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Article

Turning German Steel Production Green: Quantifying Diffusion Scenarios for Hydrogen-Based Steelmaking and Policy Implications

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Online-Appendix zu

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Appendix

Appendix 1: Input material flows

Input Material	Unit	BF-BOF	EAF	H-DR
Coal	t/Steel	0.397 ^a	0.012 ^b	0.012 ^b
Iron ore	t/Steel	1.217 ^a	/	1.504 ^c
Oxygen	t/Steel	0.085 ^a	0.063 ^d	0.100 ^d
Flux	t/Steel	0.220 ^a	0.034 ^e	0.060 ^e
Scrap	t/Steel	0.221 ^a	1.116 ^d	/
Natural gas	GJ/Steel	0.431 ^a	0.150 ^b	0.150 ^b
Electrode	kg/Steel	/	1.500 ^b	1.500 ^b
Hydrogen	t/Steel	/	/	0.051 ^c
Electricity	MWh/Steel	/	0.667 ^c	1.075 ^{c, f}

Sources: a) Remus et al.(2012), pp. 95, 188, 224, 304, 369. b) Demus et al.(2016), p. 565. c) Vogl et al.(2018), pp. 739-741. d) Birat(2020), p. 7. e) Kirschen et al.(2011), p. 6151. f) Toktarova et al.(2021), p. 19.

Appendix 2: Underlying material cost projections

■ Covered by sensitivity analysis in Chapter 4.3.5.

Material Year	Coal ^g €/t	Iron ore ^h €/t	Oxygen ⁱ €/t	Flux ^j €/t	Scrap ^k €/t	Natural gas ^h €/GJ	Electrode ^j €/kg	Electricity ^l €/MWh
2022	97	75	66	100	242	6	4	99
2024	95	71	64	97	237	6	4	99
2026	93	67	63	95	233	6	4	100
2028	91	64	61	92	228	5	4	100
2030	89	60	59	90	224	5	4	100
2032	87	56	57	87	220	5	3	101
2034	85	52	56	84	215	5	3	101
2036	83	48	54	82	211	4	3	101
2038	81	44	52	79	206	4	3	102
2040	79	41	51	77	202	4	3	102
2042	77	37	49	74	197	4	3	103
2044	75	33	47	72	193	3	3	103
2046	73	29	45	69	189	3	3	103
2048	71	25	44	66	184	3	3	104
2050	69	21	42	64	180	2	3	104

All values adjusted to the base year 2020. Sources of price data underlying the extrapolations:

g) (IBISWorld 2022), p. 4. h) (The World Bank 2022). i) (Fischedick et al. 2014), p. 577.

j) (Vogl et al. 2018), pp. 738-739. k) (BDSV 2010-2021). l) (BDEW 2022), p. 31.

Appendix 3: Other cost factors

Cost factor Year	CapEx ^m (BF-BOF, tot.) €/tSteel	CapEx ^m (BF-BOF, an.) €/tSteel	CapEx ^m (EAF, tot.) €/tSteel	CapEx ^m (EAF, an.) €/tSteel	CapEx ^m (H-DR, tot.) €/tSteel	CapEx ^m (H-DR, an.) €/tSteel	Labor ⁿ (BF-BOF, H- DR) €/tSteel	Labor ⁿ (EAF) €/tSteel
2022- 2050	476	38	198	16	446	36	39	19

All values adjusted to base year 2020 and constant due to lack of historical data. Sources:

m) Values from (Woertler et al. 2013), p. 22; methodology of utilizing annual capital costs from

(Vogl et al. 2018), p. 741. n) (Medarac et al. 2020), pp. 10-12.

Appendix 4: Underlying projections of CO₂ prices and hydrogen costs

Year	CO ₂ prices ^o €/tCO ₂ -eq			Hydrogen Costs ^p €/kgH ₂							
				Domestic Production						Import	
				Optimistic			Baseline				
	STEPS	APS	NZE	STEPS	APS	NZE	STEPS	APS	NZE	Opt.	Basel.
2022	31	41	43	4.1	4.3	4.3	4.9	5.0	5.1	3.3	4.1
2024	38	57	60	4.0	4.3	4.3	4.7	5.0	5.0	3.0	3.8
2026	44	73	78	3.9	4.3	4.3	4.5	4.9	5.0	2.9	3.6
2028	51	89	96	3.7	4.2	4.3	4.3	4.8	4.9	2.7	3.4
2030	57	105	114	3.6	4.1	4.2	4.2	4.7	4.8	2.6	3.3
2032	59	114	127	3.4	3.9	4.0	3.9	4.4	4.6	2.5	3.1
2034	60	123	140	3.1	3.6	3.8	3.7	4.2	4.3	2.3	3.0
2036	62	132	153	2.9	3.4	3.5	3.5	4.0	4.1	2.2	2.9
2038	64	140	167	2.7	3.1	3.2	3.3	3.7	3.8	2.1	2.8
2040	66	149	180	2.6	2.8	2.9	3.2	3.4	3.5	2.0	2.7
2042	68	154	188	2.4	2.5	2.6	3.0	3.1	3.2	1.9	2.6
2044	71	160	196	2.2	2.2	2.3	2.8	2.8	2.9	1.8	2.5
2046	74	165	203	2.0	2.0	2.0	2.6	2.6	2.6	1.8	2.4
2048	76	170	211	1.9	1.9	1.9	2.5	2.5	2.5	1.6	2.3
2050	79	175	219	1.9	1.9	1.9	2.5	2.5	2.5	1.6	2.3

All values adjusted to the base year 2020. Sources: o) (IEA 2021), p. 329. p) (Brändle et al. 2020); own calculations as explained in Chapter 4.1.

Bibliography

BDEW (2022): BDEW-Strompreisanalyse Januar 2022, Bundesverband der Energie- und Wasserwirtschaft e.V., URL:

https://www.bdew.de/media/documents/220124_BDEW-

[Strompreisanalyse_Januar_2022_24.01.2022_final.pdf](https://www.bdew.de/media/documents/220124_BDEW-Strompreisanalyse_Januar_2022_24.01.2022_final.pdf), 29/04/2022, 10.45 p.m.

BDSV (2010-2021): Durchschnittliche Lagerverkaufspreise für bestimmte Stahlschrottsorten in Deutschland 2010-2021 bundesweit, Bundesvereinigung Deutscher Stahlrecycling- und Entsorgungsunternehmen, URL: <https://www.bdsv.org/unser-service/markt-preise/>, 29/04/2022, 10.40 p.m.

IBISWorld (2022): World price of coking coal, Business environment report A5215.

Remus, Rainer / Aguado-Monsonet, Miguel A. / Roudier, Serge / Delgado Sancho, Luis. (2012): Best available techniques (BAT) reference document for iron and steel production, Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control), EUR 25521 EN, Joint Research Centre of the European Commission, Luxembourg 2012.

The World Bank (2022): World Bank commodity price data (The Pink Sheet), Annual Prices March 2022, URL: <https://www.worldbank.org/en/research/commodity-markets>, 20/03/2022, 9.50 p.m.