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How to get green steel into the market?

Oliver Lösch, Institute for Resource Efficiency and Energy Strategies (IREES), Karlsruhe, Germany
Valentin Vogl, Marlene Arens, Lund University, Lund, Sweden

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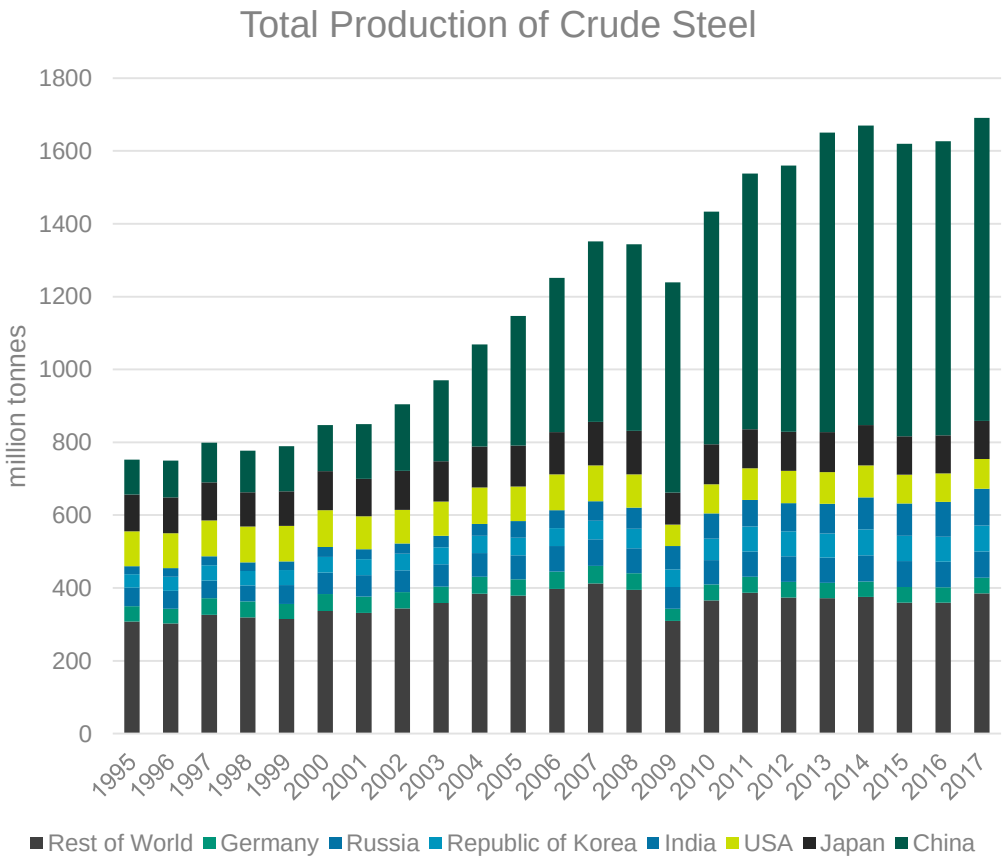
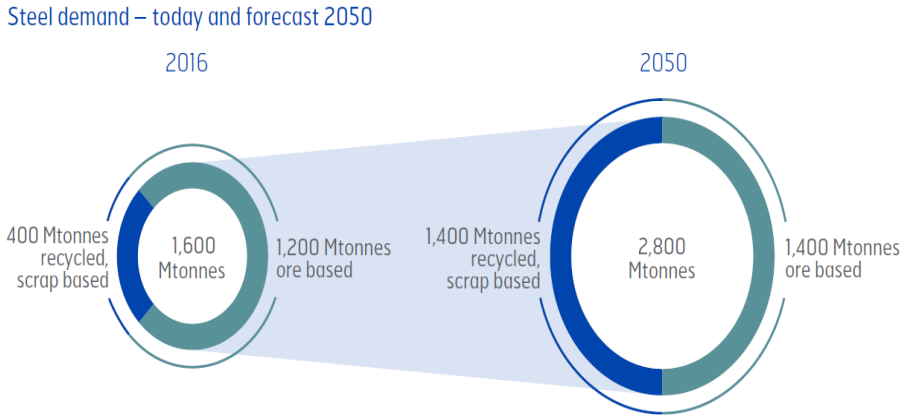
Agenda

1. Introducing the problem – steel and GHG mitigation
2. Abatement strategies
3. Why hydrogen?
4. Economic feasibility of H2/DR/EAF-route as key issue
5. The idea: finding a market and policies for green steel
6. Policy options and policy problems

1. Introduction: Steel and GHG mitigation





Source: World Steel Association

1. Introduction: steel and GHG mitigation

- Paris 2015: carbon neutrality necessary 2050 – 2100 to be in line with 2°C target, 2050 for 1.5°C
- Steel industry very relevant: ~ 7 % of total global GHG → ~ 2.7 GT CO_2 eq.

CO2 eq. Emissions due to steelmaking, globally					
	Production 2007 [Mt]	Production 2017 [Mt]	CO2 eq. 2007 [Gt]	CO2 eq. 2017 [Gt]	Δ CO2 2007 - 2017
BF/BOF	**846**	**1179**	**1.7**	**2.4**	**41.2%**
Scrap/EAF	315	348	0.19	0.21	10.4%
CH4/DR/EAF	48	74	0.05	0.07	55.5%
Sum	**1209**	**1601**	**2**	**2.7**	**38.5%**

2. Abatement strategies

- High efficient BF/BOF process, incremental technology add-ons

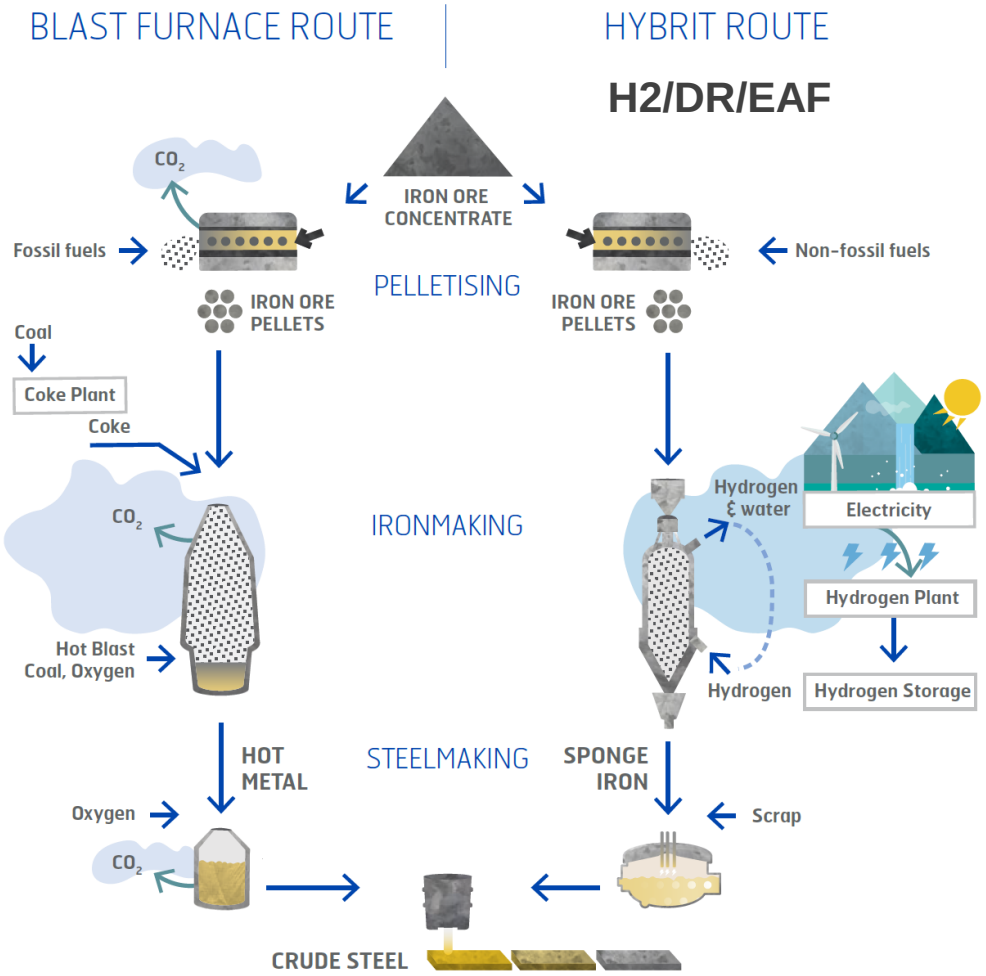
Theoretical minimum: 1.37 t CO2/t_cs

	BF/BOF (Ø EU)	BF/BOF (BAT)	TGR-BF/BOF-CCS	CH4/DR/EAF	H2/DR/EAF	EE/Scrap/EAF	EE/Electrolysis
CO2 eq t /t_cs	1.9	1.5	0.6	0.7	0.05	0.1	0.02
Δ / t_cs		~21%	~68%	~63%	**~97%**	**~95%**	99%
Energy [GJ] /t_cs	18.1		15.6		13.1	2.5	9.3
Δ / t_cs			~ 14 %		~ 27.5 %	~ 86 %	~ 49 %

Source: Indicative numbers for typical steel processing plants taken from recent peer-reviewed literature

- CCU/CCS: *„Keeping (fossil) carbon in the loop or pumping it in the ground“*
- CDA: *„Avoiding the use of carbon“* (Carbon Direct Avoidance)

3. Why hydrogen?



<u>Why is DR/EAF-route advantageous?</u>

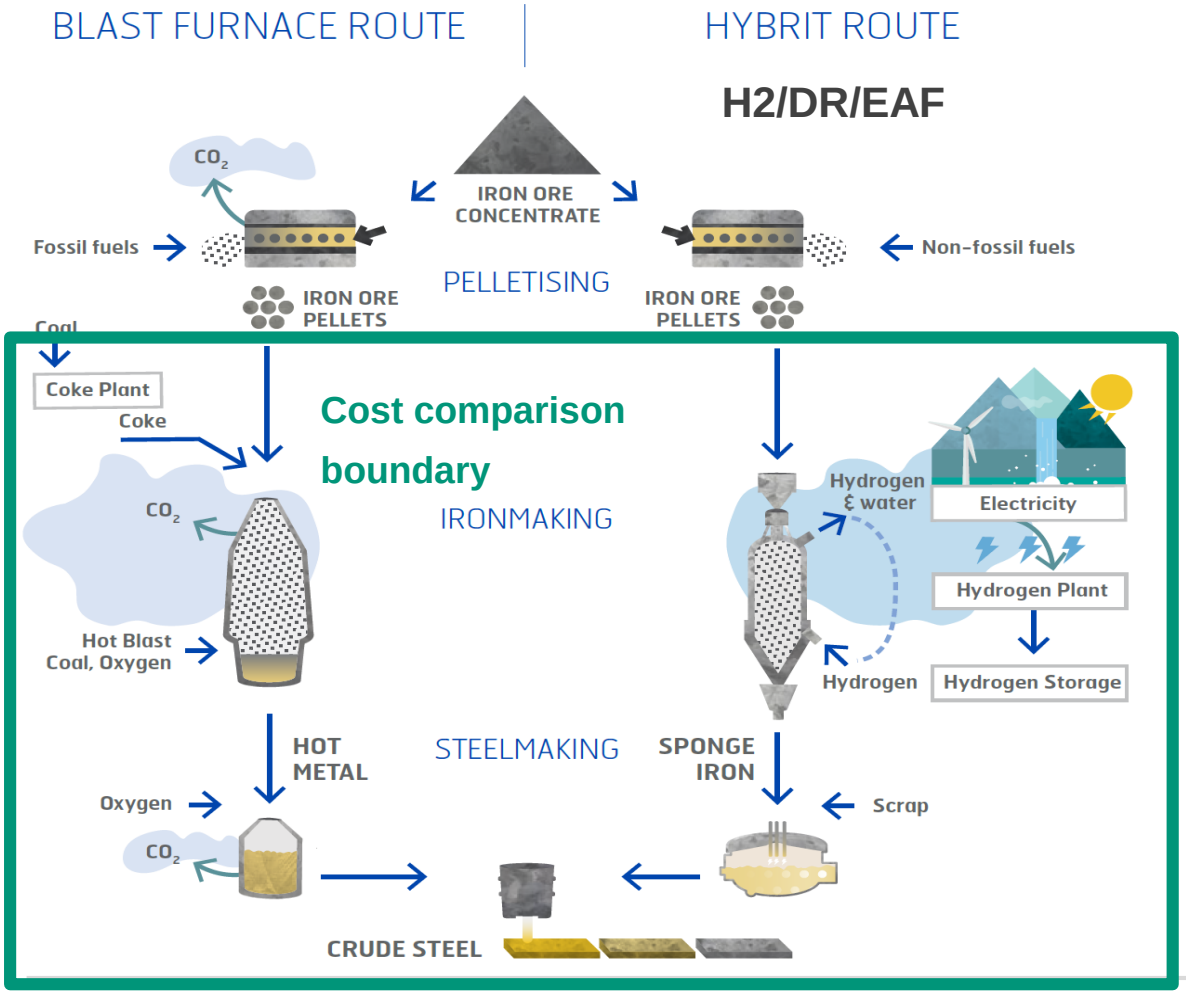
- CDA: No need to keep any C „in the loop“ or C injections
- CH4/DR/EAF mature
- A broad range of flexibility options:
  - Flexible change of reducing agents: CH4, H2, or both
  - Storage options for H2 and DRI

    → adaption to electricity prices

    → potential revenues for system services

4. Economic Feasibility of H2-DRI-EAF as key issue

- Competitiveness is the most prominent issue, not technical feasibility



Assumptions for cost comparison (Vogl et al. 2018):

- CAPEX amortisation time (20y)
- New H2/DR/EAF vs. BF/BOF religning
- 100 % DRI-feed to EAF (no scrap)
- Electrolyser η = 72 %
- RES for EAF

4. Economic Feasibility of H2-DRI-EAF as key issue

→ H2/DR/EAF-process: add ~3.5 MWh_el /t_cs

→ Electricity price is decisive for cost-differentials

el. price	BF/BOF prod. costs	H2/DR/EAF prod. costs	abatement costs	prod. cost increase	prod. cost increase
EUR/MWh	EUR/t_cs	EUR/t_cS	EUR/tCO2	EUR/tLS	%
20	307	361	30	54	18%
40	**307**	**431**	**68**	**123**	**40%**
60	307	500	106	193	63%
80	307	570	144	262	85%
100	307	639	183	332	108%

Source for production costs, abatement costs: Vogl et al. 2018

- Long investment cycles of steel plants and given GHG mitigation targets for 2050:

→ marketability should be achieved before 2030!

- How should it work out with unclear development of CO2-price? → Investment uncertainties…
- Other difficulties add to risk-avoidance / investment-reluctance in Europe: excess capacities, protectionism/tariffs, import pressure …

5. The idea: opening up a market for green steel

What difference would it make for retail prices, if a complete pass-through of cost differentials is assumed? A relevant example to look at - cars:

	Gasoline Current Average	Diesel Current Average	Gasoline Light-weight	Diesel light-weight
Primary steel content (t)	0.52	0.67	0.09	0.15
Absolute cost increase (€) at electricity price of:				
20 €/ MWh	28	36	5	8
40 € / MWh	64	83	11	18
60 € / MWh	100	129	18	29
80 € / MWh	136	176	24	39
100 € / MWh	172	223	31	50
Current retail price (€/car)	20000	27500	21700	29700
Relative cost increase at electricity price of:				
20 €/ MWh	0.1%	0.1%	0.0%	0.0%
40 € / MWh	0.3%	0.3%	0.0%	0.1%
60 € / MWh	0.5%	0.5%	0.1%	0.1%
80 € / MWh	0.7%	0.6%	0.1%	0.1%
100 € / MWh	0.9%	0.8%	0.1%	0.2%

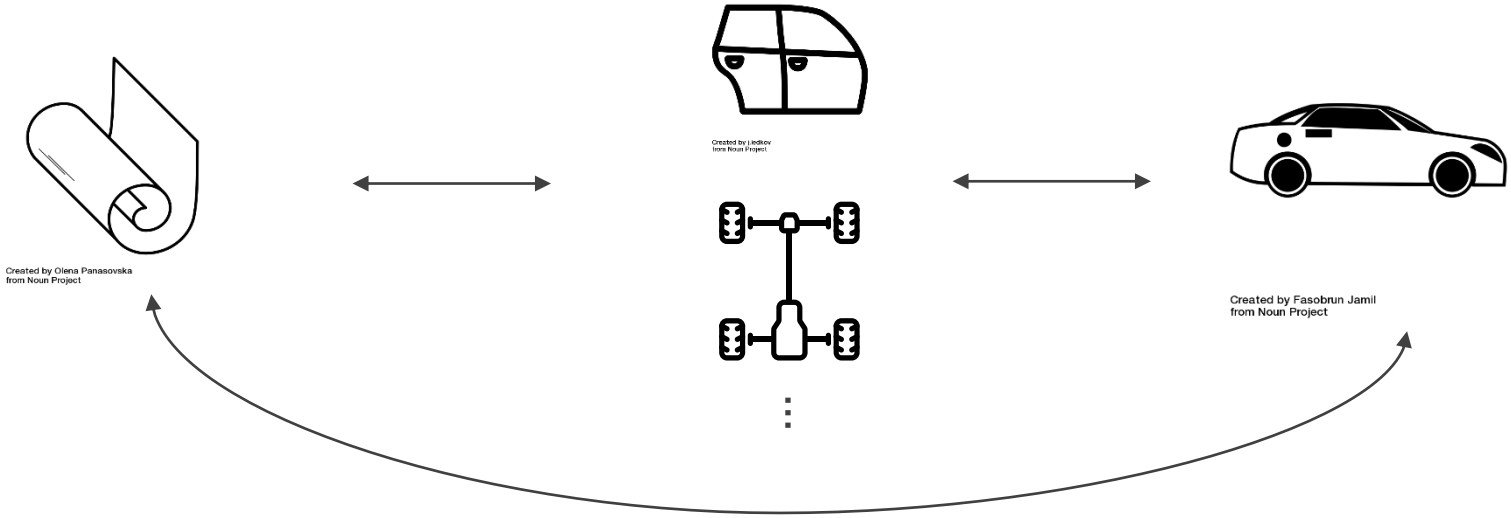
Source: Rootzen et al. 2016, Vogl et al. 2018, own calculations

4. Policy options and obstacles: The EU Emission Trading System (ETS)

- Cap-and-trade for greenhouse gas emissions within the EU (and some others affiliated), established 2005
- The idea: While the total amount of EUA will be reduced over time, the price for the emission certificates will rise, thus enabling investment in more efficient (or low-carbon) technologies.
- The problems:
  - free-allocation to processes and industries that face international competition (“Carbon Leakage”)
  - current surplus-EUAs (addressed now through MSR etc., but is that sufficient?)
  - It’s a market: uncertain future price of EUAs
- Its current impact on steelmaking is low (free-allocation, unclear benchmarks for alternative technologies)
- Current benchmarking methodology can be seen itself as disincentive for breakthrough technologies

→ Incentives for breakthrough-innovations somewhere between unlikely or unclear

4. Policy options – do we need one?



- Simple approach: One steel company wants to sell „green“ steel to one automotive companies, to asure level of demand to allow buildup of industry-sized H2/DR/EAF-plant
- Steel company could offer „green steel“ label etc. as incentive

- Problem: manifold of component suppliers → How to engage them?
- Problem: risk sharing

→ How to adress drop out of sources or sinks? Or significant production fluctuations / structural changes?

4. Policy options - regulation: performance standards / quotas / certificates

„Set a maximum value for embedded specific CO2-Emissions by law („performance standard“), or define a quota for green steel purchases, or implement a certificate-market“

- Idea: forcing manufacturing industries to phase-in „Green Steel“
  → As shown, price-differential pass-through should be not a big problem!

  Problems:

  - competing materials: comparable regulation would be needed for e.g. aluminum;
  - common market: policies would have to be implemented on EU domestic market
  - interference with ETS: quotas / standards /certificates would translate into a de-facto minimum EUA-price, but only for the industry sector

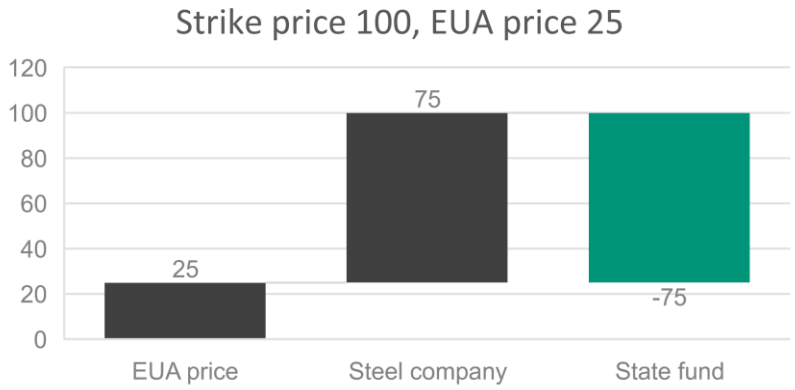
  → what to do with bechmarks and allocation?

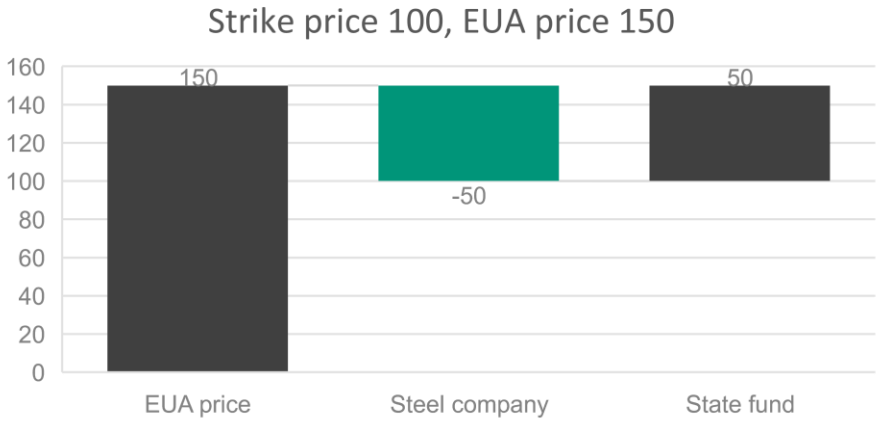
4. Policy options – market oriented state-support: Carbon CfDs

„Make it competitive by guaranteeing carbon-price level according to abatement costs“

- Carbon contracts for difference (CfD)
  - Pre-defined price for CO2 is basis for contract; it defines who pays the difference between actual auctioning price and preset strike-price
  - Predefined contract period – could be aligned with typical depreciation time (~20 y)

As long as CO2-price is lower than green steel abatement costs, contracting could be interesting to enable market entry





4. Policy options – market oriented state-support: Carbon CfDs

→ Seems to be an elegant and feasible idea for adressing economic risk! But…

- Project-based approach: criteria for eligibility?
- Must be compatible with EU state aid regulations → rather unclear
- International competitiveness: smooth transition to level playing field only if rising CO2-prices are globally foreseeable → Otherwise prolonged susidizing possible

- And: in the end, its not really an option for pass-through of costs → *Is it feasible to have contractual risk-sharing agreements further down the value chain?*

… a lot of ongoing questions. Very relevant issues, considering new funding schemes for innovations in basic materials industries (ETS-Innovation Fund, Germany's new decarbonising programme for industry sector)

→ You are very welcome to join the discussion!

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Thank You!

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