$700 per tonne by 2023-30

3 Molten oxide electrolysis



Australia – Korea Iron Ore Trade

- South Korea is one of Australia's largest iron ore export markets, accounting for around 6% of Australia's total iron ore exports.
- In 2020, Australia exported AUD$6.6 billion of iron ore to South Korea.
- Australian exports accounted for around 75% of South Korea's iron ore imports in 2020.



Recent Industry Cooperation

3 Aug 2021

POSCO and Roy Hill to reduce carbon emissions across mining and steel businesses

8 July 2021

Rio Tinto and POSCO sign climate MOU

20 March 2021

Hyundai Motors and Fortescue sign hydrogen development MOU

Business Korea 3 Aug 2021

POSCO and Roy Hill to reduce carbon emissions across mining and steel businesses

Business Wire 8 July 2021

Rio Tinto and POSCO sign climate MOU

Next Steps

- Consultation with industry and research
- Development of Partnership Initiatives with Korea

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