Electrolyzer Supply Chains

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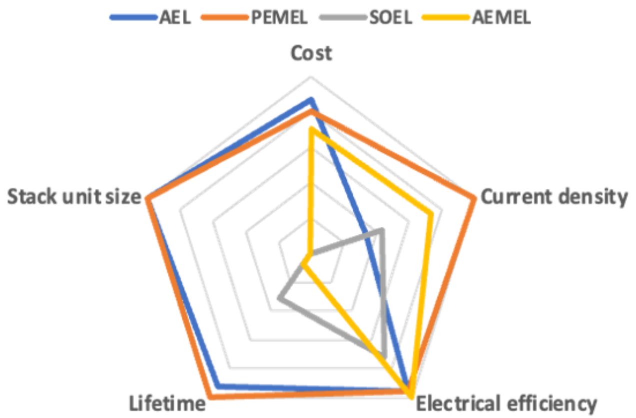
Abbreviations

- AEL: Alkaline Electrolyzer
- PEMEL: Proton Exchange Membrane Electrolyzer
- SOEL: Solid Oxide Electrolyzer
- AEMEL: Anion Exchange Membrane Electrolyzer
- KOH: Potassium hydroxide
- CCM: Catalyst Coated Membrane
- GDL: Gas Diffusion Layer
- PTL: Porous Transport Layer
- BPP: Bipolar Plate
- CapEx: Capital Expenditure
- BOP: Balance of Plant

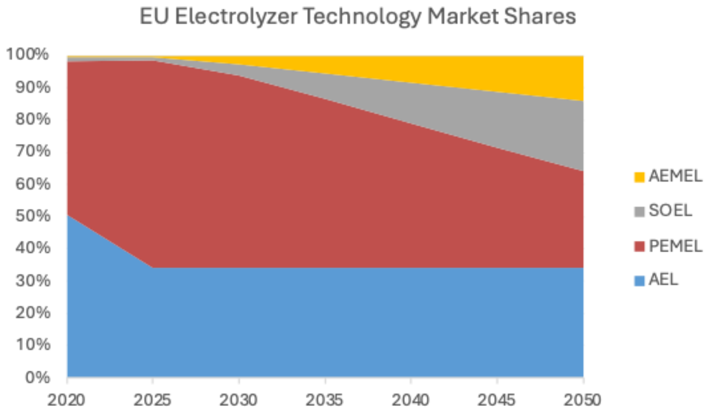
Performance overview of main electrolyzer types

	Alkaline Electrolyzer (AEL)	Proton Exchange Membrane Electrolyzer (PEMEL)	Solid-Oxide Electrolyzer (SOEL)	Anion Exchange Membrane Electrolyzer (AEMEL)
TRL[1]	9	9	8	7
Stack Lifetime[2]	60-90k hours	50-80k hours	20-25k hours	60-90k hours
BOP Lifetime[2-4]	20 years			
EU Strategic/Critical Raw Materials[5]	La, Sr, V, Co, Mn, Ni	Pt, Ir, Ru, Rh, Pd, Mn, Cr, Ni,	Nb, Mg, Ce, B, La, Y, Gd, Sr, Co,…	Ce, La, Co, Si, Mn, Mo, Ni
CapEx[6-7]	2020: 270 USD/kW 2050: 100 USD/kW	2020: 400 USD/kW 2050: 100 USD/kW	2020: >2000 USD/kW 2050: <200 USD/kW	2020: 600 2050: <200 USD/kW

Performance[6]



Market Outlook[5-6]



Main stack components as listed by the Net Zero Industry Act (NZIA)

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	AEL	PEMEL	SOEL	AEMEL
As listed by NZIA[8]	• Stacks • Separators (diaphragm or membranes tailored for water electrolysis) • Bipolar plates • Electrodes • Frames • Gaskets / sealants	• Stack • Membrane electrode assemblies (3-layer) / catalyst coated membranes • Porous transport layers/ gas diffusion layers • Bipolar plates • Gaskets / sealants	• Stacks • Electrolytes & electrodes • High-temperature gaskets / sealants • Interconnectors • Meshes	• Stack • Membrane electrode assemblies (3-layer) / catalyst coated membranes • Porous transport layers/ gas diffusion layers • Bipolar plates • Gaskets / sealants
Further components in the focus, added by SOUVERÄN project team	• End plate • Current collector • Tie rod • Electrolyte • Porous transport layer	• End plate • Current collector • Tie rod	• End plate • Current collector • Tie rod • Electrolyte • Buffer layer/diffusion barrier	• End plate • Current collector • Tie rod

Technology Descriptions - Alkaline Electrolyzer (AEL)

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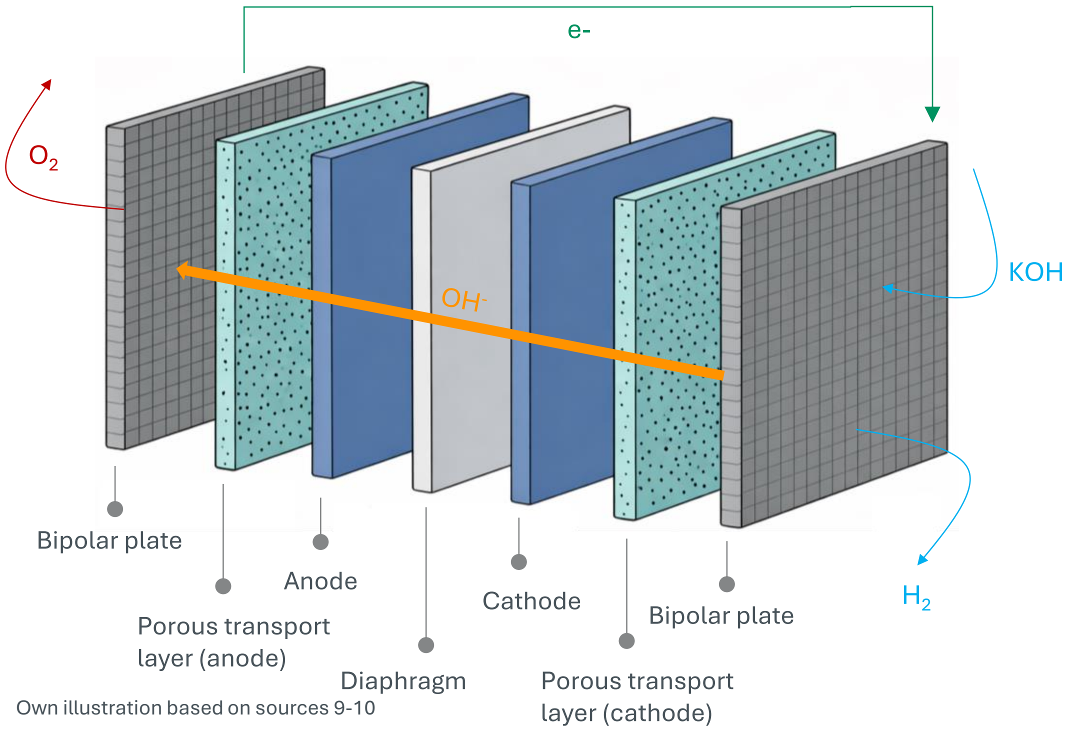

Own illustration based on sources 9-10

Components	Functionality	Commonly used materials
Bipolar plate	ensures transport of educts and products within the cell	nickel, carbon steel or stainless steel
Porous transport layer	conducts electrons, assists in thermal management, and facilitates transport of educts and products	nickel foam/mesh
Anode	oxygen evolution reaction	nickel/nickel alloy, or carbon steel
Diaphragm	ionic conduction while separating H_2 and O_2	zirconia based composites
Cathode	hydrogen evolution reaction	nickel/nickel alloy, or carbon steel
Electrolyte	ionic charge transport via hydroxide ions	aqueous potassium hydroxide (KOH)

Sources 3,6,11-14

Advantages	Disadvantages
use of earth-abundant and inexpensive materials	high material requirements
high technological maturity and long operational experience	low current density
long stack lifetime	slow load response

Sources 3,6,11-14

In AEL, water is electrochemically split into hydrogen and oxygen, with hydroxide ions acting as charge carriers between cathode and anode. At the cathode, water is reduced to hydrogen and hydroxide ions. The hydroxide ions migrate through the electrolyte and diaphragm to the anode, where they are oxidized to oxygen and water. KOH serves as an inert electrolyte that enables ionic transport but is not consumed.

Sources: 3,6,11-14

Technology Descriptions - Proton Exchanger Membrane Electrolyzer (PEMEL)

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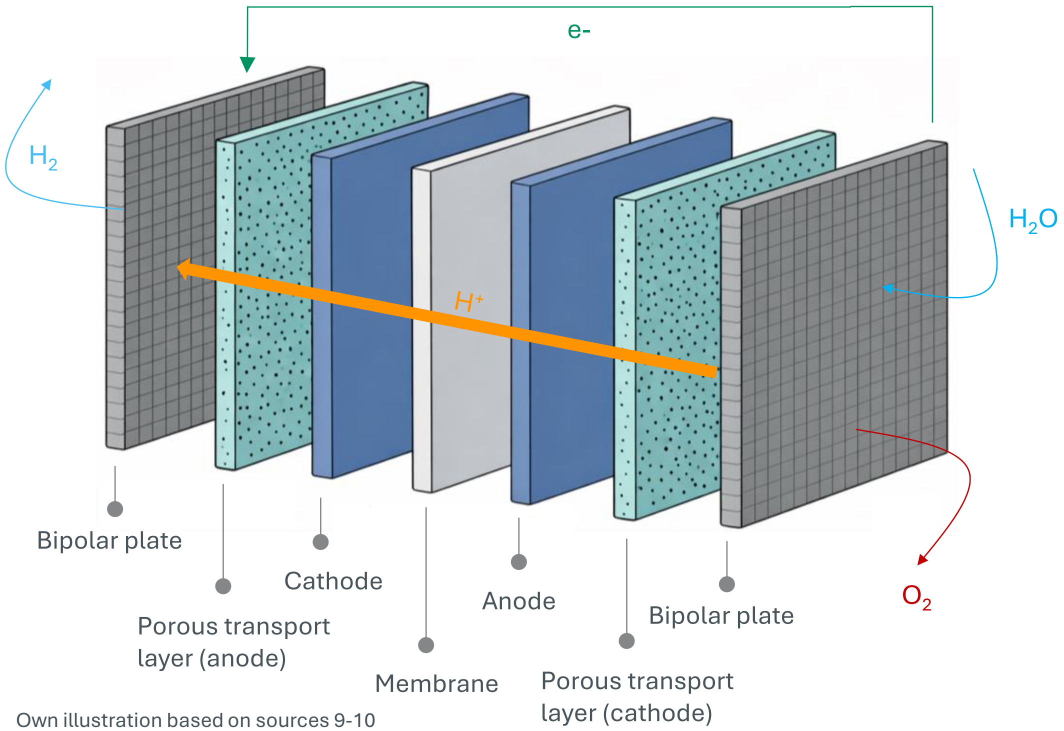

Own illustration based on sources 9-10

Components	Functionality	Commonly used materials
Bipolar plate	ensures transport of educts and products within the cell	platinum or gold coated titanium
Porous transport layer	conducts electrons, assists in thermal management, and facilitates transport of educts and products	porous titanium
Anode	oxygen evolution reaction	mostly iridium oxide
Membrane	ionic conduction while separating H_2 and O_2	polymer electrolyte membrane, mostly nafion
Cathode	hydrogen evolution reaction	platinum coated carbon paper

Sources 3,6,11-14

Advantages	Disadvantages
high current density and compact system design	dependence on scarce, noble metal catalysts and membrane materials
high hydrogen purity and low gas crossover	higher capital costs
fast load response	lower stack lifetime compared to AEL

Sources 3,6,11-14

In PEMEL, water is electrochemically split into hydrogen and oxygen using a solid polymer electrolyte that conducts protons. At the anode, water is oxidized to oxygen, protons, and electrons, while protons migrate through the membrane to the cathode where they are reduced to hydrogen. The membrane simultaneously enables ionic transport and separates the product gases.

Sources: 3,6,11-14

Technology Descriptions – Solid Oxide Electrolyzer (SOEL)

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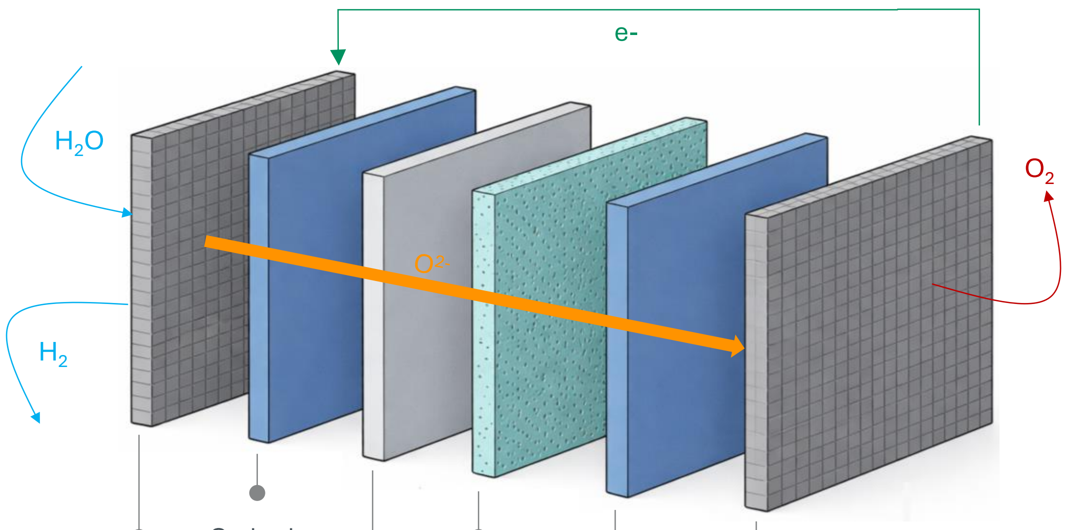


Own illustration based on sources 9-10

Advantages	Disadvantages
high electrical efficiency due to high temperature operation	high operating temperatures leads to material degradation
ability to utilize waste heat	limited operational lifetime and current technological maturity
potential for reversible operation as fuel cell	complex system design and slow dynamic response

Sources 3,6,11-14

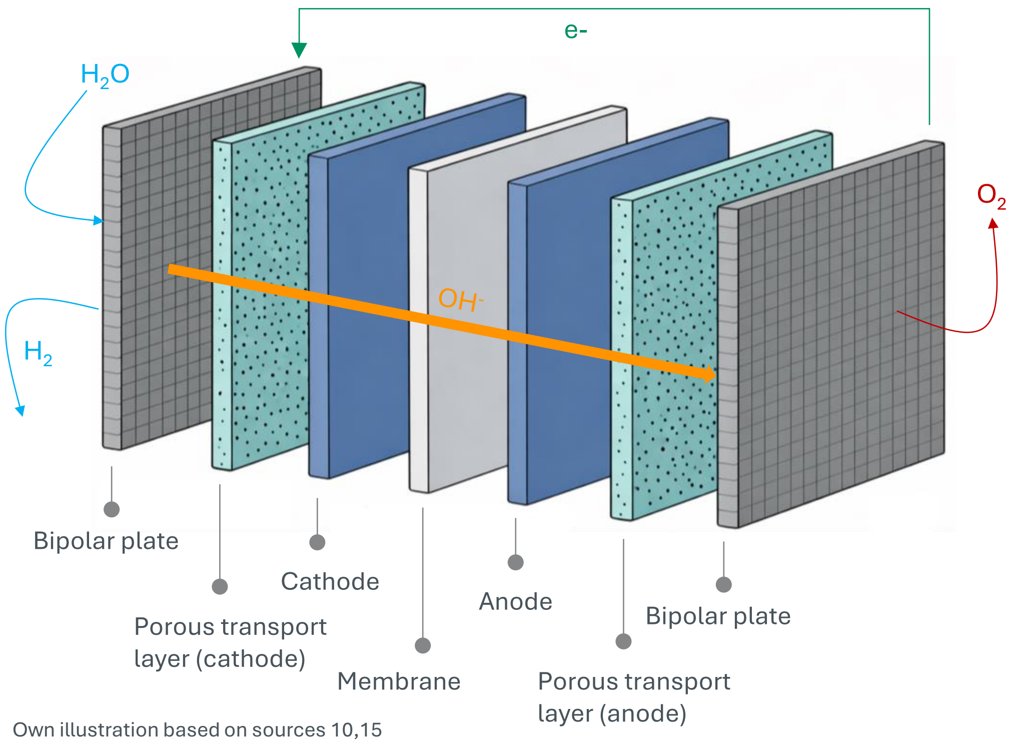
Components	Functionality	Commonly used materials
Interconnector	electrical connection between cells, gas separation, mechanical support	ferritic steel
Cathode	steam reduction to hydrogen and oxide ions	nickel yttria stabilized zirconia or cerium oxides
Electrolyte	oxide ion conduction and gas separation	yttria stabilized zirconia
Diffusion barrier	suppression of chromium migration and interfacial degradation	cerium based oxides
Anode	oxygen evolution reaction	lanthanum strontium magnetite or cobalt ferrite

Sources 3,6,11-14

In SOEL, steam is electrochemically split into hydrogen and oxygen at high temperature using a ceramic oxide ion conducting electrolyte. At the cathode, steam is reduced to hydrogen and oxide ions, which migrate through the solid electrolyte to the anode. There, oxide ions are oxidized to oxygen, releasing electrons to complete the circuit.

Sources: 3,6,11-14

Technology Descriptions – Anion Exchange Membrane Electrolyzer (AEMEL)



Own illustration based on sources 10,15

Components	Functionality	Commonly used materials
Bipolar plate	current collection, gas distribution, mechanical support	Stainless steel or nickel coated steel
Porous transport layer	gas diffusion, water management, electrical contact	nickel foam, stainless steel mesh, carbon-based substrates
Anode	oxygen evolution reaction	nickel based catalysts, nickel iron oxides
Membrane	hydroxide ion conduction and gas separation	polymer membranes
Cathode	hydrogen evolution reaction	nickel, nickel molybdenum alloys

Sources 3,6,11-14

Advantages	Disadvantages
no reliance on scarce noble metal catalysts	limited membrane stability under alkaline conditions
fast load response	lower ionic conductivity compared to PEM membranes
suitable for high pressure operation	low TRL

Sources 3,6,11-14

In AEMEL, water is electrochemically split into hydrogen and oxygen using a solid polymer membrane that conducts hydroxide ions. At the cathode, water is reduced to hydrogen and hydroxide ions, which migrate through the membrane to the anode. There, hydroxide ions are oxidized to oxygen and water, while the membrane simultaneously enables ion transport and gas separation.

Sources: 3,6,11-14

Manufacturing stages of electrolyzers – Exemplified by PEMEL

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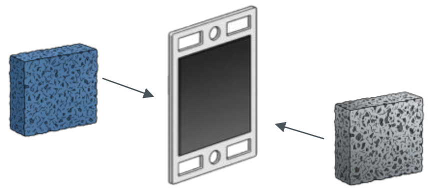
Membrane Electrode Assembly (MEA)[16]

- **CCM**: Mixing → Decal coating → Decal drying → Hot pressing → Decal removing → Subgasket application
- **GDL**: Carbon paper forming → Impreg-nating → Graphit-izing → Hydro-phobing → Microprous layer application → Sintering
- **PTL**: Mixing → Tape casting and drying → Cutting → Debinding and sintering

→ Joining & Separating



Own illustration based on sources 10,16

Bipolar Plate[16]

- **BPP**: Forming → Separating & trimming → Sand-blasting → Coating & polishing → Joining → Leakage testing → Gasket application

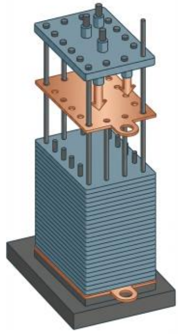
Own illustration based on sources 10,16

Stack Production[16]

- **Stack**: Stacking & preassembling → Com-pressing → Tensioning → Leakage testing → Isolation testing → Cell voltage monitoring assembly → Break-in & testing

System Production[16]

- Balance of plant (BOP) assembly → Electrical integration → End of line testing



Own illustration based on sources 10,16

Key players along the electrolyzer supply chain

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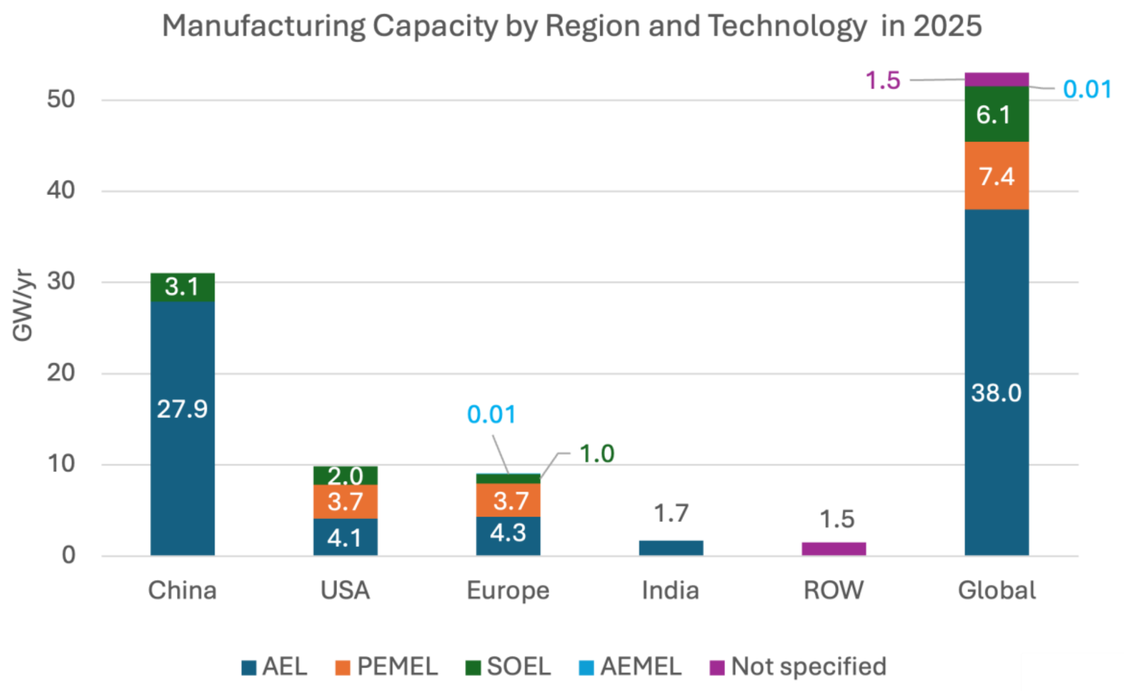
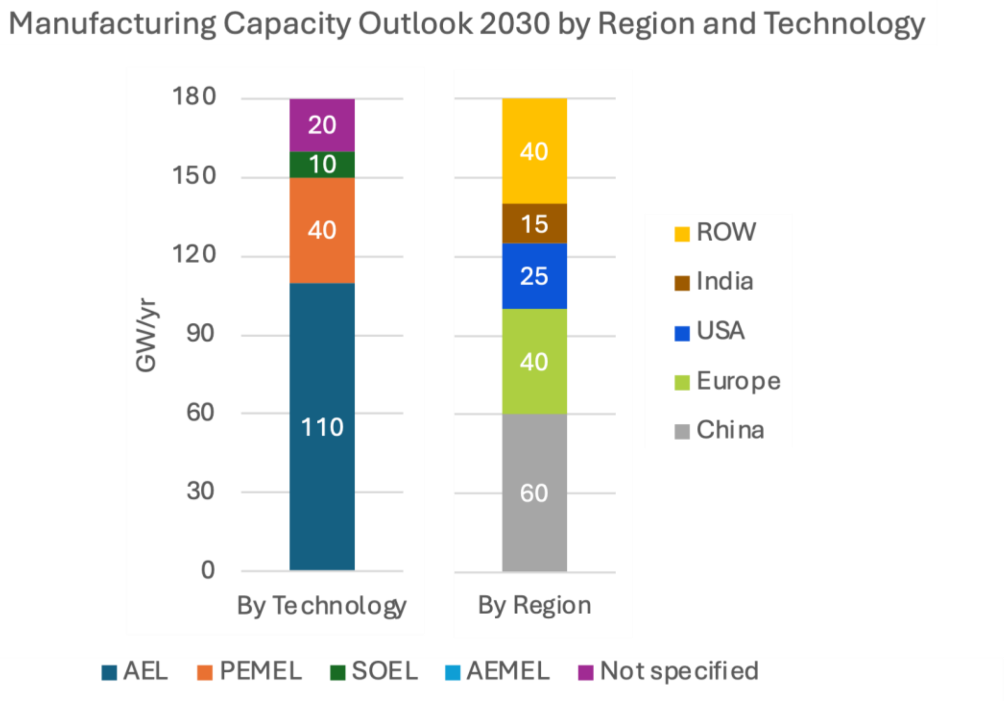
	Raw materials				Processed materials				Components	Assemblies
	AEL	PEMEL	SOEL	AEMEL	AEL	PEMEL	SOEL	AEMEL		
EU	4%	1%	5%	2%	29%	18%	14%	20%	35%	50%
Rest of Europe	3%	3%	6%	4%	7%	4%	19%	9%	10%	10%
USA	2%	3%	2%	2%	27%	43%	15%	27%	29%	19%
China	31%	14%	38%	38%	15%	17%	24%	23%	10%	6%
Russia	4%	6%	3%	3%	1%	0%	1%	1%	0%	0%
Japan	0%	0%	0%	1%	8%	8%	2%	2%	10%	10%
Taiwan	0%	0%	0%	0%	1%	0%	0%	3%	0%	0%
Korea	0%	0%	0%	0%	1%	0%	2%	1%	1%	0%
Rest of Asia	14%	8%	10%	12%	9%	6%	8%	13%	1%	0%
Africa	18%	45%	15%	18%	0%	0%	4%	0%	1%	1%
Latin America	13%	8%	12%	12%	1%	0%	3%	0%	0%	0%
Others	10%	11%	7%	8%	2%	3%	7%	3%	5%	3%

Own illustration based on sources 5,17

Current manufacturing capacity landscape and future outlook



Own illustration based on sources 12, 18-27



Own illustration based on sources 12, 18-27

Highlights

- Many projects in Europe, Africa, Australia, America, and the US recently faced delays or cancellations
- For the first time, the IEA cut its production prediction with a 37 million metric ton H_2 decline annually by 2030
- Manufacturing capacities still rose by around 40% in 2025 compared to 2024 (mainly driven by China)
- However, the output of these plants is estimated only around 10%, meaning that there is a large excess capacity
- Despite this, based on announced expansions, manufacturing capacities could reach around 180 GW by 2030

Sources: 12,18-27

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