Supplementary Information

Table S1. Complete reference summary for all 29 included studies, listing specific data provided, study methodology, geographic scope, and data collection period.

Ref.	Authors & Year	Specific Data Provided	Study Methodology	Geographic Scope	Data Collection Period
1	Ishaq et al. (2022)	SMR CO_2 emissions 9–10 kg/kg H_2; H_2 utilisation overview	Narrative review	Global	2015–2022
2	Nikolaidis & Poullikkas (2017)	SMR LCOH $1–2/kg H_2; biomass $2–3/kg H_2; cost component proportions	Comparative techno-economic review	Global	2010–2016
3	Younas et al. (2022)	Regional energy consumption; capacity factors; geographic comparisons	Narrative overview	Global	2015–2022
4	Kayfeci et al. (2019)	Technical principles of H_2 production pathways	Book chapter review	Global	Pre-2019
5	Aasberg-Petersen et al. (2011)	SMR reaction chemistry; $CH_4 + H_2O \rightarrow CO + 3H_2$; catalytic processes	Experimental and catalysis review	Industrial (global)	Pre-2011
6	Bhaskar et al. (2023)	CCS: 90% capture efficiency; +20–30% cost; blue	Techno-economic analysis	Norway / Europe	2020–2023

		hydrogen techno-economics			
7	Carmo et al. (2013)	PEM efficiency 70–85%; membrane thickness; water purity; lifecycle emissions <0.5 kg CO_2/kg H_2	Comprehensive review	Global	Pre-2013
8	IRENA (2022)	Electrolyser CAPEX decline; LCOH projections; renewable electricity prices	Institutional modelling report	Global	2015–2022
9	Li et al. (2025)	Biomass gasification syngas production; carbon neutrality; gasification stages	Review	Global	2015–2024
10	Dash et al. (2023)	Distributed electrolysis advantages; transport energy penalties	Narrative review	Global	2015–2022
11	IEA (2022)	Regional H_2 strategy; trade infrastructure; PEC and biological H_2 TRL assessment	Institutional report	Global	2020–2022
12	IEA (2023)	Carbon pricing scenarios; LCOH convergence; Chile electrolysis targets	Institutional report	Global	2021–2023

13	Bloomberg NEF (2023)	LCOH breakdown; environmental externality monetisation; 20-year analysis	Industry modelling report	Global	2020–2023
14	Basu (2010)	Gasification stages: drying, pyrolysis, oxidation, reduction	Textbook	Global	Pre-2010
15	Rostrup-Nielsen & Sehested (2002)	Ni catalyst sulfur poisoning; 40% activity loss above 0.1 ppm S	Experimental catalysis	Laboratory	Pre-2002
16	Xu & Froment (1989)	SMR kinetics; 72% efficiency at 850°C; steam-to-carbon ratio 2.5–3.0	Experimental kinetics	Laboratory	Pre-1989
17	Grigoriev et al. (2006)	PEM overpotential losses; efficiency drop 82%→68% above 1.5 A/cm²	Experimental electrochemistry	Laboratory	Pre-2006
18	Ito et al. (2011)	AEL current density 200–400 mA/cm²; current collector characterisation	Experimental	Laboratory	Pre-2011
19	Rapagnà et al. (2000)	Syngas H_2: 45–50 vol% low-lignin vs 30–35 vol% high-lignin; steam ratio 0.6–1.0	Experimental gasification	Laboratory	Pre-2000
20	Ptasinski et al. (2007)	Moisture >30% drops efficiency 68%→42%; 2.5	Exergy analysis	Lab / modelling	Pre-2007

		MJ/kg per 10% moisture increase			
21	Hauch et al. (2020)	SOE theoretical efficiency >90%; material degradation	Review	Global / Lab	2015–2020
22	Pina et al. (2021)	HT-PEM 120–180°C; polybenzimidazole membranes; 90% efficiency	Book chapter	Global	Pre-2021
23	Voutchkov (2018)	Desalination energy 3–5 kWh/m³; feedstock transport costs; 9 L water/kg H_2	Review	Global	2010–2018
24	Gude (2016)	Water constraints for electrolysis; desalination sustainability	Review	Global	Pre-2016
25	Mohammadi & Mehrpooya (2018)	PEM efficiency; electrolyser–renewable coupling	Comprehensive review	Global	2010–2018
26	Tabbi et al. (2016)	Solar PV capacity factors 15–35%; solar electrolysis 55–65 kWh/kg H_2	Numerical simulation	Global	Pre-2016
27	Sánchez et al. (2020)	AEL efficiency 60–70%; 15 kW experimental validation; SMR >50% global H_2	Experimental validation	Spain / Europe	2018–2020

28	Guandalini et al. (2015)	Wind capacity factors; hybrid CF 60–80%; 50–56 kWh/kg H_2	Energy and economic modelling	Europe	Pre-2015
29	Guerra et al. (2021)	Electrolytic H_2 cost competitiveness; LCOH sensitivity; 2030 projections	Techno-economic analysis	USA / Global	2018–2021