Global Hydrogen Review 2023: Assumptions Annex

International Energy Agency

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Global Hydrogen Review 2023: Assumptions annex

This annex collects the various assumptions that underpin the analyses throughout the *Global Hydrogen Review 2023.* For technologies, global averages are presented. However, several analyses in the report present regional examples, for which costs will vary with material and labour inputs and differ from the global average. These input parameters reflect choices made by the IEA on the basis of different sources of information consulted.

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Renewable electricity cost and full load hours

Solar PV

	LCOE (USD/MWh)		Full load hours (h)
Region	2022	NZE 2030	
Australia	41	27	2 330
Chile	32	21	3 060
China	23	15	2 550
European Union	36	24	2 170
India	21	13	2 550
Japan	119	80	1 330
Middle East	35	22	2 890
North Africa	42	26	2 680
United States	41	27	2 490

Offshore wind

	LCOE (USD/MWh)		Full load hours (h)
Region	2022	NZE 2030	
Australia	60	38	4 990
Chile	90	60	5 890
China	72	45	4 120
European Union	51	30	4 980
India	71	44	4 100
Japan	127	76	4 530
Middle East	114	72	4 050
North Africa	108	68	4 160
United States	89	53	4 940

Onshore wind

	LCOE (USD/MWh)		Full load hours (h)
Region	2022	NZE 2030	
Australia	37	34	3 660
Chile	41	38	4 220
China	40	37	3 130
European Union	38	36	3 690
India	35	30	3 090
Japan	102	94	3 290
Middle East	63	57	3 280
North Africa	59	54	3 240
United States	34	31	4 420

Notes: LCOE = levelised cost of electricity; NZE = Net Zero Emissions by 2050 Scenario. Renewable electricity generation costs and full load hours for good resource conditions in a region or country.

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CO_2 prices and costs

CO_2 prices

Region	CO_2 price (USD/tCO_2)	
	2022	NZE 2030
Advanced economies	4-50	130-140
Selected emerging market and developing economies*	0-10	90
Other emerging market and developing economies	0	15-25

* Includes Brazil, China, India, Indonesia and South Africa.

CO_2 transport and storage cost for CCUS

Region	(USD/tCO_2)	
	2022	NZE 2030
United States	14	12
Middle East	14	12
Europe	51	33
China	15	12
Rest of the world	24	20

Notes: CCUS = carbon capture, utilisation and storage; NZE = Net Zero Emissions by 2050 Scenario.

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Production pathways

Hydrogen

Technology	Parameter	Units	2022	NZE 2030
Water electrolysis	CAPEX* (global average)	**USD/kW$_e$**	1 640	610
	CAPEX* (China)	**USD/kW$_e$**	1 070	420
	Efficiency (LHV)	**%**	65%	69%
	Annual OPEX	**% of CAPEX**	3%	3%
	Stack lifetime (operating hours)**	**hours**	50 000	50 000
Natural gas reforming	CAPEX	**USD/kW$_{H2}$**	730	720
	Efficiency (LHV)	**%**	76%	76%
	Annual OPEX	**% of CAPEX**	5%	5%
Natural gas reforming w/CCUS	CAPEX	**USD/kW$_{H2}$**	1 440	1 420
	Efficiency (LHV)	**%**	69%	69%
	Annual OPEX	**% of CAPEX**	4%	4%
	CO_2 capture rate	**%**	95%	95%
Coal gasification	CAPEX ***	**USD/kW$_{h2}$**	2 680	2 640
	Efficiency (LHV)	**%**	60%	60%
	Annual OPEX	**% of CAPEX**	5%	5%
Coal gasification w/CCUS	CAPEX ***	**USD/kW$_{H2}$**	2 790	2 750
	Efficiency (LHV)	**%**	58%	58%
	Annual OPEX	**% of CAPEX**	5%	5%
	CO_2 capture rate	**%**	95%	95%

* CAPEX includes the electrolyser system, electric equipment, gas treatment, plant balancing, and engineering, procurement and construction (EPC).

** Stack lifetime can reach up to 95 000 h. The selected value (50 000 h) comes from the IEA's analysis of the optimum economic lifetime, considering degradation issues.

*** For China, CAPEX is assumed to be 50% of the world average for coal gasification and 52% for coal gasification with CCUS.

Notes: LHV = Lower heating value; NZE = Net Zero Emissions by 2050 Scenario. All CAPEX refers to the installed cost of the technology. 25-year lifetime and a 95% availability factor assumed for hydrogen production from natural gas, 25-year lifetime and 90% availability factor are assumed for the production of hydrogen from coal. Availability factors for electrolysis are based on the full load hours of electricity shown in the previous section. For water electrolysis, water costs and possible revenues from oxygen sales have not been considered in the cost analysis.

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Hydrogen-based fuels

Haber – Bosch (Ammonia)

Parameter	Units	2022	NZE 2030
CAPEX (including air separation unit)	**USD/(tNH_3/y)**	770	770
Annual OPEX	**% of CAPEX**	3%	3%
Electricity consumption	**GJ/t_{NH3}**	4	4

Fischer-Tropsch (synthetic liquid fuels)

Parameter	Units	2022	NZE 2030
CAPEX	**USD/kW_{liquid}**	2 220	1 770
Efficiency (LHV)	**%**	57%	57%
Annual OPEX	**% of CAPEX**	5%	5%
Variable O&M	**USD/MWh_{prod}**	5.6	4.7
Lifetime	**years**	30	30
Electricity consumption	**GJ/$GJ_{product}$**	0.018	0.018

Notes: The efficiency refers to the final transport fuels, from the energy content of hydrogen used in the FT synthesis. Assumed cost of feedstock: biogenic CO_2 USD 30/tCO_2, DAC CO_2 USD 600-1 000/tCO_2 (today), USD 200-700/tCO_2 (2030).

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Hydrogen transport

Hydrogen onshore pipelines

Parameter	Units	Small	Medium	Large
Lifetime - pipelines	**years**	42	42	42
Lifetime - compressor	**years**	24	24	24
Operation conditions	**% of design capacity**	75%	75%	75%
Diameter	**inch**	20	36	48
Design Capacity	**GW H_2, LHV**	0.9	3.6	12.7
Inlet pressure	**bar**	30	30	40
Outlet pressure	**bar**	50	50	80
Utilisation	**%**	57%	57%	57%
Compression power	**MW_e/1 000 km**	6	40	183
CAPEX - new pipeline	**MUSD/km**	1.8	2.6	3.2
CAPEX - repurposed pipeline	**MUSD/km**	0.3	0.5	0.6
CAPEX - compressor	**MUSD/MW_e**	4.0	4.0	4.0

Note: MUSD = million USD.

Seaborne transport

Tankers

Parameter	Units	Liquefied hydrogen	LOHC	Ammonia
Capacity	**$t_{carrier}$/tanker**	10 200	34 700	51 800
CAPEX	**MUSD/tanker**	410	45	70
Speed	**km/h**	30	28	32
Boil-off rate[1]	**%/day**	0.60%	0.00%	0.02%
Flash rate[2]	**%**	1.00%	0.00%	0.02%
Fuel consumption[3]	**MJ/km/tanker**	-	1 770	2 650

[1] The boil-off gas is the gas that spontaneously evaporates from liquefied gas due to the extremely low temperatures.
[2] The flash rate is the rate of loss that occurs upon each loading/unloading of liquefied gas.
[3] Ship carrying liquefied hydrogen uses carrier gas for propulsion, so the fuel for the ship would not incur an additional energy consumption.
Note: MUSD = million USD.

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Import and export terminals: storage tanks

Terminal	Parameter	Units	Liquefied hydrogen	LOHC	Ammonia
Import	Capacity	**$t_{carrier}$/tank**	12 800	3 300	36 700
	CAPEX	**MUSD/tank**	1 270	85	115
	OPEX	**USD/year as a % of CAPEX**	3%	3%	3%
	Electricity consumption	**kWh/kgH_2**	0.190	0.013	0.003
	Boil-off rate	**%/day**	0.07%	0.01%	0.01%
Export	Capacity	**$t_{carrier}$/tank**	12 300	3 300	36 700
	CAPEX	**MUSD/tank**	1 160	85	115
	OPEX	**USD/year as a % of CAPEX**	3%	3%	3%
	Electricity consumption	**kWh/kgH_2**	0.200	0.013	0.001
	Boil-off rate	**%/day**	0.07%	0.01%	0.01%

Note: MUSD = million USD.

Liquefied hydrogen

Technology	Parameter	Units	Value
Liquefaction	CAPEX	**USD/t H_2/day**	NA
	OPEX	**USD/t H_2/day**	NA
	Electricity consumption	**kWh/kg H_2**	6
Regasification	CAPEX	**USD/t H_2/day**	20
	OPEX	**USD/t H_2/day**	1
	Electricity consumption	**kWh/kg H_2**	0.06

Note: NA = not available due to confidentiality.

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Liquid Organic Hydrogen Carrier (LOHC)

Technology	Parameter	Units	Value
Conversion[1] to LOHC	CAPEX	**USD/t H_2/year**	790
	OPEX	**USD/year as a % of CAPEX**	3%
	Electricity consumption	**kWh/kg H_2**	0.004
Reconversion[2] to H_2	CAPEX	**USD/t H_2/year**	3 000
	OPEX	**USD/year as a % of CAPEX**	3%
	Electricity consumption	**kWh/kg H_2**	1.50
	Fuel consumption	**kWh/kg H_2**	13.6
	Dehydrogenation rate	**%**	98%
	PSA hydrogen recovery rate	**%**	99%
	LOHC loss	**%/cycle**	0.80%

[1] Conversion: LOHC = Toluene +H_2 → Methylcyclohexane (MCH).
[2] Reconversion: LOHC = MCH → Toluene + H_2.
Notes: PSA = Pressure swing adsorption. System lifetime assumed to be 30 years, unless stated otherwise.

Ammonia cracking

Technology	Parameter	Units	Value
Ammonia cracking	CAPEX	**USD/t H_2/year**	3 050
	OPEX	**USD/year as a % of CAPEX**	3%
	Electricity consumption	**kWh/kg H_2**	1.50
	Fuel consumption	**kWh/kg H_2**	9.7
	Dehydrogenation rate	**%**	99%
	PSA hydrogen recovery rate	**%**	99%

Notes: PSA = Pressure swing adsorption. Data for ammonia conversion are included in the table on ammonia production above.

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