Next Generation Electrolyser Technologies :

Green Hydrogen Production Perspective of Electrolyser Manufacturers

Keynote Session – WHES 2023

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Agenda

- **Overview : Electrolyser market today**
- Imperatives for India : Developing local capacity
- Way forward

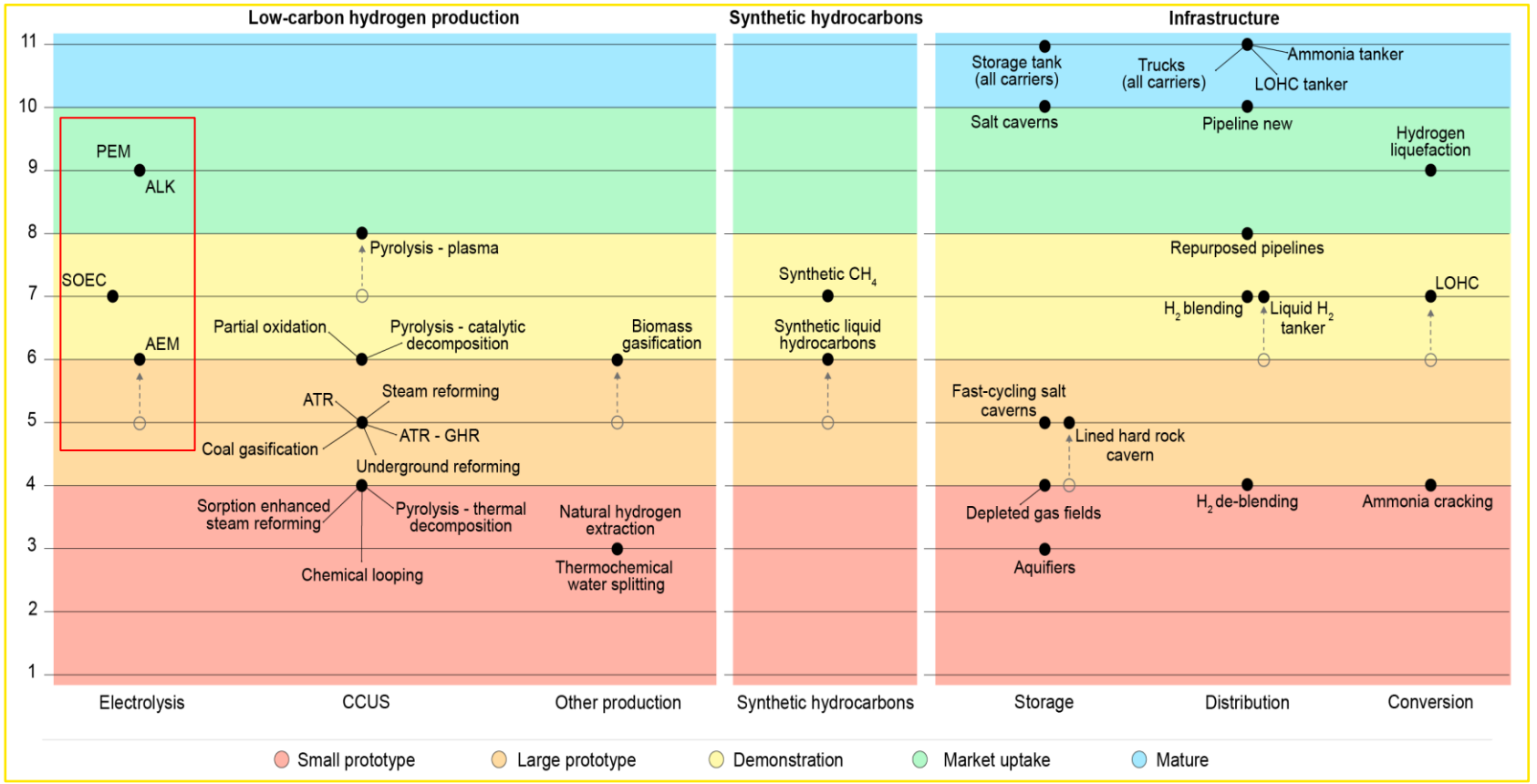
Technology development is advancing across the hydrogen value chain, though several key technologies, particularly in end-uses, are far from being commercial

Key Takeaway

- For electrolysis PEM and ALK lead the pack with TRL 9
- A market entry with TRL 7 or lower represents a hurdle for market entry

Notes: AEM = anion exchange membrane; ALK = alkaline; ATR = autothermal reformer; CCUS = carbon capture, utilization and storage; CH_4 = methane; GHR = gas-heated reformer; HT = high temperature; LOHC = liquid organic hydrogen carrier; LT = low temperature; NH_3 = ammonia; PEM = proton exchange membrane; SOEC = solid oxide electrolyser cell. Biomass refers to both biomass and waste. Arrows show changes in technology readiness level as a consequence of progress in the last year. For technologies in the CCUS category, the technology readiness level refers to the overall concept of coupling production technologies with CCUS and high CO_2 capture rates. Pipelines refer to onshore transmission pipelines. Storage in depleted gas fields and aquifers refers to pure hydrogen and not to blends. LOHC refers to hydrogenation and dehydrogenation of liquid organic hydrogen carriers. Ammonia cracking refers to low temperature ammonia cracking. Technology readiness level classification based on Clean Energy Innovation (2020).

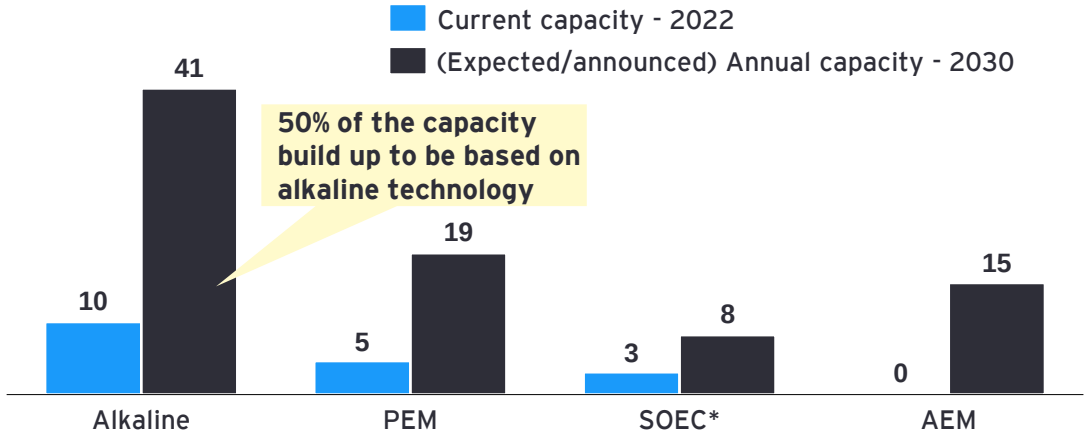
Technology readiness levels (TRL) of production of low-emission hydrogen and synthetic fuels, and infrastructure



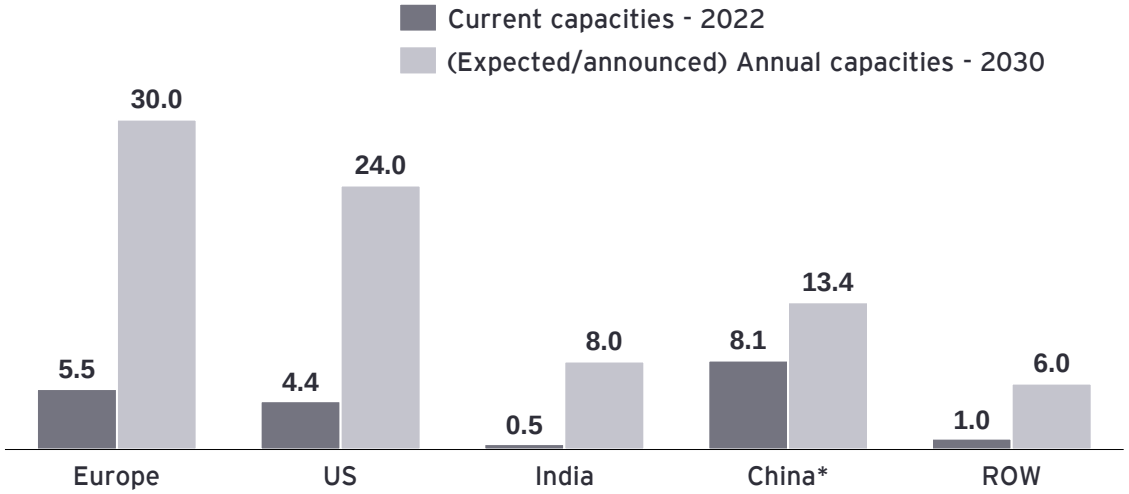
Sources: IEA, Global Hydrogen Review 2022, : ETP Clean Energy Technology Guide, IEA (2022).

While incentives are pushing hydrogen adoption, uncertain outlook for Green Hydrogen prompts electrolyser manufacturers to scale back their expansion plans

Electrolyser manufacturing capacity by technology, GW (2022, 30)



Electrolyser manufacturing capacity by region, GW (2022, 30)



- Global electrolyzer manufacturing capacity is expected to grow at a CAGR of ~22% to achieve 80GW capacity by 2030
- Alkaline expected to be the most dominant technology occupying ~ 50% share of the capacity closely followed by PEM. SOEC and AEM currently have limited focus.
- In China, Alkaline is predominant technology, with growing interest in PEM. Similarly, In India as well -Major global players like Greenko-John Cockerill, L&T- McPhy and Reliance-Steisdal are setting up Alkaline plants
- While EU observes development in both Alkaline & PEM technology. ~60% of global electrolyser capacity is announced in Europe
- US largely remains technology agnostic with development of all four technologies –Alkaline, PEM, SOEC & AEM

Note: SOEC capacity might have some overlap with SOFC (Fuel cell) manufacturing capacities

Source: Company websites, Press releases, EY analysis, IEA

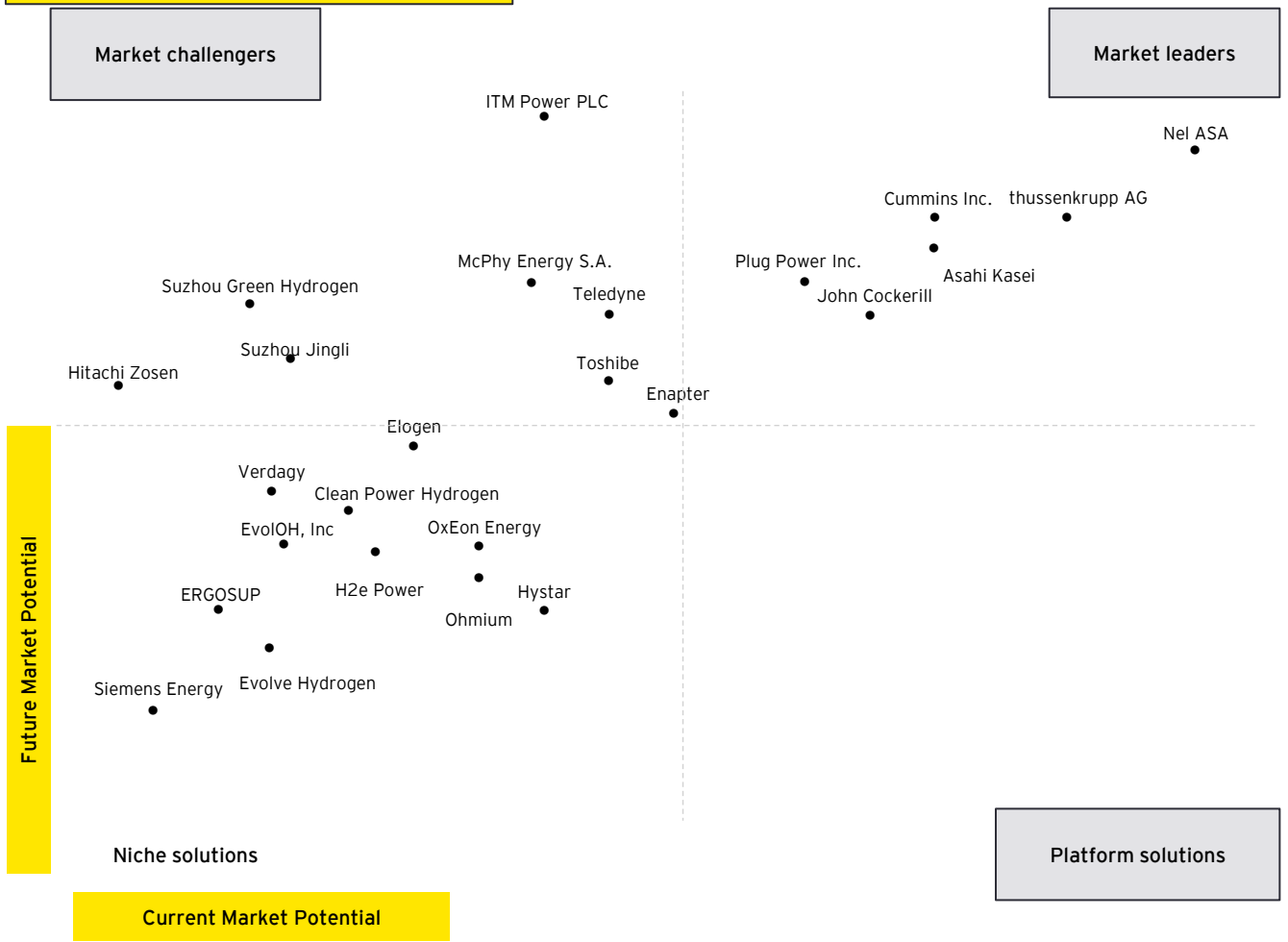
Global Landscape: While fee players have a broad positioning in the market, in terms of Electrolyser type and target applications; other players tend to focus on a specific technology

Product Matrix for Key Companies

Company Name	Alkaline	PEM	AEM	SOEC
Plug Power Inc.		•		
Asahi Kasei Corporation	•	•		
Nel ASA	•	•		
thyssenkrupp AG	•			
Cummins. Inc.	•	•	•	
Teledyne Energy Systems Inc				•
ITM Power PLC		•		
Hitachi Zosen Corporation		•		
Elogen		•		
Ohmium				•
h2e Power Systems Pvt. Ltd				•
Hystar				•
Evolve Hydrogen Inc.			•	
EvolOH, Inc			•	
OxEon Energy, LLC				•
John Cockerill	•			
Enapter AG			•	
Siemens Energy		•		
McPhy Energy S.A.	•			
Toshiba Energy Systems & Solutions Corporation				•

Source: BIS Research: Water Electrolysis Market – A Global and Regional Analysis

Competitive Position Matrix



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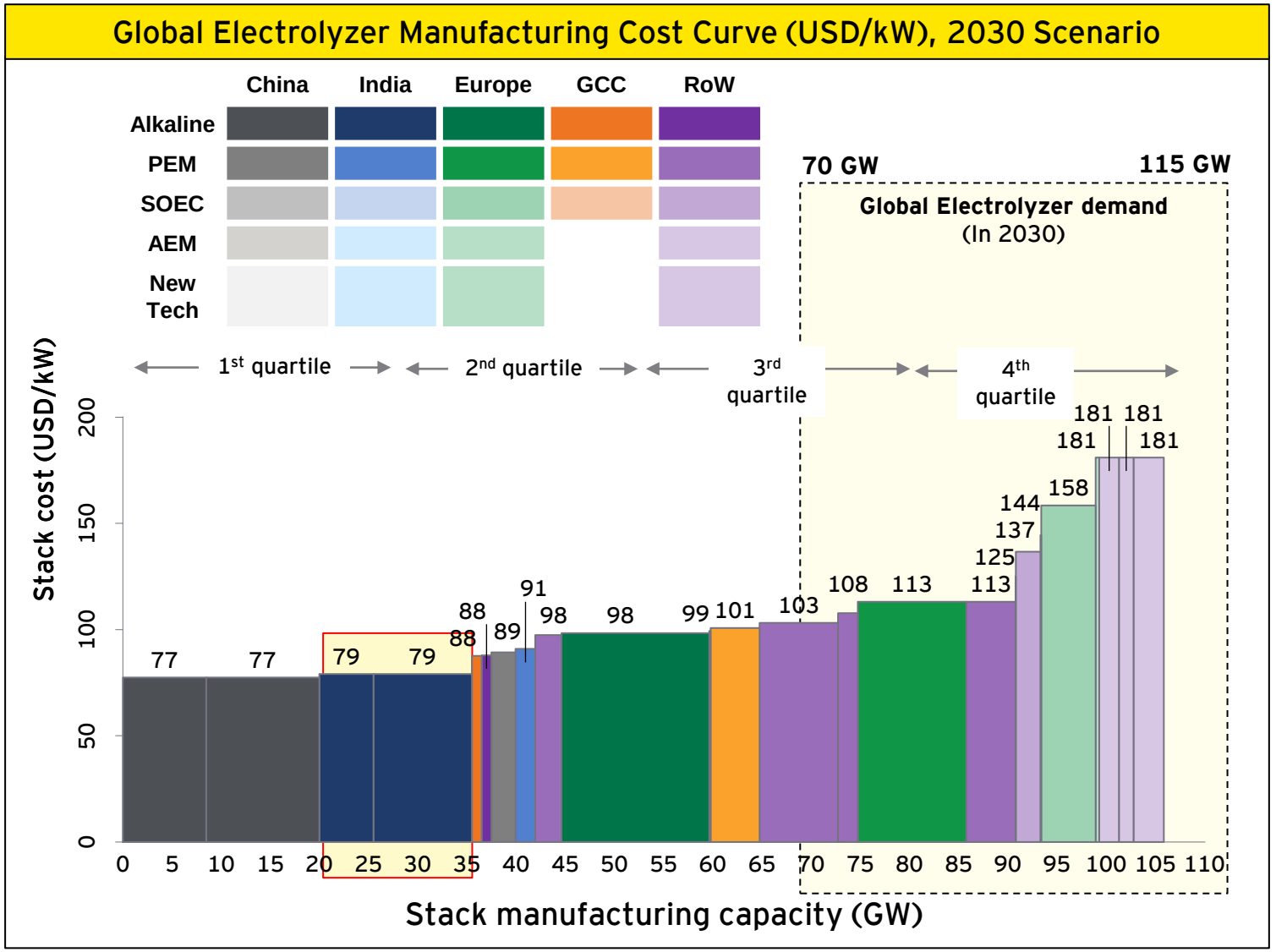
India's electrolyzer stack manufacturing was already in an advantageous position and is expected to become more cost competitive after the government incentives



- India demand – supply gap: 5 MMTPA of GH2 production by 2030, requiring about 15 GW of electrolysers
- As of July 2023, the committed capacity of electrolyzer capacity manufacturing is about 5 GW, of which 500 MW is under construction
- India expected to be highly cost competitive by 2030: 1st quartile for both Alkaline and PEM electrolyzers
- SIGHT Incentives for electrolyzers reduce the stack costs in order to kick-start the local ecosystem

Notes:
- Cost of capital is considered based on the assumption that the project is fully financed through debt; Prices inclusive of shipping charges; Analysis doesn't include recently released PLI
- Prices are uncertain for SOEC, AEM and other new technologies such as E-TAC, MFE, and rugged cell as they are emerging.

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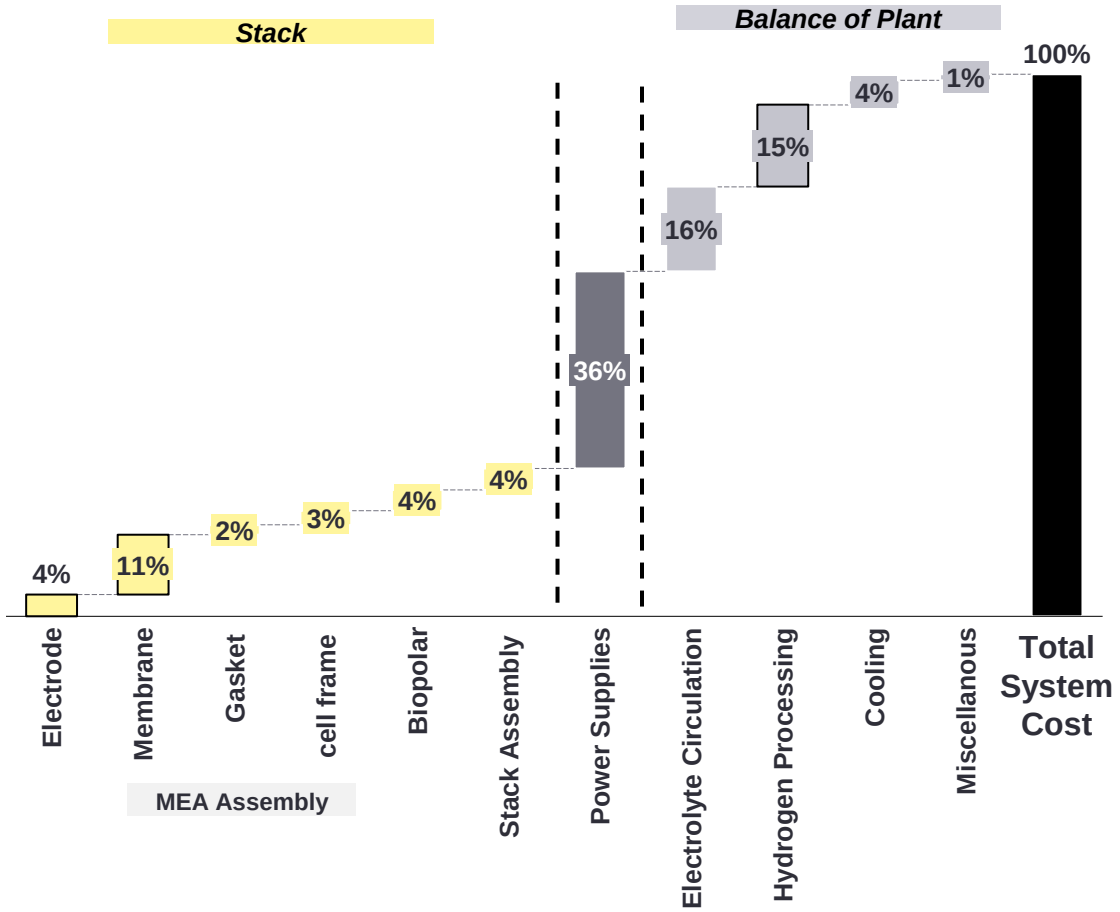
Major cost contributors of electrolyser system are power supplies & Balance of Plant (BoP) components, while stack occupies less than 1/3rd share of the cost

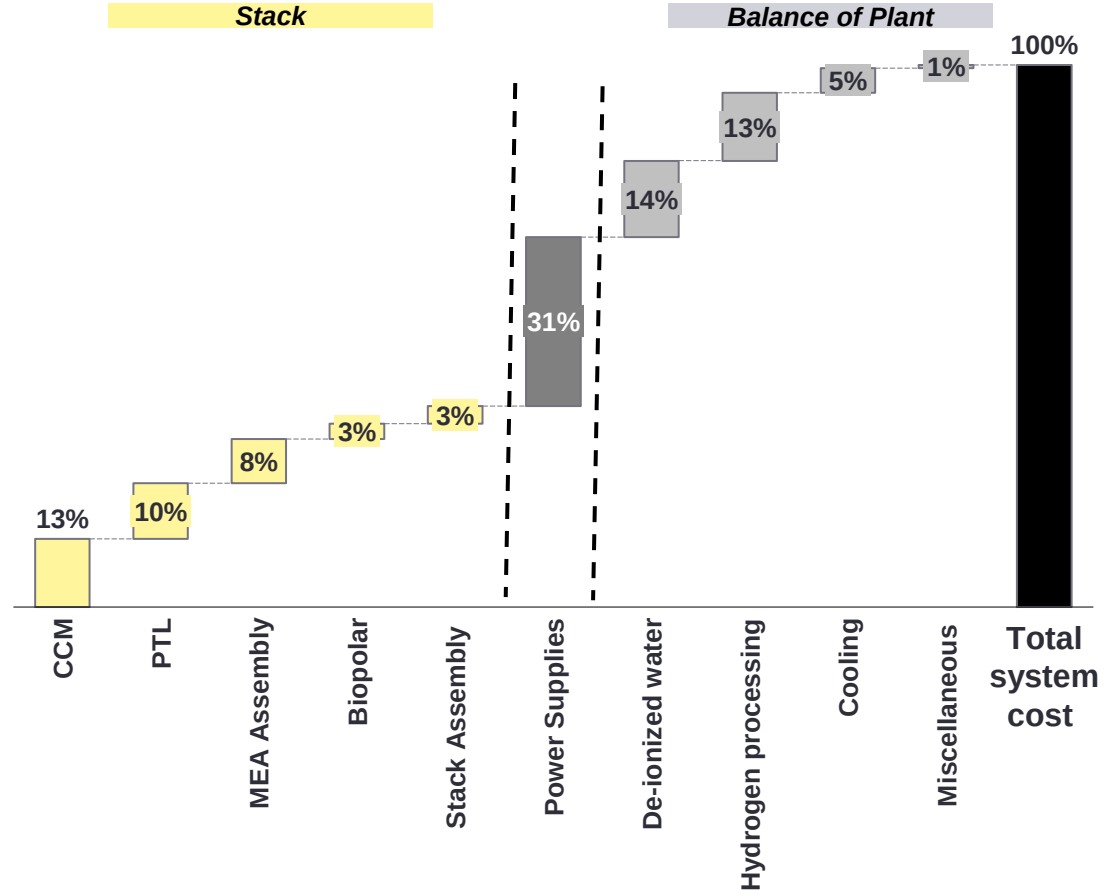
Alkaline Electrolyzer componentwise cost break up -$/kW

1MW @ 10 units/yr production rate



PEM Electrolyzer component wise cost break up (1MW) -$/kW

1MW @ 10 units/ yr production rate



- Power electronics dominates the cost of the electrolyzer system (AC/DC& DC/DC rectifiers are expensive components , Integrating electrolyzer to DC source e.g. Solar, Wind shall reduce the power electronics cost
- Balance of plant is also a major cost contributor, all the components are largely outsourced.

Note :*1.Assessment based on Secondary research , EY model analysis, 2. BoP cost are derived from secondary source*
Source: EY analysis, Argonne NREL, research papers,

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Electrolyzer cost breakdown: Current localized manufacturing supply base is very limited for tier 3 materials - making component manufacturing attractive opportunity

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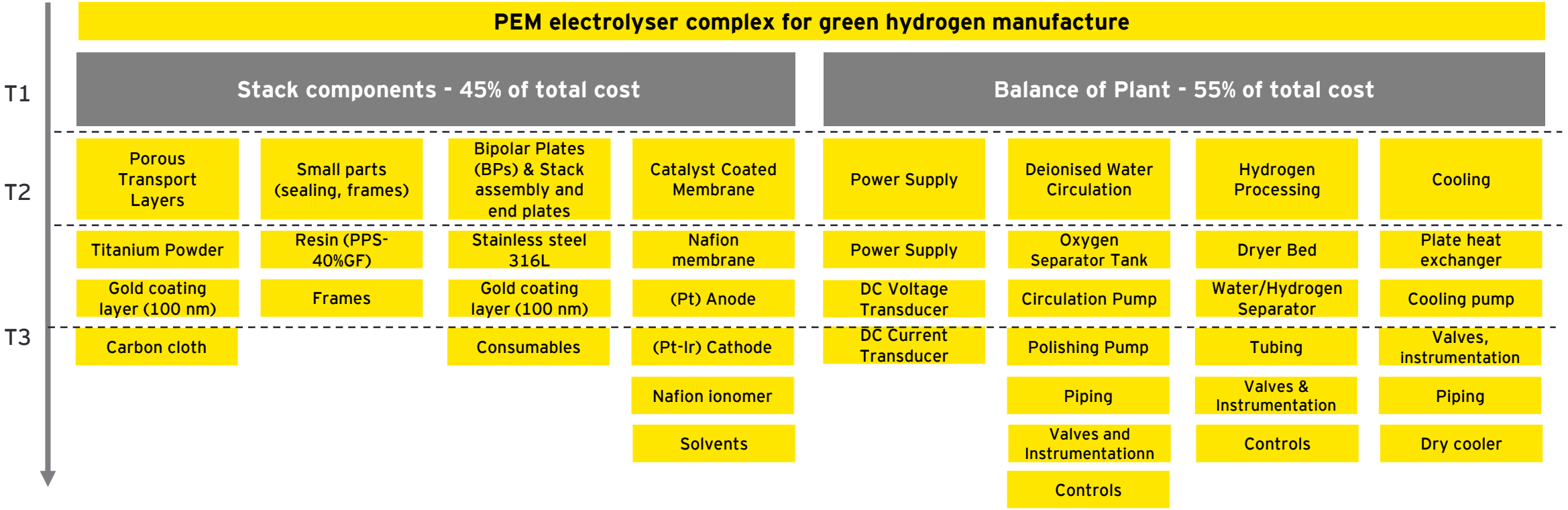

Component manufacturing becomes a very attractive proposition considering the current local supply chain base in India for green hydrogen is quite nascent. Key components include:

Electrolytes e.g. acids	***Cathode / anode materials Ceramic & Polymeric membranes and filters***	***Aluminium casings/ Frame***	***Electrical Cables, wires***

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What does India need to do to kick-start electrolyser manufacturing

Providing impetus to Electrolyser manufacturing

- **Regulatory enablement and policy support**
- **Developing local supplier ecosystem**
- **Focus on R&D and technology development**
- **Develop and support champions in each technology (Alkaline / PEM)**

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