Australia's role in a global green steel transition

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Outline

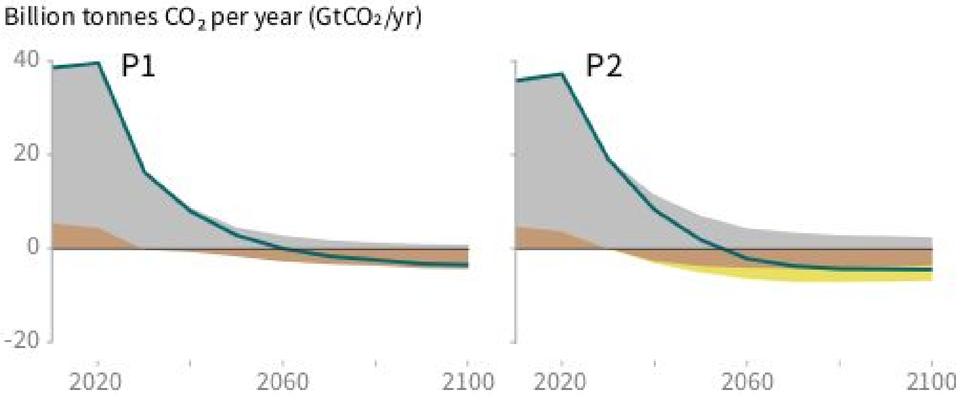
- Steel, iron ore and Australia’s role
- Conventional steel vs green steel
- Local advantage, sense of scale
- Scenarios and outlook

Context

Paris Agreement & IPCC Special Report SR15

"*Energy and process efficiency by themselves are insufficient*" to limit warming to 1.5°C (C.2.3).

Scenarios resulting in 1.5°C of warming require at least 59% reduction in the use of coal for primary energy by 2030



Major pledges in 2020:

- Japan
- Korea
- China (*2060)

...all aiming for **net-zero CO_2** emissions by 2050.

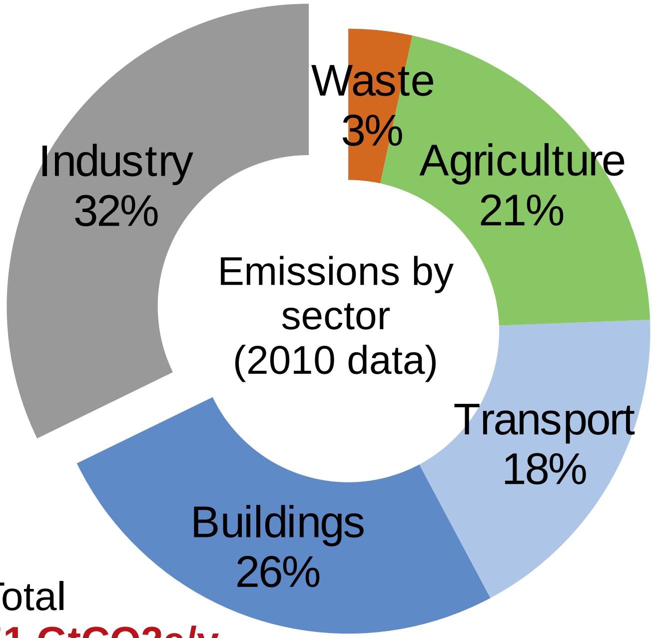
Also:

- NSW Net Zero Plan
- US rejoined Paris Agreement
- EU making targets legally binding

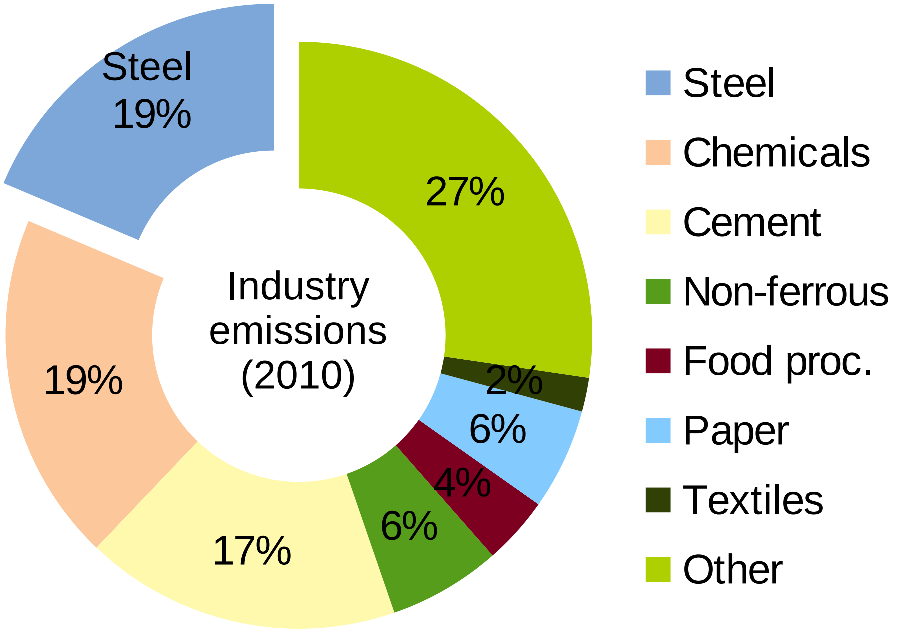
Science https://is.gd/XRe6rW
Nikkei Asia https://is.gd/ldrp3q
Guardian https://is.gd/soe4Y5

IPCC 2019 http://ipcc.ch/sr15

Steelmaking: a big emission source



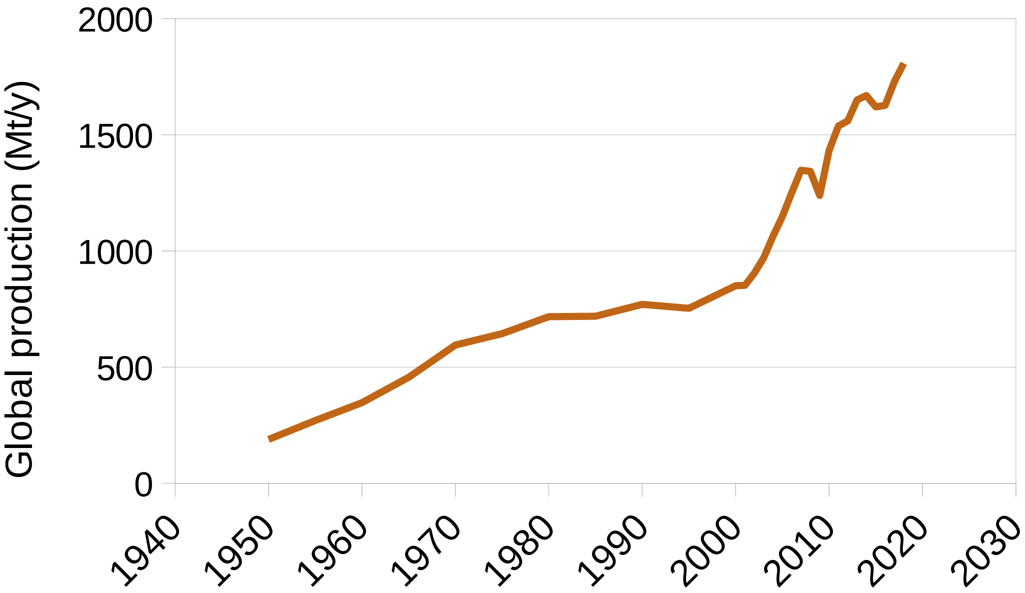
Total
51 GtCO2e/y



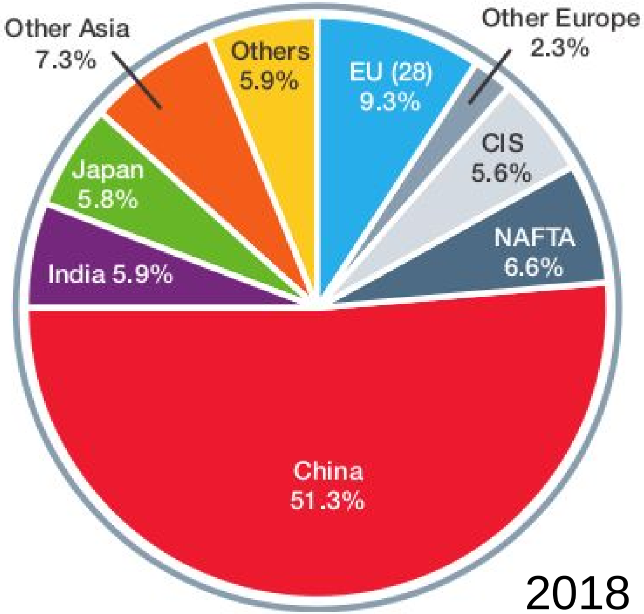
This ‘**sector-based**’ analysis includes both direct and indirect emissions.

Bajželj, Allwood & Cullen, 2013 doi:10.1021/es400399h; cited by IPCC AR5

Crude steel production



Australian production **5.3 Mt/a**

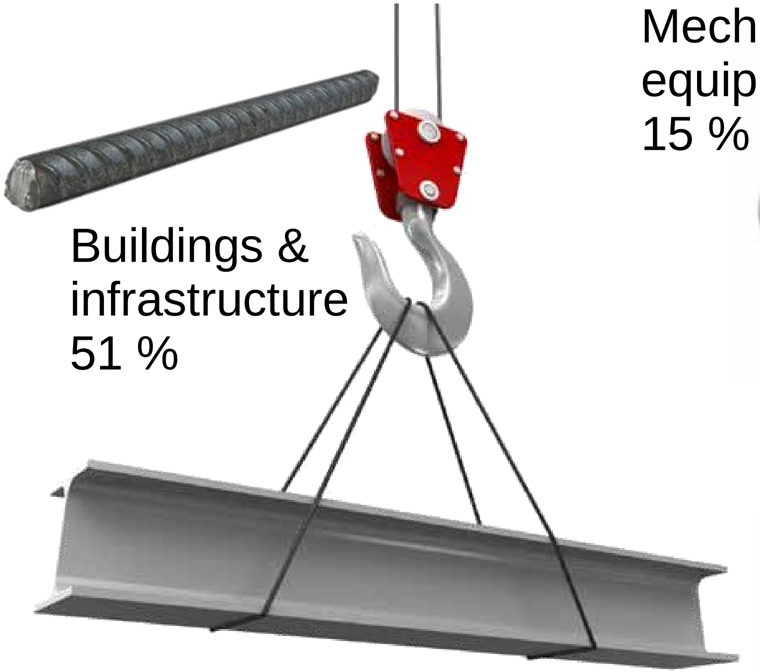


2018

Global crude steel production is currently **1808 Mt/a**, mostly in China, India, Japan. This is up from 850 Mt/y in 2000.

World Steel 2019 https://is.gd/fjhNlp
Aust Steel Inst https://is.gd/jnAOk3

Major uses of steel



Buildings & infrastructure 51 %

Mechanical equipment 15 %

Automotive 12 %

Metal products 11 %

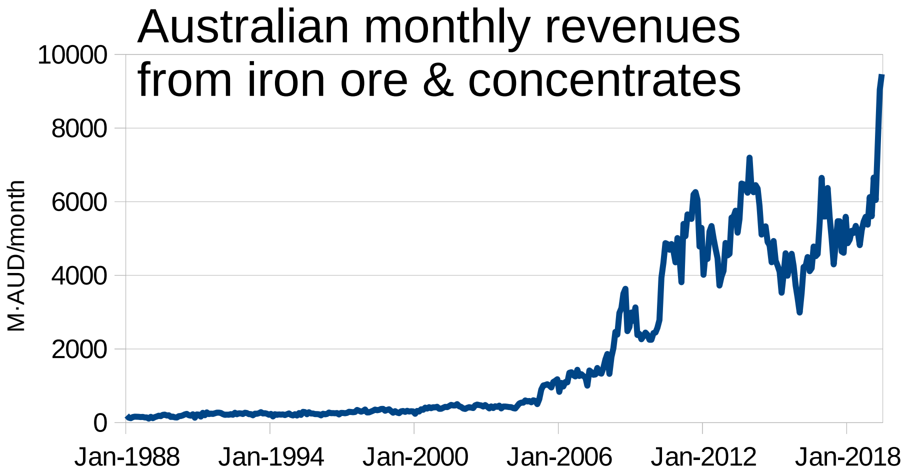
Other transport 5%

Domestic applicances 3%

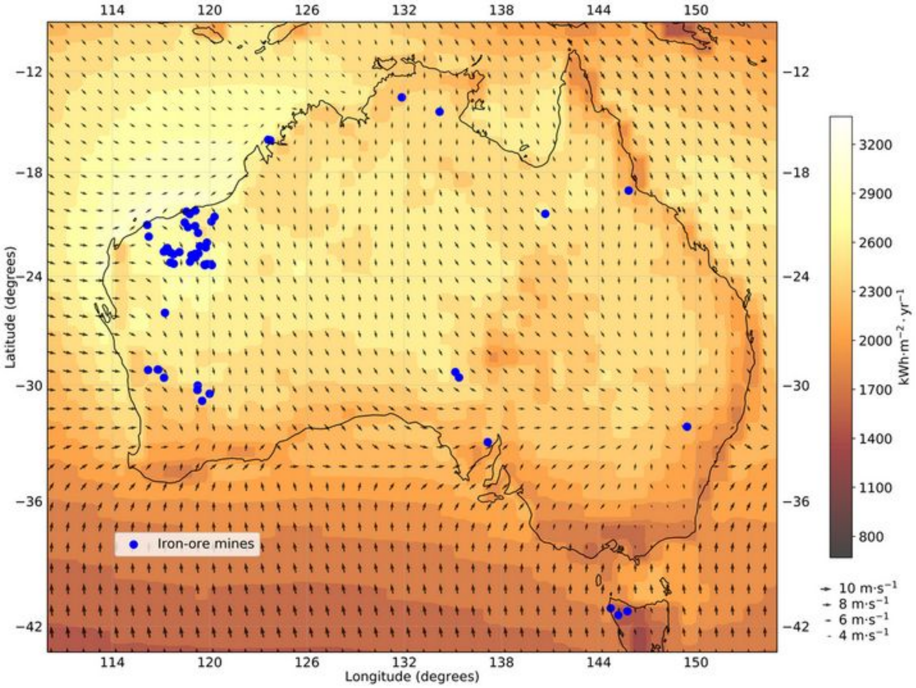
Electrical equipment 3%

Allwood 2012; World Steel https://is.gd/K7EGVK

Australian iron ore



Rio Tinto, BHP, FMG, Grange...

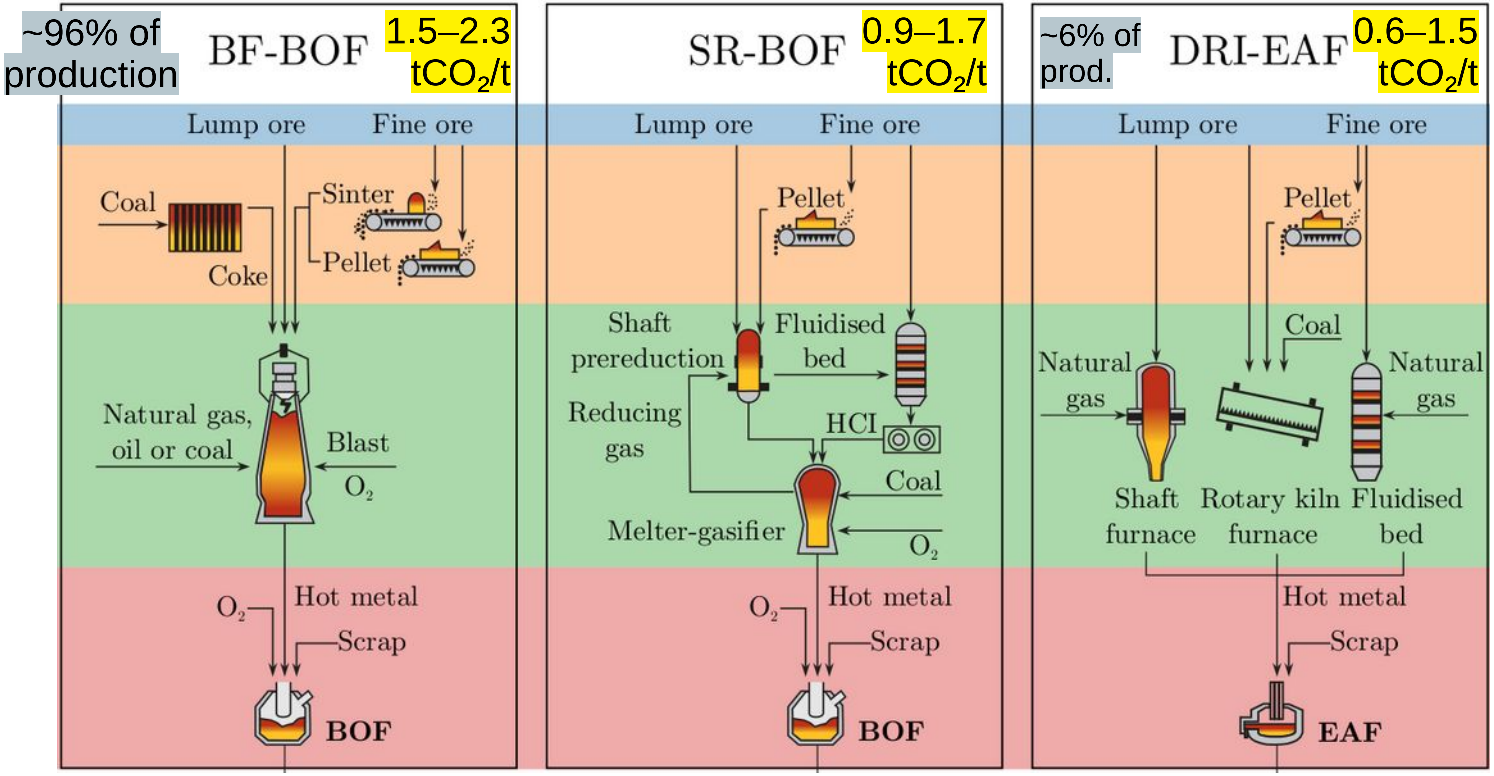


Locations of Australian iron ore mines

Australia is easily the largest iron ore exporter in the world (0.9 Gt/y of total 2.5 Gt/y produced), and dominates the ore imports to China, Japan and South Korea.

ABS 2019 https://is.gd/RvKJlG, USGS

Conventional steelmaking

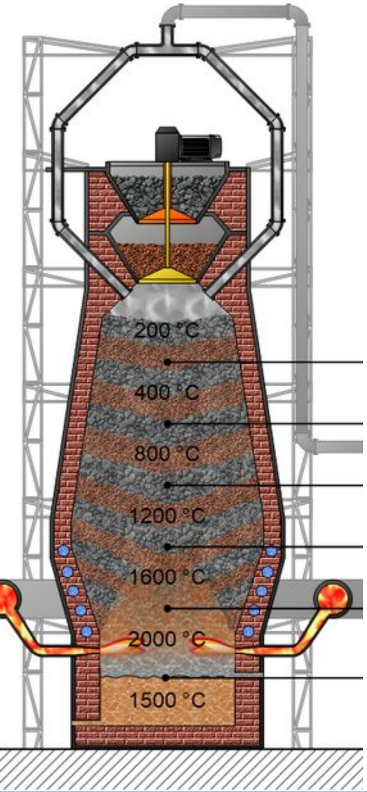


Greenhouse gas emissions per tonne of steel produced.

Fraction of world primary ('virgin') steel production.

Figure: Rahbari

BF-BOF



Coal (coke), iron ore and flux (limestone) are piled in from the top.

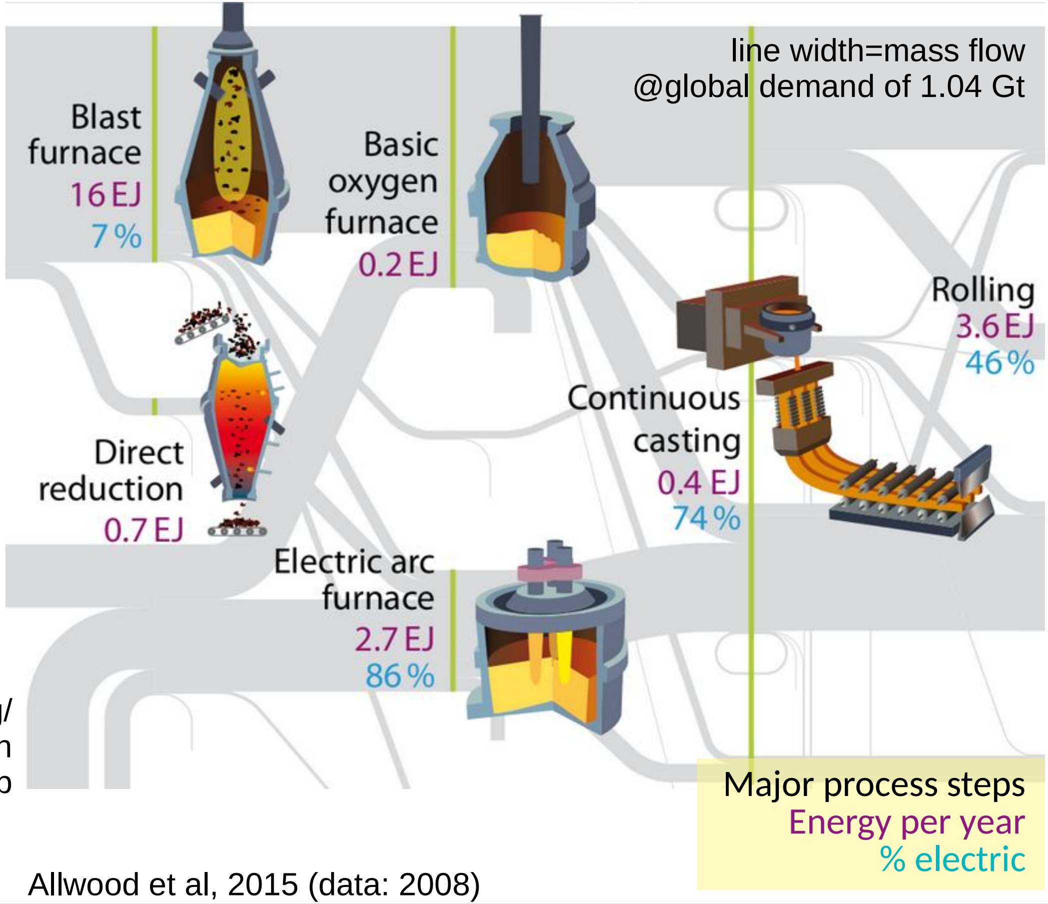
Air/oxygen are pumped in near the bottom.

Molten iron and 'slag' flow out the bottom.

iron ore

recycled steel

forming/ fabrication scrap



Allwood et al, 2015 (data: 2008)

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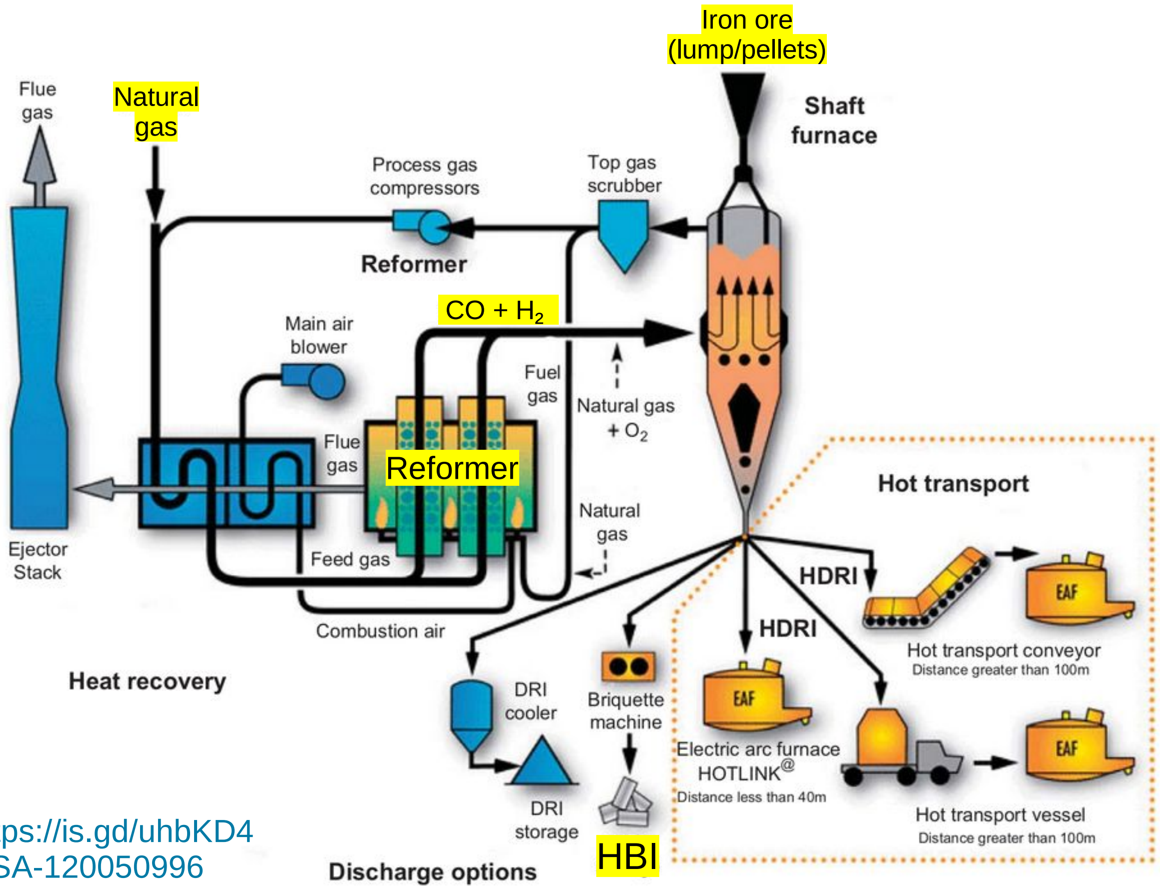
DRI

Direct reduced iron (DRI) is produced typically from natural gas in countries like India, Iran, Russia and Mexico.

The Midrex process is ~70% of current DRI (~5% of total crude steel), but there have been numerous related processes developed and trialled, including FINMET in Australia, Circored, HYL I and HYL III.

Typically ~40% H_2 is used (from NG). Up to 90% H_2 has been trialled, but only in isolated demo plants.

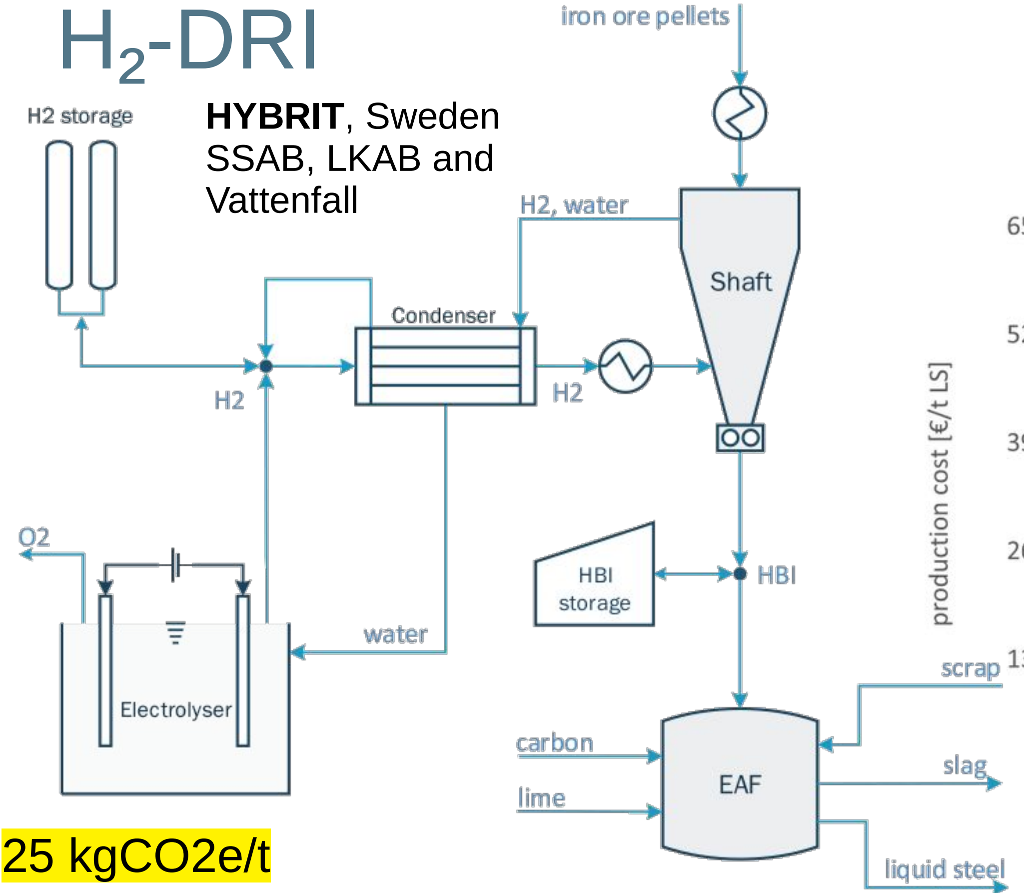


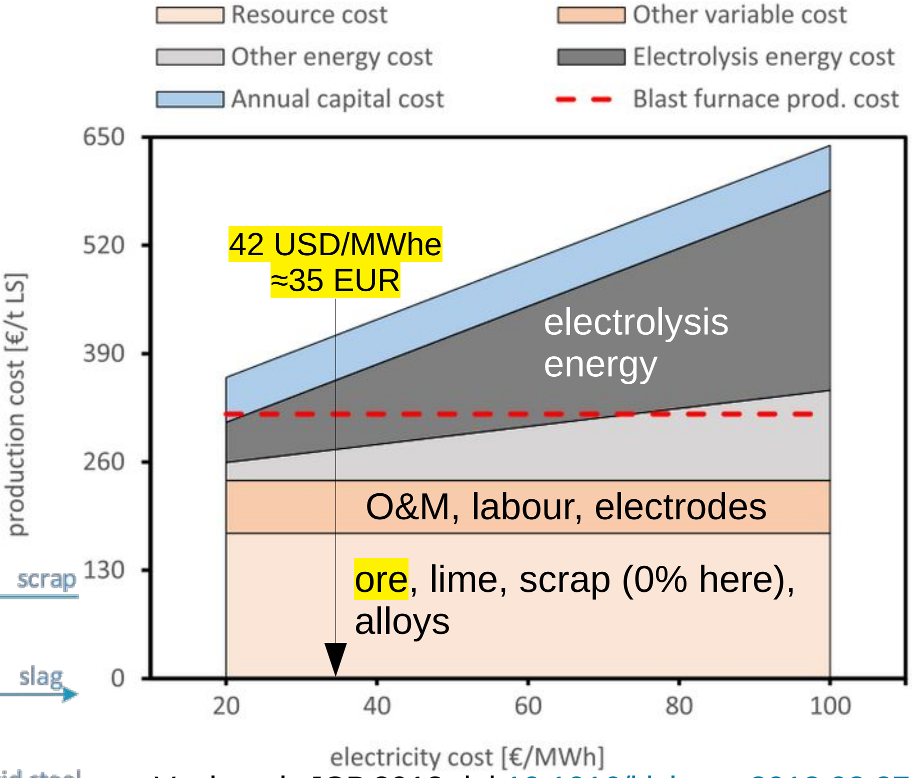
Montague/MIDREX 2012 https://is.gd/uhbKD4
Sah/Dutta doi:10.1081/E-EISA-120050996

Aug 2020 ‘starting the test operation’ https://is.gd/fpRGQr. 1 Mt/a demo planned 2023.

H_2-DRI

HYBRIT, Sweden
SSAB, LKAB and Vattenfall

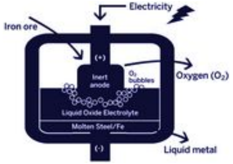




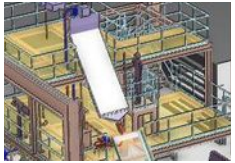
Vogl et al, *JCP* 2018 doi:10.1016/j.jclepro.2018.08.279

25 kgCO2e/t

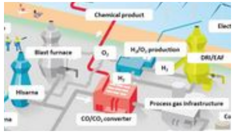
Other efforts



Boston Metal
Direct electrolytic ironmaking (early days!)
https://is.gd/FKrGVS



ArcelorMittal ‘SIDERWIN’ electrowinning process, low temperature (early days!)
https://is.gd/nGQR2O



Tata Steel Europe
HIsarna coal+CCS/CCU
https://is.gd/dDB9M9
(~75% reduction in CO2?)
https://is.gd/ukhzAb

ArcelorMittal/Midrex ‘MIDREX-H2’. Initially grey hydrogen, migrating later to green (~100% reduction in CO_2).
https://is.gd/iBSIjT

Primetals ‘HYFOR’ fluidised bed H_2 DRI
(~100% CO_2 reduction)
https://is.gd/0NOrZI

thyssenkrupp H_2 injection into BF (≤20% CO_2 reduction)
https://is.gd/xHpUmx

Salzgitter ‘SALCOS’
H_2 DRI adddition to BF, gradually replace BF/BOF with EAF
(~100% CO_2 reduction)

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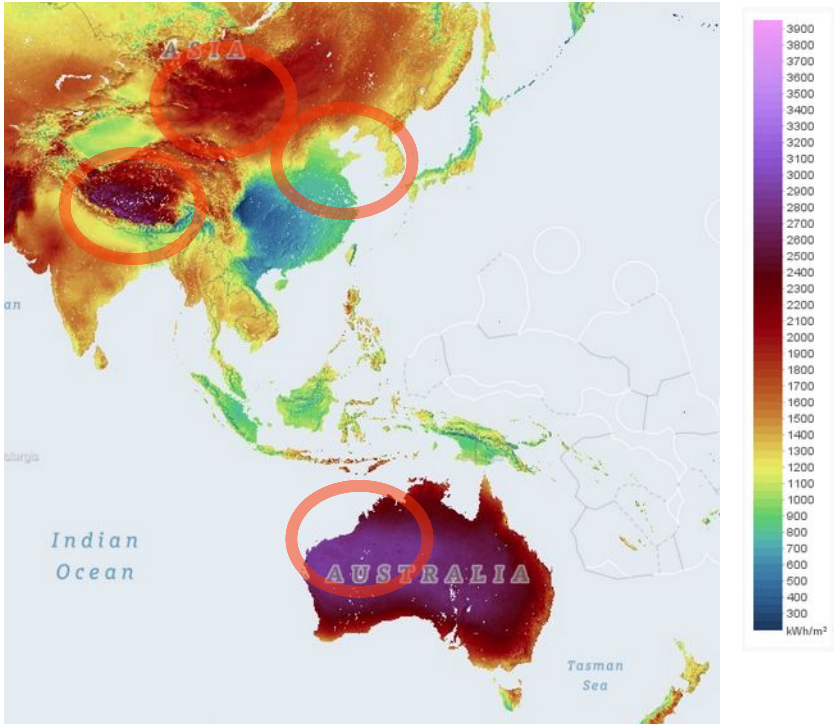
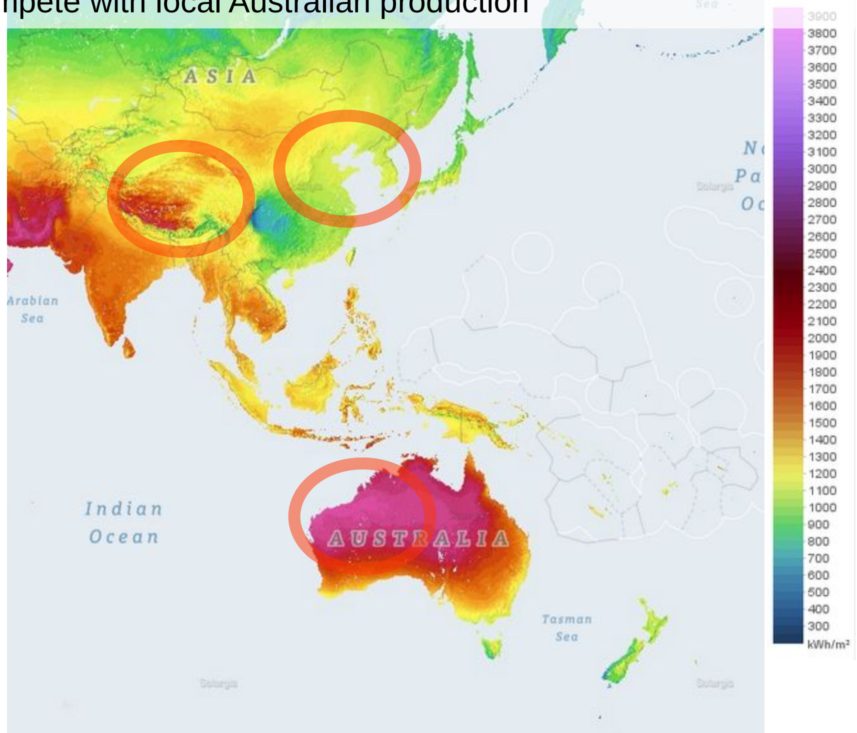
A local advantage?

Australia has very good ore and excellent solar resource co-located. Current production, dominantly China, would have to pay for shipping, transmission and higher(?)-cost power to compete with local Australian production

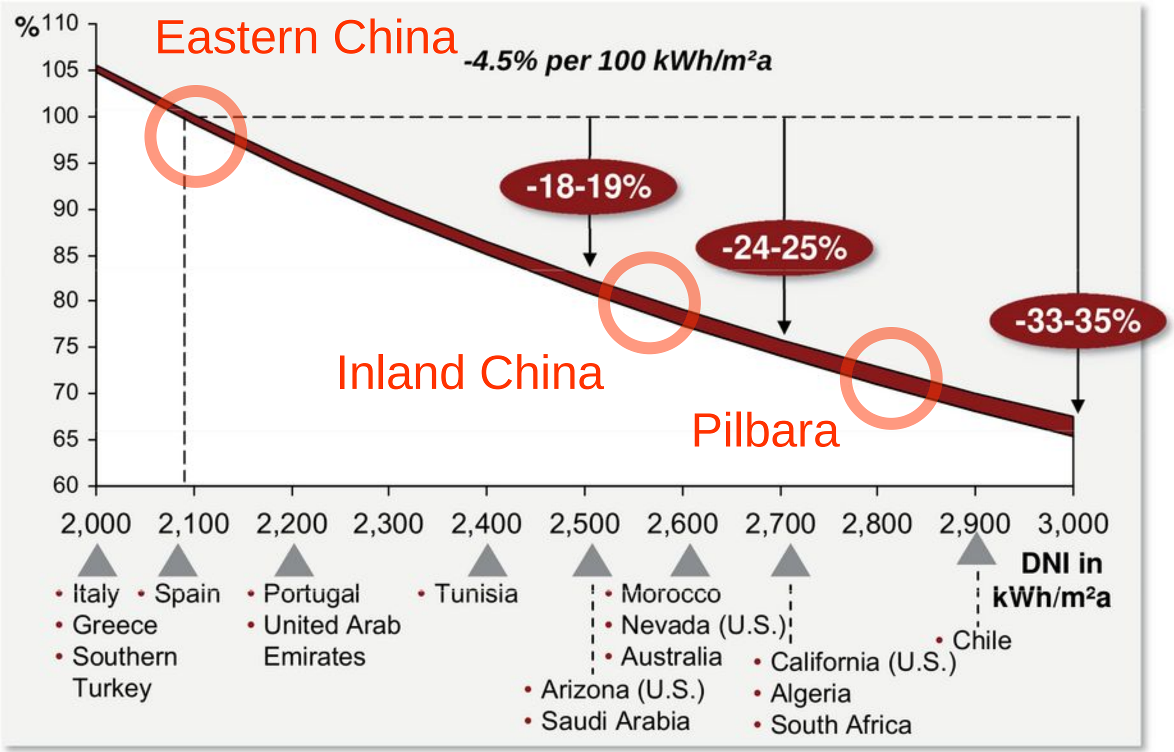


Direct Normal Irradiance (CSP)



Global Horizontal Irradiance (PV)

Cost of solar energy



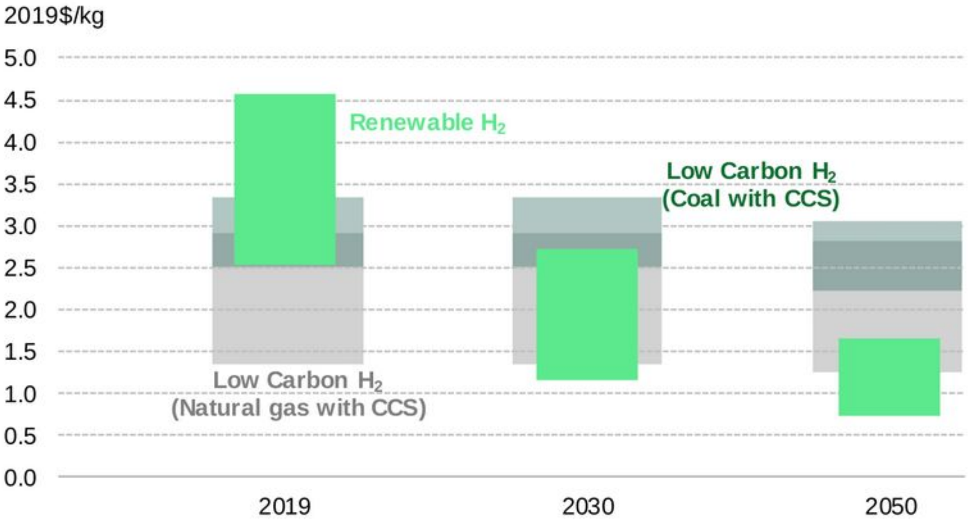
Relative reduction in LCOE (for CSP) as a function of the solar resource. PV trend is very similar.

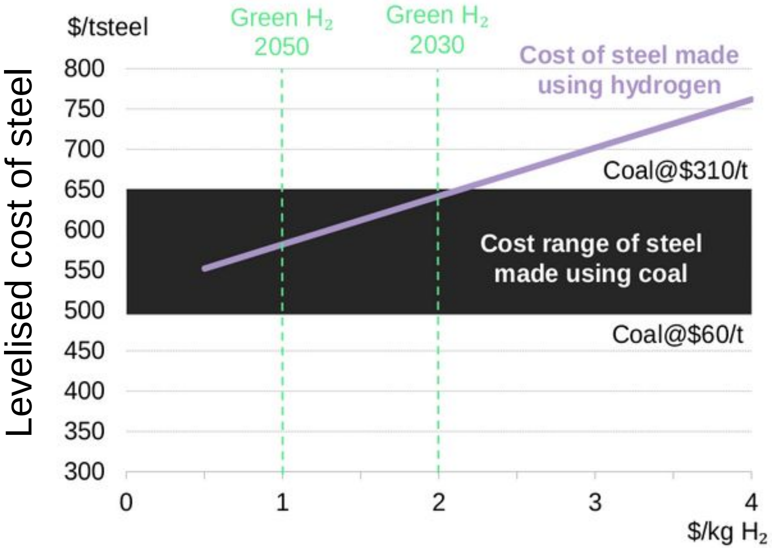
Electricity could be as much as 30% cheaper in the Pilbara compared to Eastern China, excluding storage costs.

AT Kearney 2010 / ESTELA

Cost projections

Big changes!
~90% reductions in cost of photovoltaic solar power and wind power over the last 10 years.
~40% reduction in alkaline electrolysers in Europe the last 5 years; even more in China.
Green hydrogen projected to overtake blue from ~2030.





BloombergNEF, Mar 2020 https://is.gd/EccBCN

Sense of scale

Note emerging large projects Asian Renewable Energy Hub (**AREH**) and **Suncable**.

To process *all* of Australia’s export ore into steel using hydrogen reduction would require **1500 TWh/y**, about 7× our current electricity demand on the NEM.

But ensuring that electricity/hydrogen **supply** could be properly matched to steelmaking **demand** would require large amounts of energy storage.

ANU https://is.gd/8gPWKo

How else could it go?

‘Blue’ hydrogen fron NG + CCS

Nuclear power for H_2 production

Offshore wind

Long-range HVDC

H_2 on ships

Biomass-fired ironmaking

CO_2 electrolysis

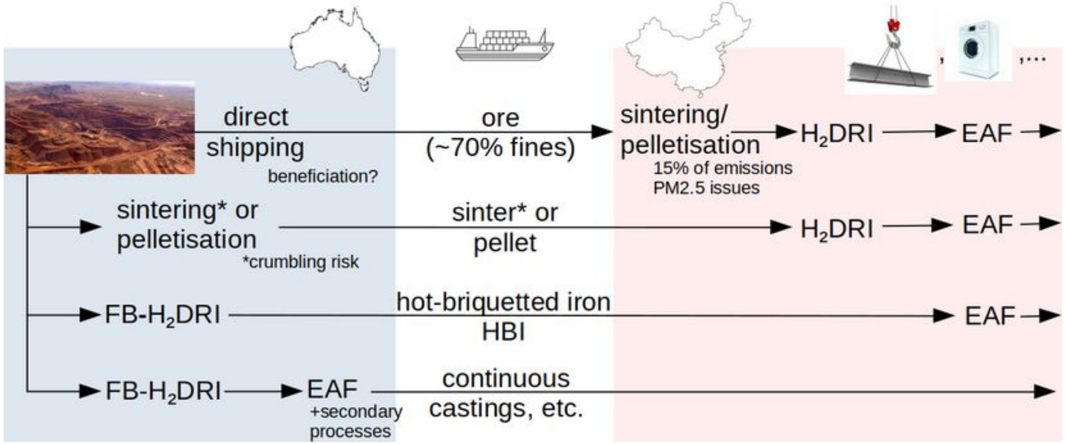
More recycling

Material efficiency

Material substitution

Markets for green steel?

Different configurations: ironmaking can be remote from the steelmaking stage, eg via shipping of hot briquetting iron (HBI), as previously in the Boodarie HBI plant (Port Hedland)



Economic considerations

- Processing **all** our exported iron ore in Australia, and selling steel instead of iron ore could contribute $200B or more to our economy.
- If we transition away from coal, this would more than cover the income hole.

However, we do need to evaluate the economic conditions carefully, in contrast to the scenarios in Japan, Korea, China and India.

Cost breakdown (2015)	Raw Material	Energy & reductant	Labour & overheads	Capital charges	Total cost
Australian breakdown	31%	25%	28%	15%	100%
World cost breakdown	40%	27%	21%	12%	100%

DIIS, 2016 (Sub. #18, *Future of Australia's Steel Industry*) https://is.gd/a2Yl3z

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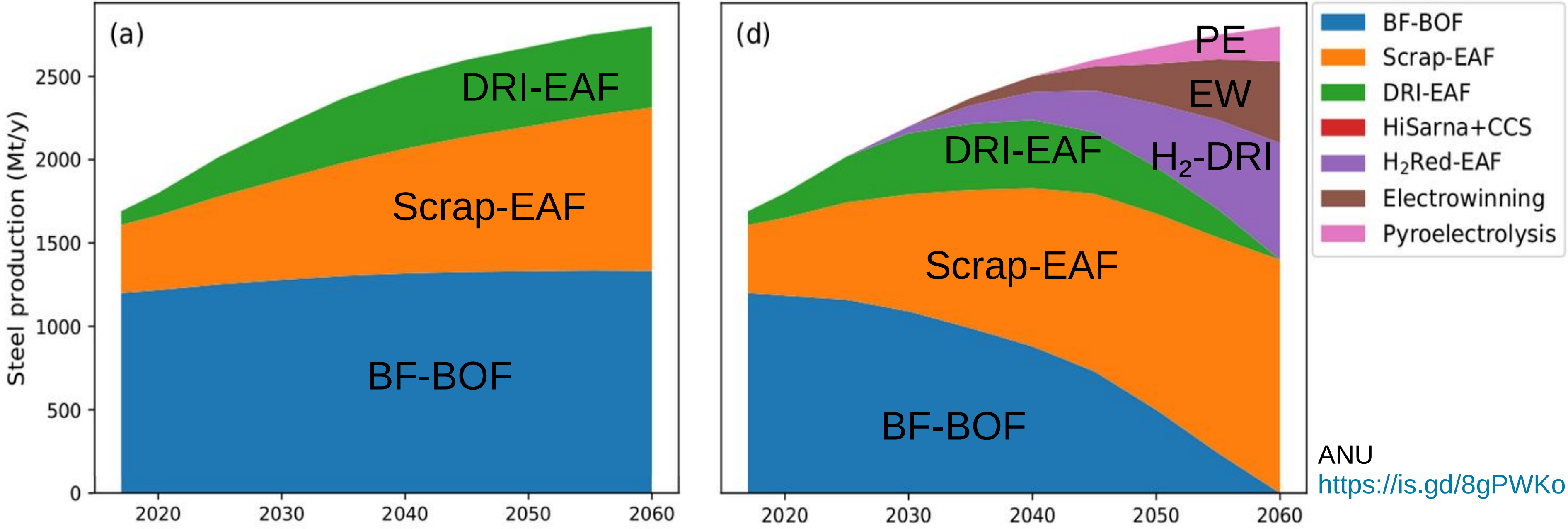
Sectoral decarbonisation

Question: are breakthrough technologies required before the steelmaking industry can align itself with the Paris Agreement target of 1.5°C of warming?

Business as usual

Zero-carbon scenario



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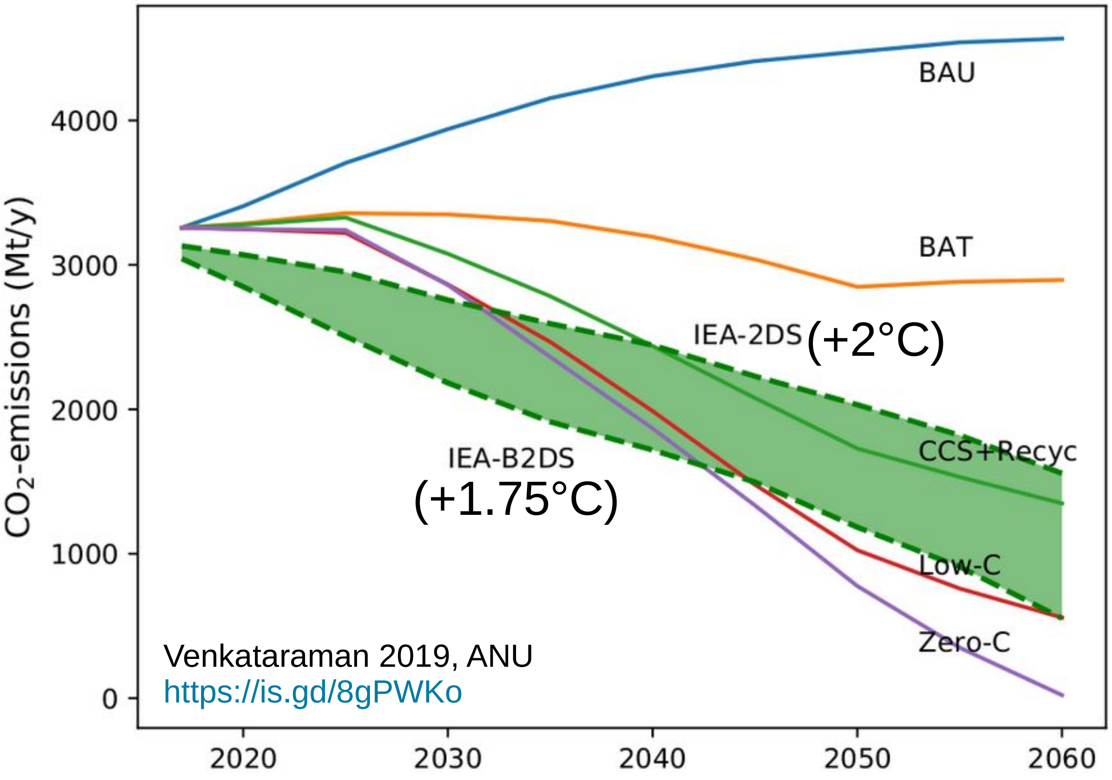
https://is.gd/8gPWKo

Sectoral decarbonisation scenarios



Venkataraman 2019, ANU
https://is.gd/8gPWKo

Our findings to date are that optimistic deployment of CCS and top gas recycling alone would **not** be consistent with 1.5°C of warming, and that breakthrough technologies are **required**.

Only fully decarbonised green steel is consistent with Paris Agreement targets.

Key points here:

- From 2030, H_2 ironmaking is forecast to start becoming competitive. Multiple major commercialisation efforts.
- Under these conditions, the urgency for securing a long-term coking coal supply could be questioned.
- Australian iron ore and steel producers should be (and are) looking to benefit from local advantages from our coincidence of natural and renewable energy resources for a local green steel industry.
- Arguably, insisting on the highest environmental standards in our mining approvals will only help to the accelerate the green steel transition, and increase Australia’s eventual competitiveness in this space.

I would like to acknowledge the invaluable input from
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Rod Dry

Lunar flux mapping at ANU SG4 big dish Photo: Martin Kaufer