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HEAVY INDUSTRY LOW-CARBON TRANSITION COOPERATIVE RESEARCH CENTRE

AUSTRALIAN EXPORTS OF IRON ORE AND GREEN IRON INTO GREEN CHINESE STEEL MAKING VALUE CHAINS

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Australian Government
Department of Industry, Science and Resources

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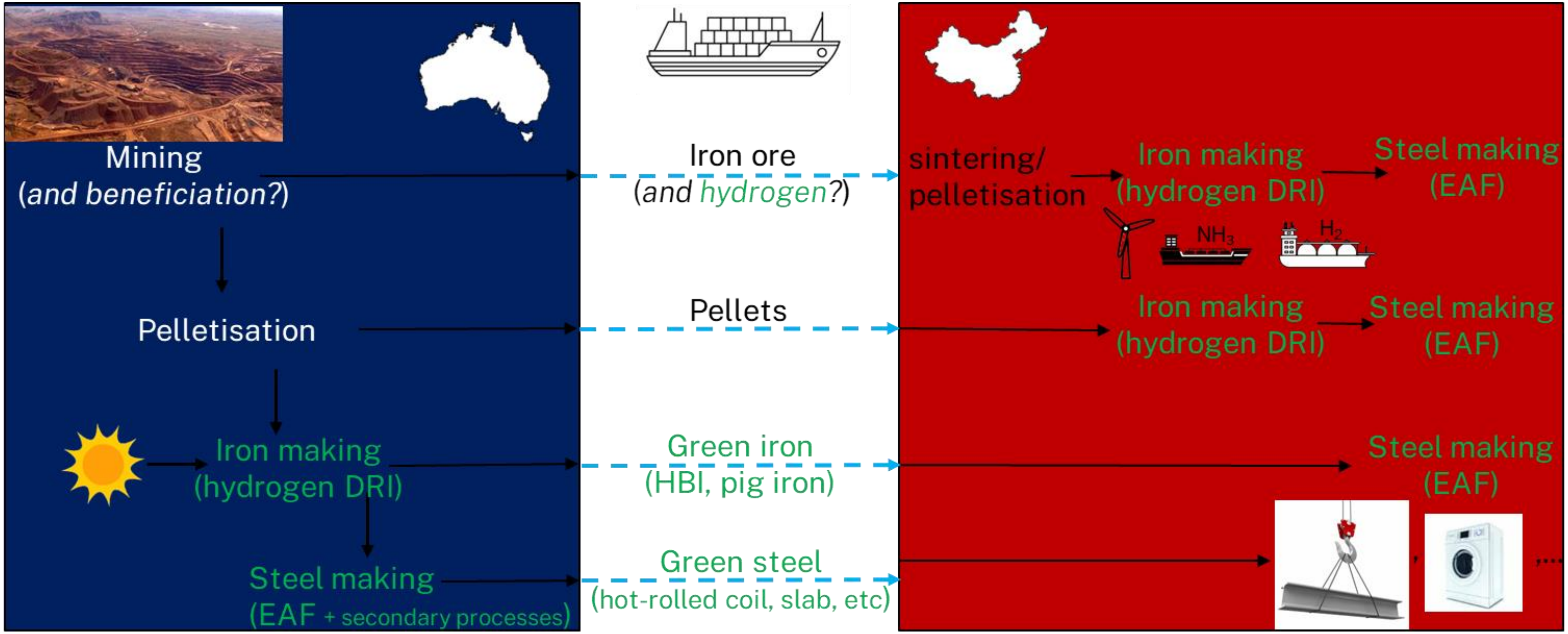
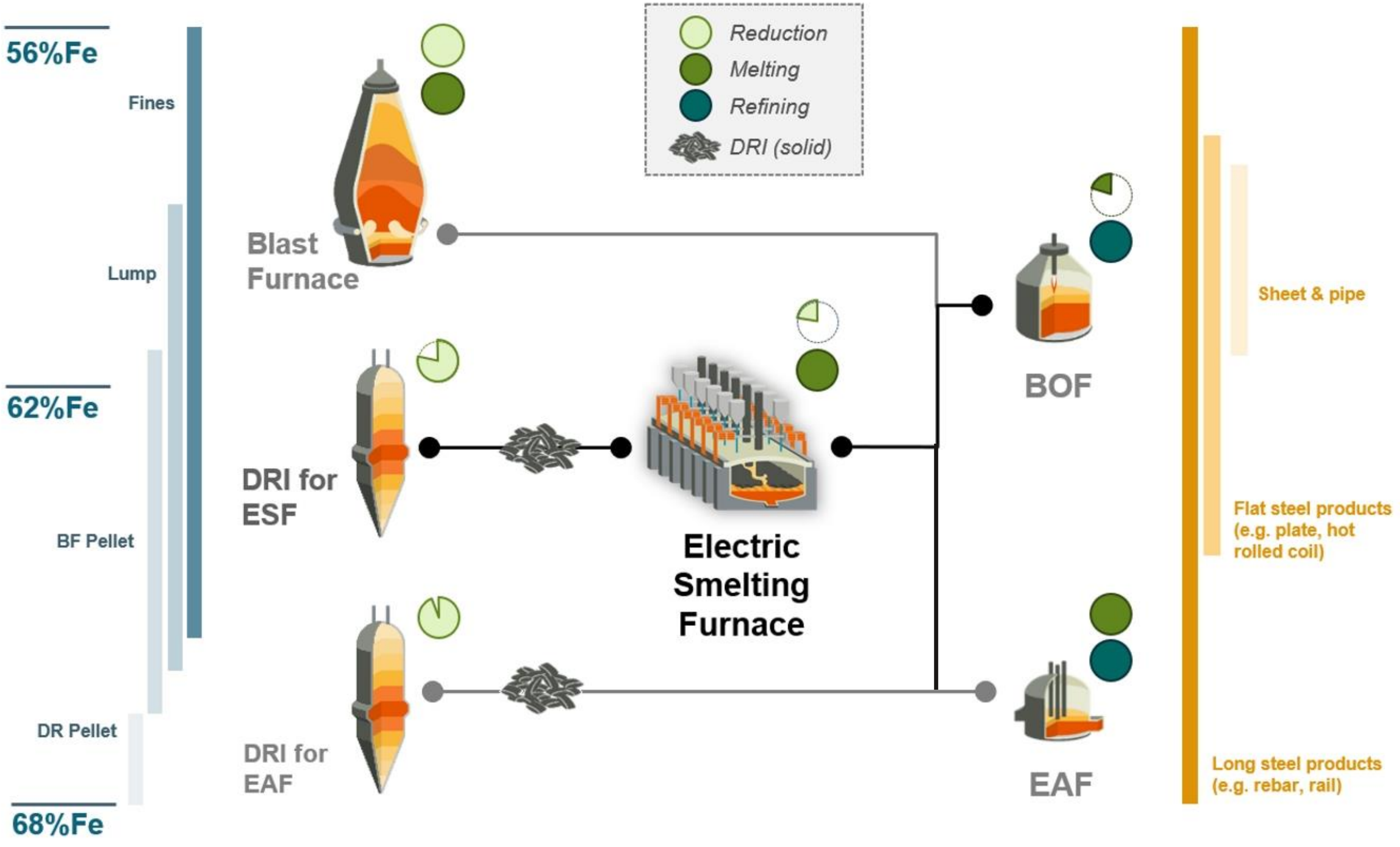
REORGANISING VALUE CHAINS FOR GREEN STEEL?

- **May reduce the cost of transitioning to green steel**
- **Benefits from low-cost Australian renewables**



GREEN STEEL MAKING WITH LOW GRADE ORES



BF-BOF

- Conventional method with coking coal
- Highly suited to Australian ores (Pilbara hematite)

H_2DRI-ESF-BOF or

H_2DRI-ESF-EAF

- Green steel routes also suited for Australian ores

H_2DRI-EAF

- Scrap recycling and green steel from very high-grade ores

MODEL NODES AND PRODUCTION ROUTES CONSIDERED

Route #	Process in Australia, or other ore/iron producer	Process in China	Exported product
1	Mining, beneficiation	Blast furnace – BOF	Iron ore
2	Mining, beneficiation	Grey or blue DRI – EAF	Iron ore
3	Mining, beneficiation, green DRI – HBI	ESF – BOF	HBI
4	Mining, beneficiation, green DRI – HBI	EAF	HBI
5	Mining, beneficiation, green DRI – ESF	ESF – BOF	Pig iron
6	Mining, beneficiation, green DRI – ESF	EAF	Pig iron
7	Mining, beneficiation, green DRI – EAF	None	Steel
8	Mining, beneficiation, green DRI – ESF – BOF	None	Steel

Countries with iron ore mining included

- All countries

Countries with iron and steel processing nodes included

- China (N,S,W), Australia, Brazil, Chile, Egypt, UAE

Countries with demand included

- China

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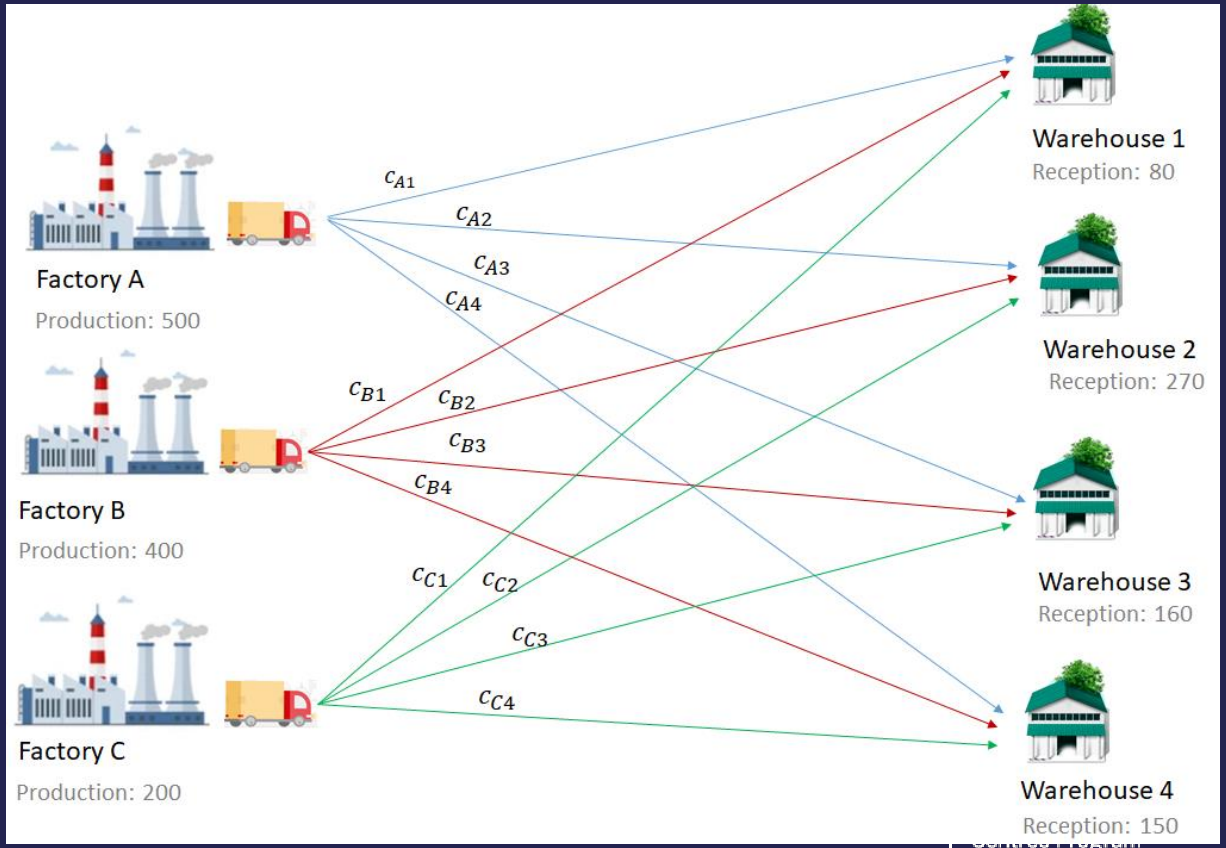
Optimisation model

Least-cost Linear Programing model to identify the least costly way to supply a given supply of Chinese demand for green steel, given:

- Cost of:
  - Mining
  - Transport
  - Processing (beneficiation, DRI, EAF etc)
  - Energy and other inputs
- With constraints on:
  - Production capacity
  - Processing capacity
  - Transport capacity

Supply Transport Demand



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Process modelling

- Mining
- Beneficiation
- Pelletisation
- Sintering
- DRI
- Briquetting (HBI)
- Smelting (ESF)
- EAF
- BF
- BOF

Modelling…

- Power consumption
- Thermal energy cons.
- Reductant cons.
- Flux consumption
- Slag production
- Emissions production

… dependent on

- Iron ore composition: % fe, SiO_2, Al_2O_3, P, S,
- Hematite vs magnetite
- Location or plant specific penalties/bonuses
- Process

Data sources

- CRU iron ore and steel costing data
- ANU techno-economic modelling
- Curtin Uni emissions modelling

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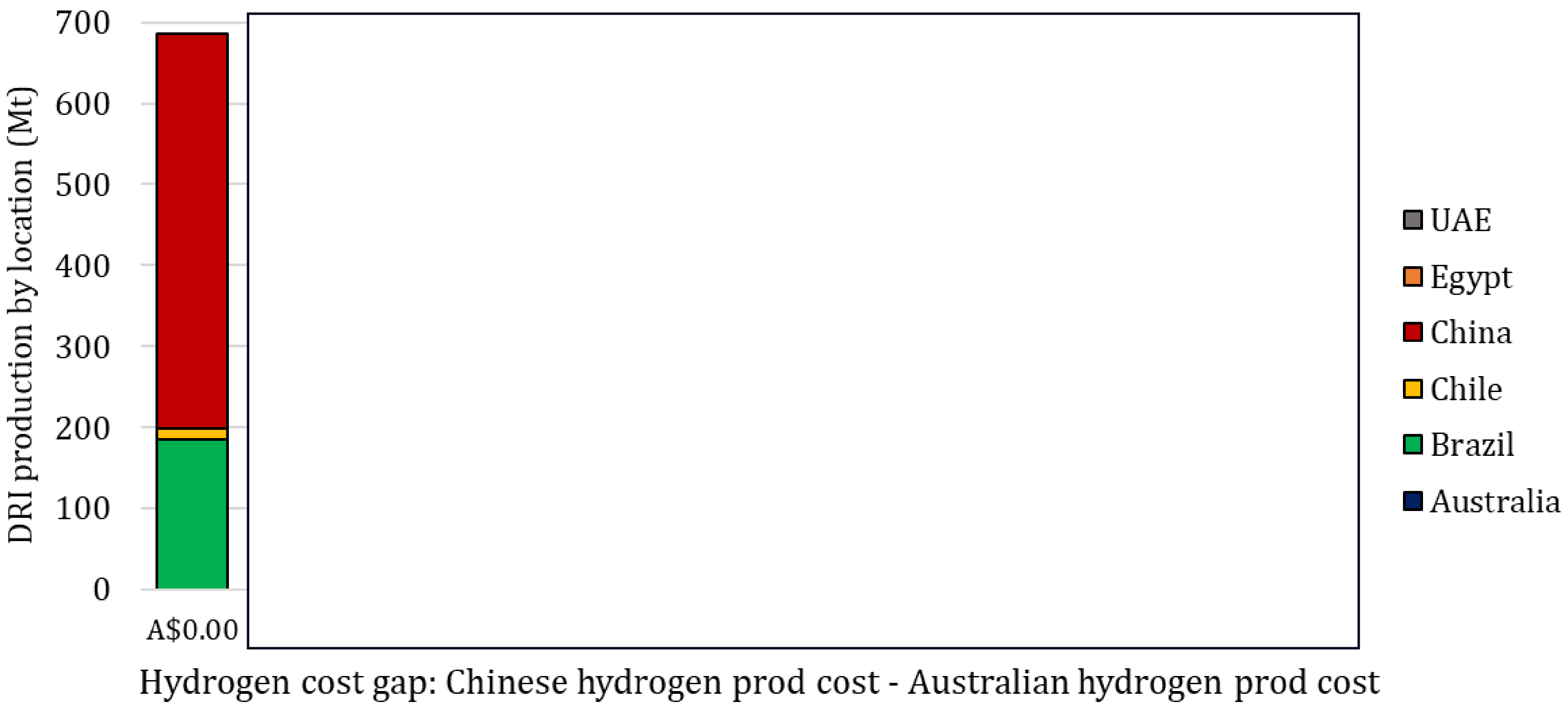
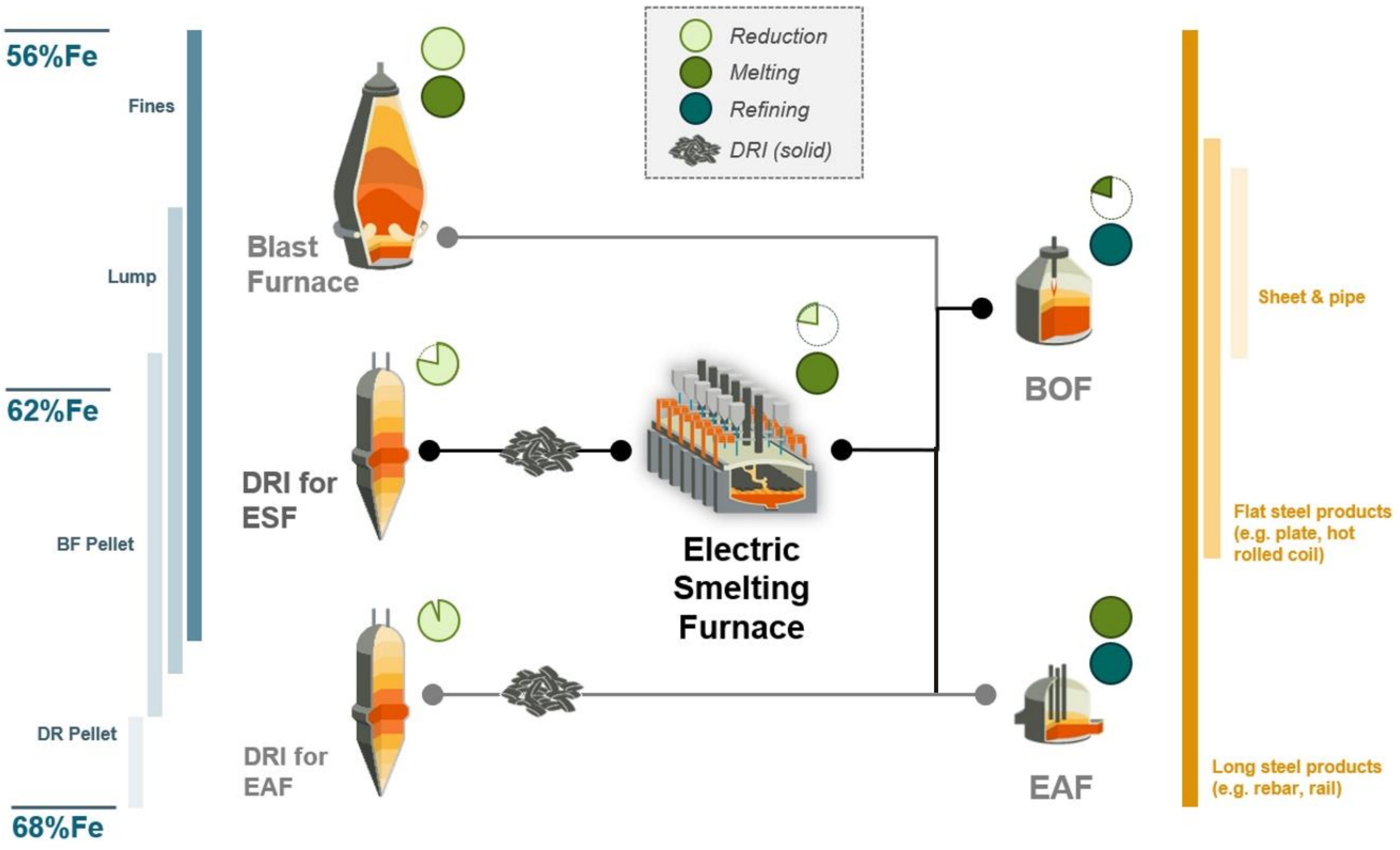
How much cheaper does Australian vs Chinese hydrogen need to be, to make Australian iron production competitive?

For a 2035 Chinese market demanding 100% green steel (and 300 Mt EAF capacity)

- At hydrogen production cost parity, all H_2DRI making occurs in China, Brazil, Chile *(though with Australian ore shipped to China for DRI making)*
- At just a A$0.50 cost gap, our model forecasts 300 Mt of green ironmaking in Australia



GREEN STEEL MAKING WITH LOW GRADE ORES



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H_2DRI-EAF

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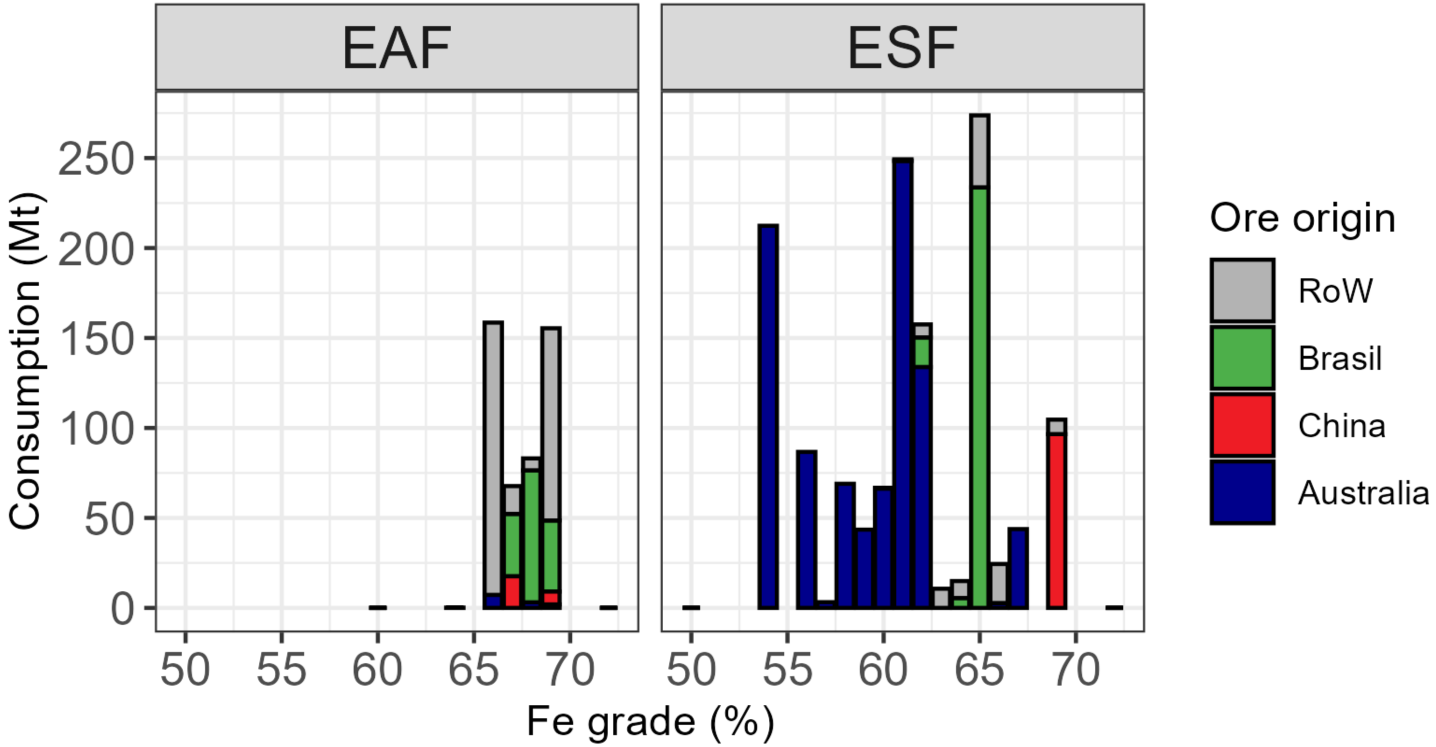
What ores are processed via the Electric Arc Furnace (EAF) versus the Electric Smelter Furnace (ESF) pathway?

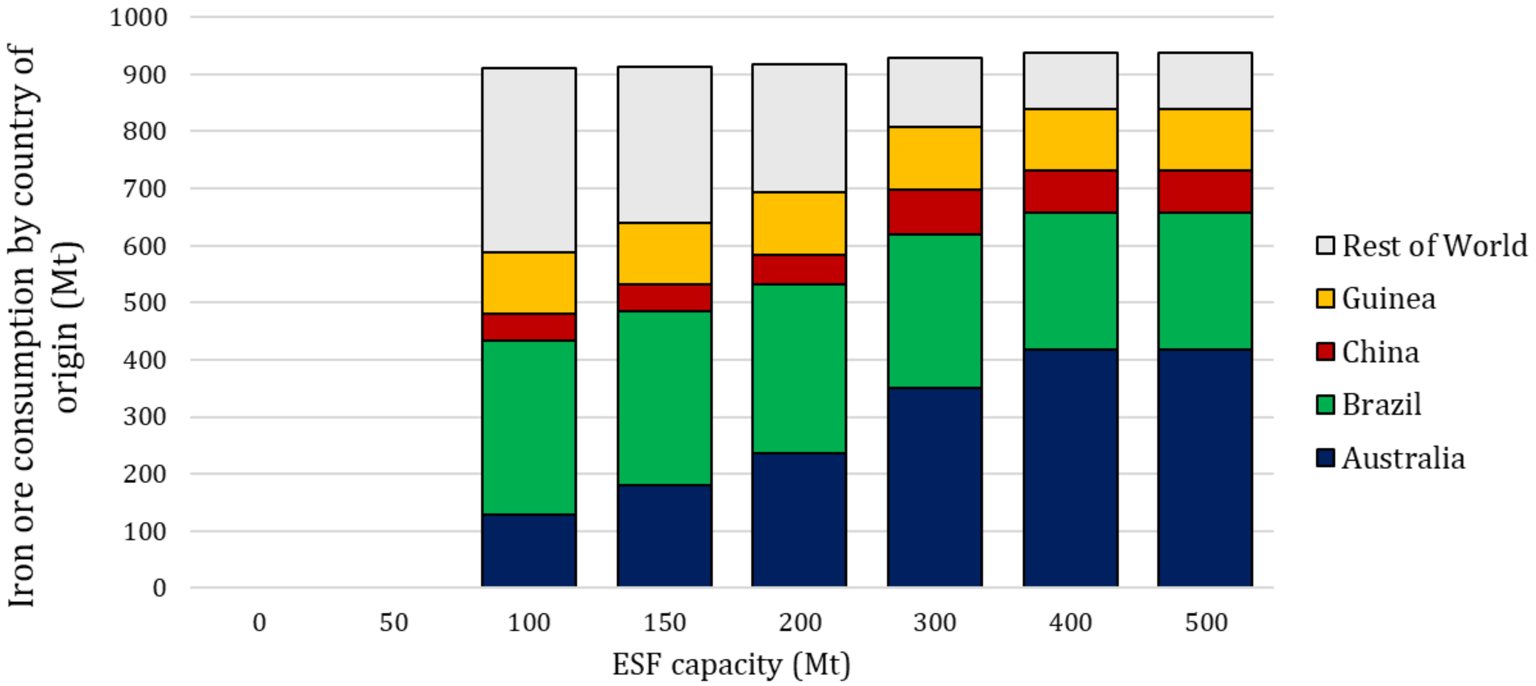
- Only very high Fe grade ores processed via the EAF pathway
- Processing of bulk of Pilbara ores via current EAF pathways prohibitively costly
- High Fe grade requirement requires high levels of beneficiation, with large weight losses. Theoretical limit of pure goethite ores is 62.8% Fe, or 66.4% for a 50/50 hematite/goethite mix



How much ESF capacity needed to ensure Australian ores are used in green steel making?

For a 2035 Chinese market demanding 100% green steel (unlimited EAF capacity)

- Demand for Australian ore scales near linearly with global ESF capacity
- Model does not solve below 100 Mt ESF capacity: not enough high-grade ores for EAF routes
- No further increase beyond 400 Mt of ESF capacity



SUMMARY

Relative hydrogen production cost will drive green iron production location

- Australian hydrogen production cost needs to be about $A0.50 lower then Chinese hydrogen production cost, for cost-competitive green iron production in Australia
- Cheap renewable project development cost, high quality renewables resources, and Government incentives such as a Hydrogen Production Tax Incentive (HPTI) may help create this cost gap

The Electric Smelter Furnace is crucial to Australian success in green steel

- Demand for Australian ore scales near linearly with global ESF capacity
- Processing of Pilbara ores very uncompetitive via the H_2DRI-EAF pathway with current technology. Other HILT CRC projects are exploring novel thermal and leaching beneficiation techniques which may improve this in the future
- Strong incentive for Australian industry and government to promote technological development and roll-out of ESF pathway

FUTURE PLANS

Model development

- Splitting Australia node to Pilbara, Geraldton, Kwinana, SA, Tasmania, with local (hydrogen) production costs estimates
- Expansion to global set of production and demand nodes
- Consider further technological development scenarios incl. potential novel beneficiation technologies

Quantitative policy evaluation

- What level of government incentives such as a Hydrogen Production Tax Incentive (HPTI) are required, or optimal?
- How will CBAMs affect the outlook?
- Choices in Chinese policy:
    - Targets as % emission reduction or as % of demand as green steel?
    - Allowing imports of iron made with natural gas?

Sensitivity analyses: what factors drive Australian export outlook

- Technical and cost development of the Electric Smelter Furnace
- Development of new beneficiation technologies that make Pilbara ores more competitive
- Demand development in different locations: e.g., EU vs China vs rest of Asian market
- What effect from early investment in green iron production capacity in Australia or elsewhere

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