Capacity Building Workshop for

Financing Institutions on Green Hydrogen

July 07, 2023

9:00 am - 5:30 pm IST

Global Electrolyser manufacturing market – Trends in technology & manufacturing capacity

Shaji John

South Asia Regional Energy Partnership (SAREP)

Speakers

Name
Designation

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What is green H2?

Hydrogen Overview

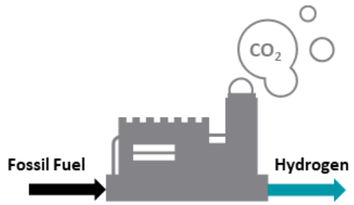
- With the energy sector representing ~75% of greenhouse gas ("GHG") emissions[(1)], the **transition of energy to renewable sources is a crucial component to mitigating global warming and climate change**

*Decarbonization technologies like renewable power and biofuels offer constructive solutions, but **green hydrogen offers the only long-term, scalable and cost-effective option** in sectors such as steel, ammonia and transportation*

Main Types of Hydrogen

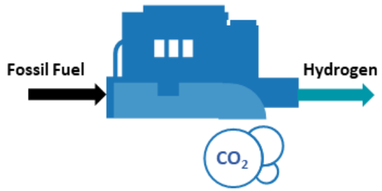
Grey Hydrogen

- Hydrogen produced from natural gas or other light hydrocarbons



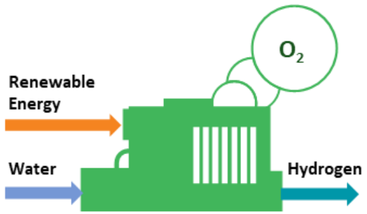
Blue Hydrogen

- Hydrogen obtained in a similar way to grey hydrogen, but with carbon capture, utilization and storage techniques applied



Green Hydrogen

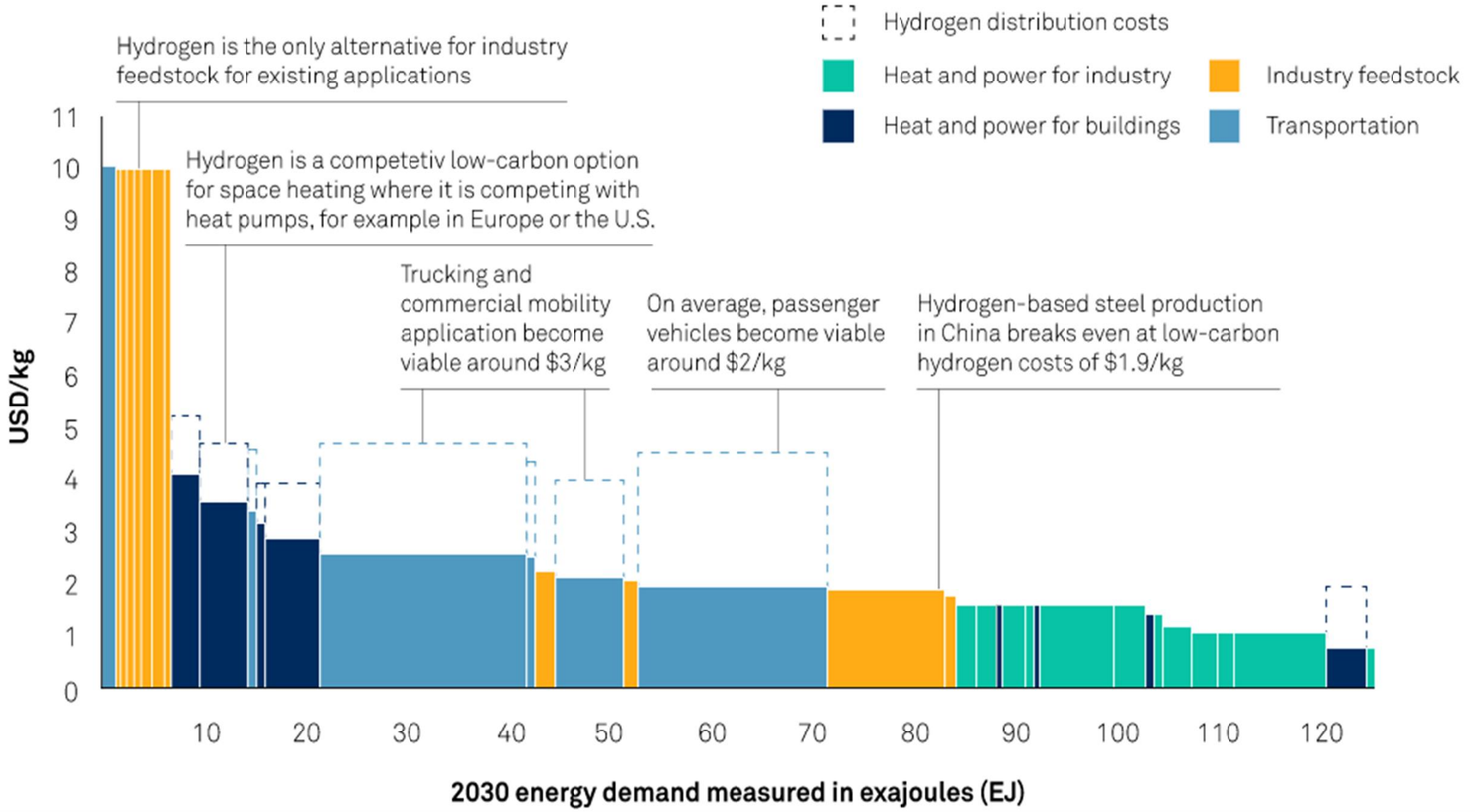
- Also called "clean hydrogen," generated from renewable energy, using water as a feedstock, through a process called electrolysis



Green hydrogen cost competitiveness

Cost Curve For Hydrogen Production Across Segments And Regions

Break-even hydrogen costs at which hydrogen application becomes competitive against low-carbon alternative in a given segment



1

Hydrogen for refineries, ammonia production and methanol are viable as of today.

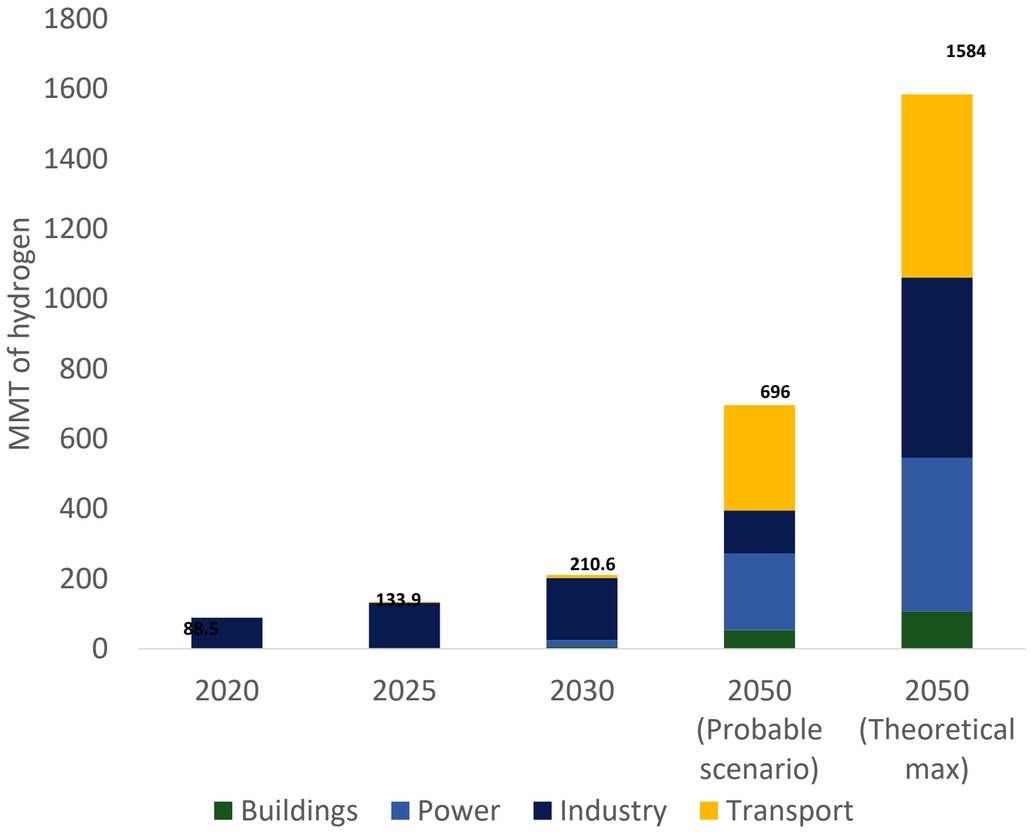
2

Applications in transportation, power and other industries start to become viable in optimal regions in 2-3 years.

Source: How Hydrogen Can Fuel The Energy Transition, S&P Global Ratings, Nov 2020

Market opportunity for green hydrogen

Projected hydrogen demand sector wise



696 Mt to 1584 Mt

Annual demand for hydrogen expected by 2050

> $11 trillion

Investment would be made in production, storage and transport infrastructure

24-50%

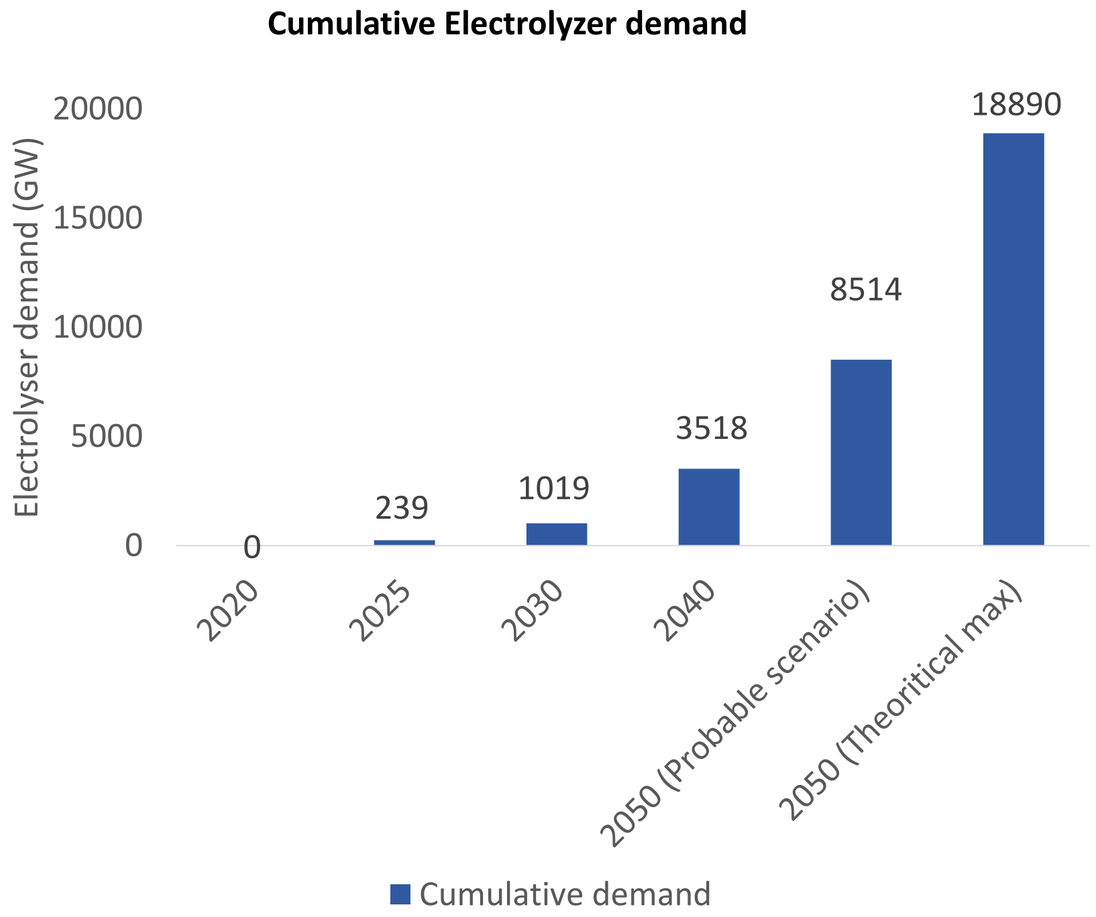
Of world's energy in 2050 would be met with hydrogen

$2 - $5 trillion/year

Of economic impact worldwide by 2050

Source: Global Hydrogen Review, pg. 44, IEA 2021, Hydrogen Economy Outlook, BNEF 2020

Market opportunity for Electrolysers



9,000 to 19,000 GW

Cumulative demand for Electrolyzer capacity by **2050** at 50% capacity utilization factor

312x

Increase in the Electrolyzer manufacturing capacity within the next decade

60%

Of the existing manufacturing capacity is concentrated within Europe

Current Capacity

~ 5.5 GW (1.5 GW AE, 1 GW PEM)

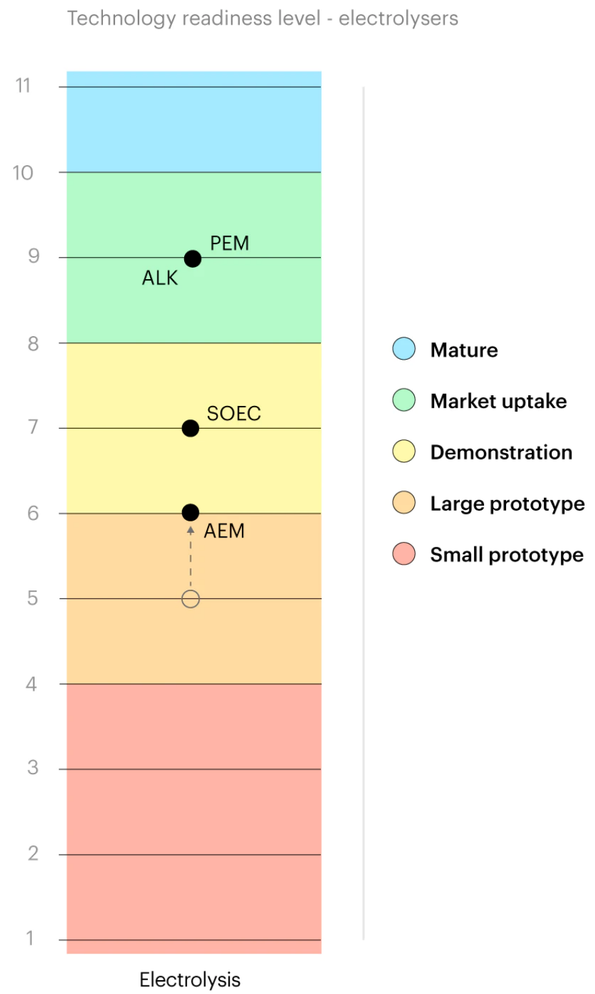
Note:
1. Includes Sales and Replacement of Electrolyzer after 15 years.
2. Estimated using hydrogen demand projections to achieve 2050 net zero from IEA

Source: Global Hydrogen Review, pg. 44, IEA 2021; State of the Hydrogen Market: Key Trends and Cost Analysis, REGLOBAL, 2020

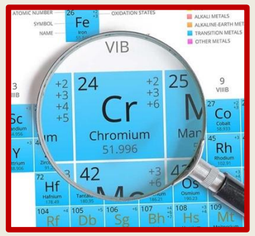
Niti Aayog estimates 160 GW of demand in India

Application		Potential H2 Market	H2 Use	Near Term Viability for India	Challenges / Unlock needed for commercial viability in India
Refinery		●	Hydrotreating Hydrocracking	✓ Grey H2 used already ✓ Green H2 costs below $2/kg	Blending mandates will unlock demand Blended costs easily absorbed
Ammonia / Fertilizer		●	Feedstock	✓ Grey H2 used already ✓ Green H2 costs below $2/kg	Blending mandates will unlock domestic ammonia demand Large export market for green ammonia (as green H2 carrier or direct use) Most fertilizer producers in India are Co-operatives and could be slow to adapt Further, urea production needs sustainable CO_2 which could be a bottleneck
Steel		●	Reducing Agent + Fuel	✓	Large export market for green steel Green steel can be sold at a premium that automobile industry can absorb Green Steel needs R&D which large players in India (Tata, JSW etc.) can afford Small players are fragmented and use Coal DRI technology which has no green H2 case study from ROW
Natural Gas blending		●	Fuel	✓	5-10% by volume H2 blends pose minimal infrastructure challenges Blended costs with natural gas easily absorbed
Methanol		◑	Feedstock	! Grey H2 used already ! Green H2 costs below $1.5/kg	Small market currently Potential of methanol blending in gasoline could unlock future demand
Mobility	Aviation	●	Fuel	!	Dependence on H2/sustainable aviation fuel ready aircrafts. Pilots expected
	Shipping	●	Fuel	!	Dependence on H2/ammonia ready ships. Pilots expected
	Trucks / Buses /Mining Equipment/Forklift	●	Fuel	!	Dependence on H2 ready trucks and buses. Pilots expected
	Other vehicles	●	Fuel	!	Battery electric expected to dominate. H2 pilots for range extenders
Power	Grid Scale	●	Fuel	!	Dependence on fuel cells or H2 ready gas turbines Attractive application when extent of grid decarbonization increases
	Small Scale	◑	Fuel	✓	Dependence on fuel cell supplier Niche or mission critical applications which require 1-2 days of power backup
Cement		●	Fuel	! Green H2 costs below $1/kg	Not viable today without carbon tax. Small pilots can be expected
Industrial Heat (generic)		●	Fuel	! Green H2 costs below $1/kg	Not viable today without carbon tax. Small pilots can be expected
Glass	Inert Atmosphere	◔	Reducing Agent	✓ Commercially viable today	
	Furnace Heat	◑	Fuel	! Green H2 costs below $1/kg	Not viable today without carbon tax. Small pilots can be expected
Heat Treatment of metals		◔	Reducing Agent	✓ Commercially viable today	
Food (Margarine)		◔	Hydrogenation	✓ Commercially viable today	

Types of Electrolyzers

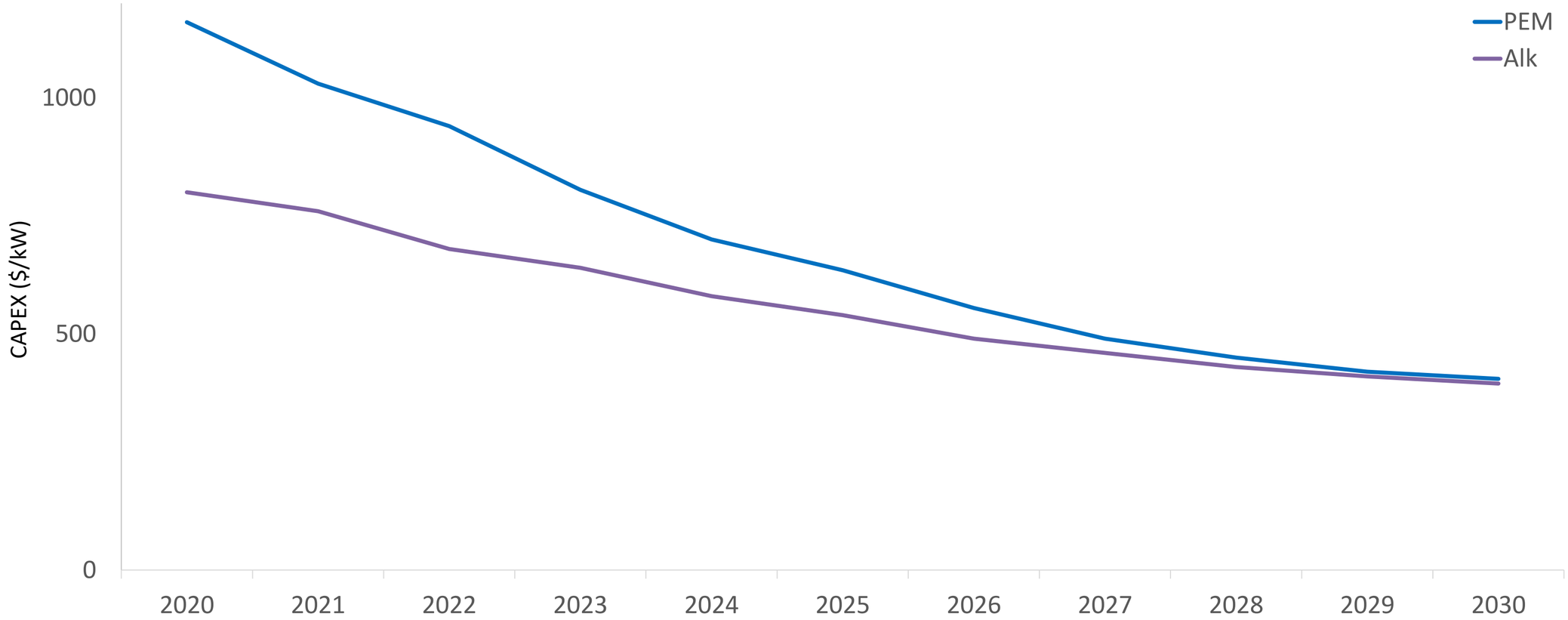


Ohmium's PEM Selection

PEM	Alkaline	Solid Oxide	Others
✓  Touch-safe Nafion™ type membrane	✗ 	✗ 	
Highest density • Moore's Law • Electronic nature	Low density • Caustic liquid process	Low density, awkward • High temperature • Thermal process • Hazardous materials	
Fast-ramp, renewables compatible	Energy storage generally required with renewables	12-hour start-ups; energy to maintain at temperature	
Superior applications integration • Directly pressure-capable • Electronics integration • Interlocked modularity possible	Awkward for applications integration • History of pressure hazard	Niche applications only • Thermal integration, high cost • Fragile ceramic - susceptible to pressure, plant changes	

Source: IEA, Electrolysers - https://www.iea.org/reports/electrolysers; IRENA 2021; Yujing Guo et al, Earth and Environmental Science 371 (2019) 042022, Mark Ruth et al, 2017 Fuel Cell Seminar | Confidential

Electrolyzer Price Forecast

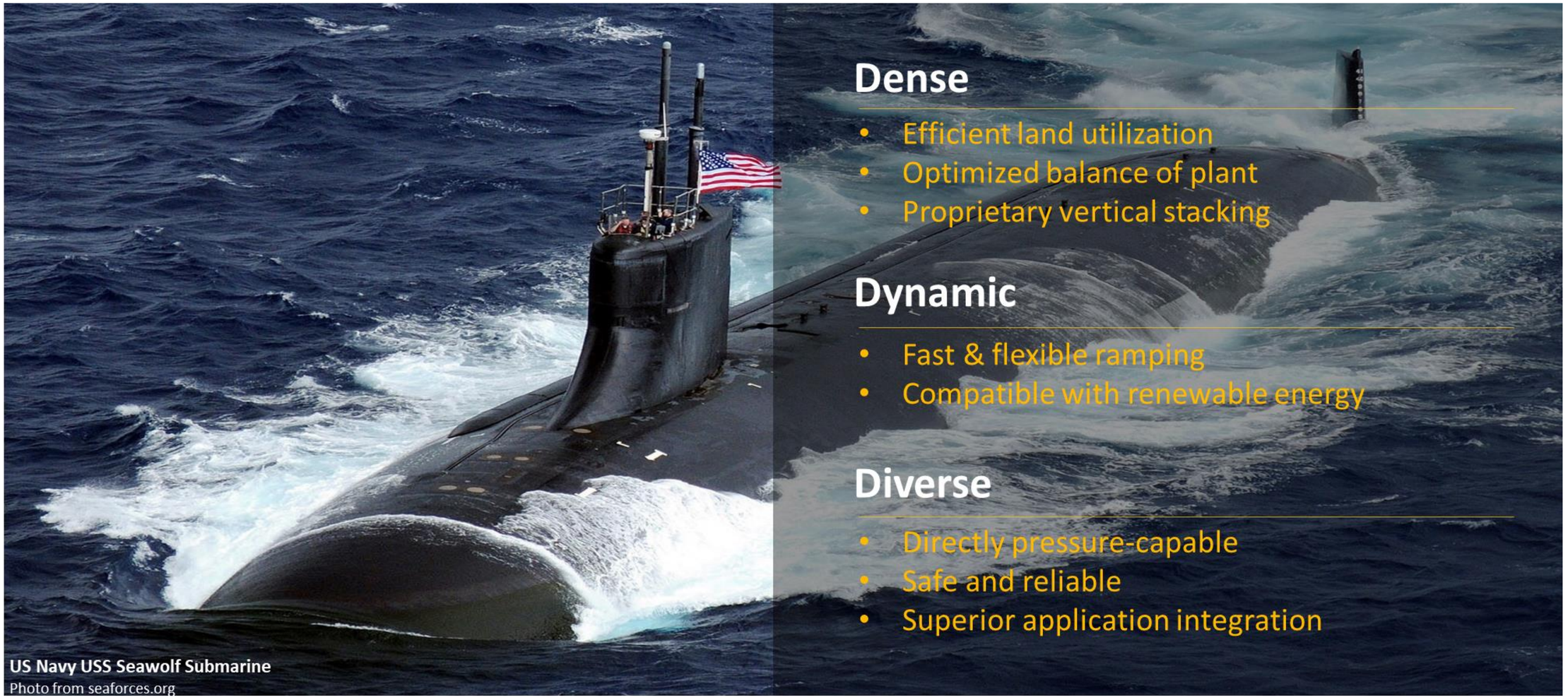


- **The prices are not apples to apples.**
- General PEM and Alkaline prices ranges are from the prices estimated by Goldman Sachs Investment Research, ”Carbonomics, The clean hydrogen revolution”, Feb 2022.

Source: Goldman Sachs Investment Research, ”Carbonomics, The clean hydrogen revolution”, Feb 2022.

About Ohmium

Leveraging NASA/US Navy PEM Advantages



Taking a Page from Henry Ford's Book…

Enabling Very Competitive Hydrogen Price

Designed for High Volume Manufacturing

- Leverage automotive supply chain
- Modular rapid to install sub-assemblies
- End-to-end supply chain control, PE to stack

Designed for Rapid, Flexible, Dense Installation

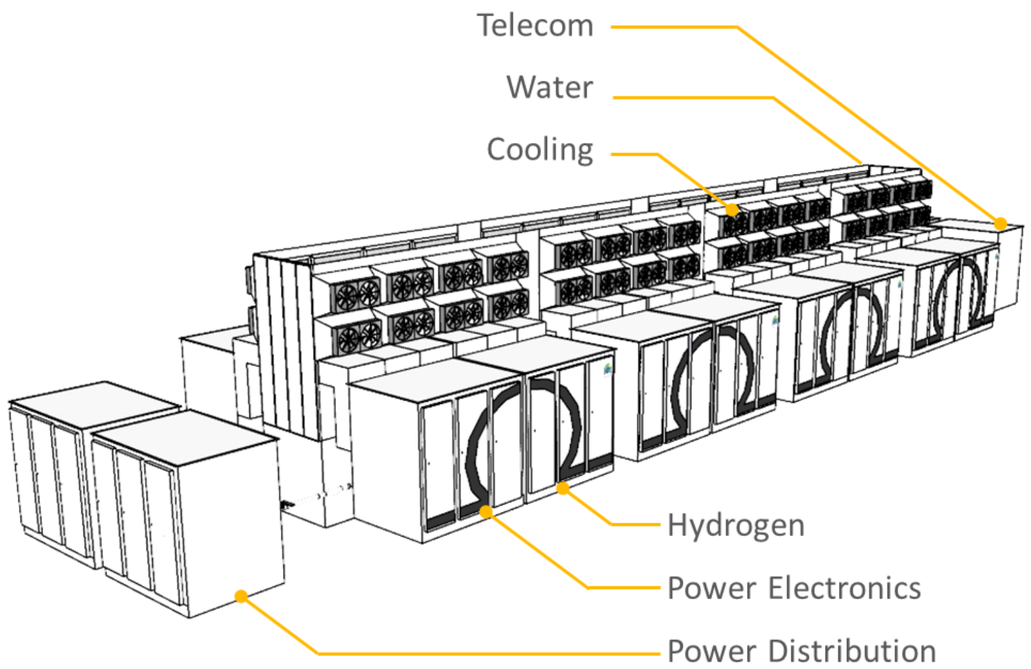
- Competitive EPC cost, elimination of cranes
- Modular design for phased construction
- Short construction & installation times

Designed for High Availability, Low Operation Cost

- Modular redundancy enabling high availability
- Rack-in, rack-out design
- Short duration service

Comprehensive Hydrogen Solution

AC Power to Pressurized Pure Hydrogen



Note: The information provided herein is for reference only and subject to change.

Output	Mark 1.5	Mark 2
H_2 production	7 x 6.0 kg/hr	7 x 9.0 kg/hr
H_2 pressure	Up to 27 bar	Up to 34 bar
H_2 purity	≥ 99.99% (high)	≥ 99.999% (ultra high)
Dynamic range	10% - 100%	10% - 100%
Ramp-up time	5 sec	4 sec
O_2 Production	Optional	Optional
Inputs		
Power	7 x 300kW$_{dc}$ 400/415/480 V$_{AC}$ 3ph 50/60 Hz	7 x 450kW$_{dc}$ 400/415/480 V$_{AC}$ 3ph 50/60 Hz
Water	7 x 1.4 SLM DI water / 7 x 2.7 SLM City water	7 x 2.1 SLM DI water / 7 x 4.0 SLM City water
Other		
Amb. temp.	-25 ˚C to 55 ˚C	
Dimensions (LWH)	8 x (2) Cabinets (1.8 x 1.4 x 2.5 m) Auxiliary Cabinets (1.8 x 1.3 x 2.2 m)	
SCADA	Fully compatible	
Comm.	TCP/IP, RS485	
Conformity	Designed to UL 2264A	

Some of our ongoing projects and collaborations

Key policy recommendations to scale-up domestic manufacturing

- Reduce entry barriers to allow new OEMs with proven and efficient technologies
  - Current qualification criteria will only allow large established conglomerates to bid in the PLI scheme
  - Allow companies who have already established their R&D and manufacturing base in India

- Do not consider reverse bidding mechanism for green hydrogen projects
  - Only 58.6% of solar capacity allocated through the auctions held in 2017 got commissioned by the end of 2018.

- Incentivise domestic bidders in public sector procurement
  - Companies with higher local content should be awarded with higher incentives and the relevant scoring mechanisms should be incorporated into the bid evaluation formula for all public sector procurement.

- Rationalise trade duties
  - Increase tariffs for imports of electrolyser stacks from 7.5% to atleast 25%

Thank You

Management Team

Board Member

Arne Ballantine

CEO and Co-Founder, Board Member

- 25 years of experience in commercializing hydrogen generation and power generation technologies
- Harvey Mudd College - Physics; U.S. Navy - nuclear engineer certification; 170 issued U.S. Patents

Kirsten Burpee

Chief Compliance Officer and Co-Founder, Board Member

- 25 years of experience of leading compliance in fuel cell and electrolyzer industries
- Former US design standards chair
- BSc. in Electrical Engineering, RPI

Ahmad Chatila

Board Chair

- Managing Partner at Fenice Investment Group
- Chairman of the Board with Ennoventure, Stealth Renewable Energy, Ohmium and Biggie Billboards
- Serves as co-founder and Director at Nexgen Power Systems and FTC Solar

Arielle Ring

CFO

- 17 years of financial experience in industrial companies
- Raised $4 billion of equity and $10 billion of debt; completed $11 billion of M&A
- Dartmouth College (Magna Cum Laude); Presidential Scholar in Mathematics

Dr. Chock Karuppaiah

CTO

- 25 years of experience in the field of PEM, solid oxide fuel cell and flow battery technologies
- Foundational PEM work at Los Alamos National Labs
- Electrochemical cell stack technology leader Plug, Bloom
- Ph.D. in Electrochemistry and Fuel Cells, RPI

Catherine Budzynski

General Counsel

- 15 years of Fortune 150, Big Law and startup experience
- Formerly Head of Legal for Aflac Global Ventures & Head of Corporate Transactions for Aflac
- JD/MBA (Boston University, Auburn University)

Ashwin Varman

COO

- 23 years of cross-geographic, multi-industry experience in business operations, customer experience, tech and quality
- Built, scaled and led diverse global operations teams to create a high level of employee trust and engagement

Dr. Rasool Aghatehrani

Chief Marketing and Strategy Officer

- 20 years of experience in renewable energy project development, power systems and power market analytics
- Ph.D. in Electrical Engineering (Power Systems), and Professional Engineer (EE), California

Archie Flores

CCO

- 20 years of experience in corporate strategy and business development in solar PV & energy
- Led a new market entrant to a dominant market share in the U.S. PV market