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Future Fuel Today

Can Green Hydrogen catapult India to energy independence?

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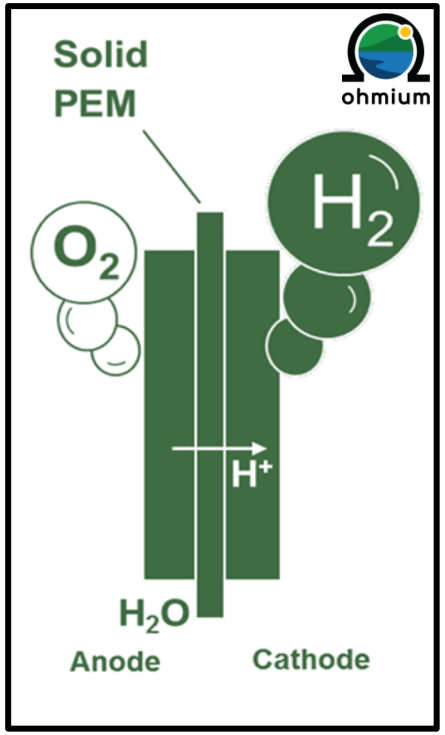
How to create Clean, Make-in-India Green Hydrogen

Electrolysis of Water – break water into hydrogen and oxygen

1. Water (H_2O) + power →H_2 and O_2
2. Electrolysis is the reverse of the Fuel Cell process
3. Electrolyzers, machines made of
    1. Power electronics
    2. Electrolyzer stacks
    3. Balance of plant (ex: pumps, controls)

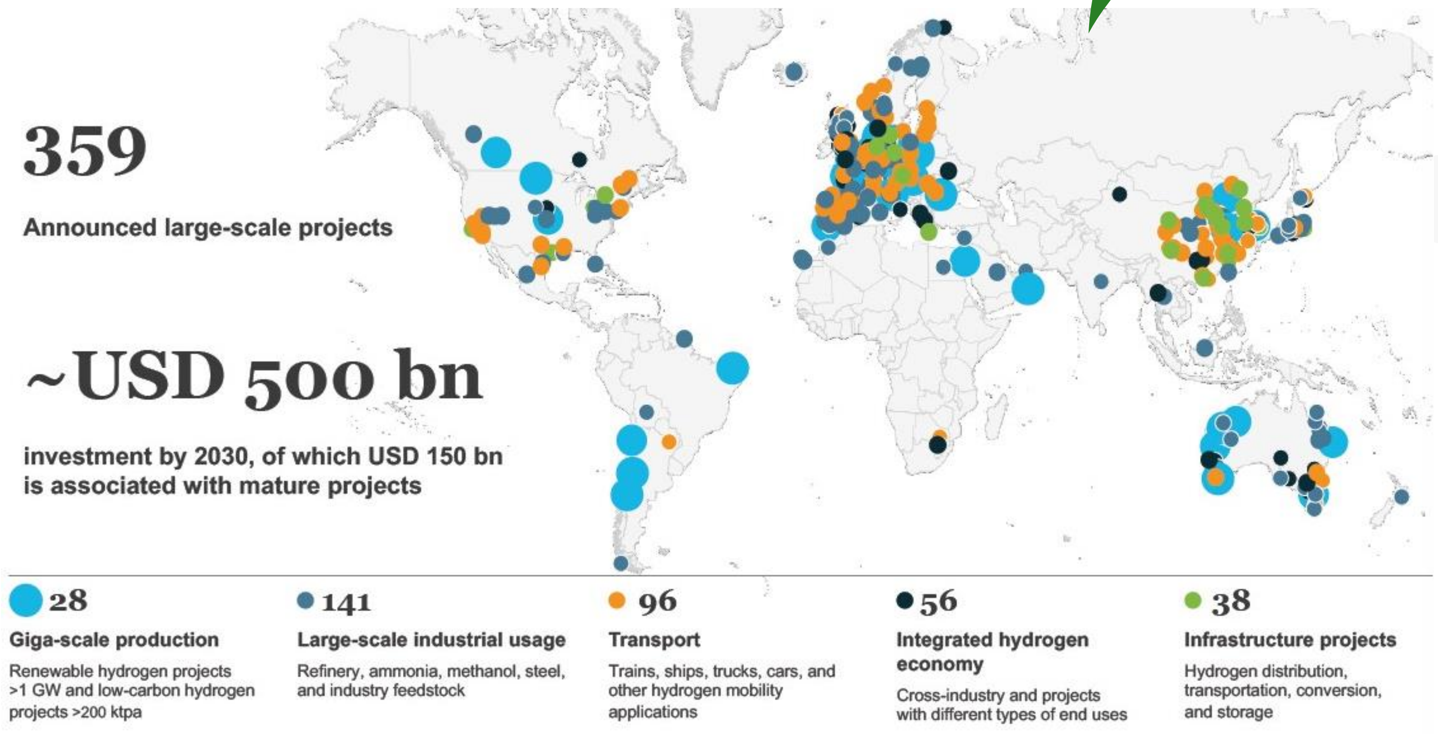
Renewable Electricity



Creates Renewable Hydrogen Gas

Projects to deploy green hydrogen is growing rapidly

An investment of USD 500 billion for H_2 production, distribution and end-user application is already announced to be made until 2030



700 Mt to 1400 Mt

Annual demand for hydrogen expected by 2050

> $11 trillion

Investment would be made in production, storage and transport infrastructure

24-50%

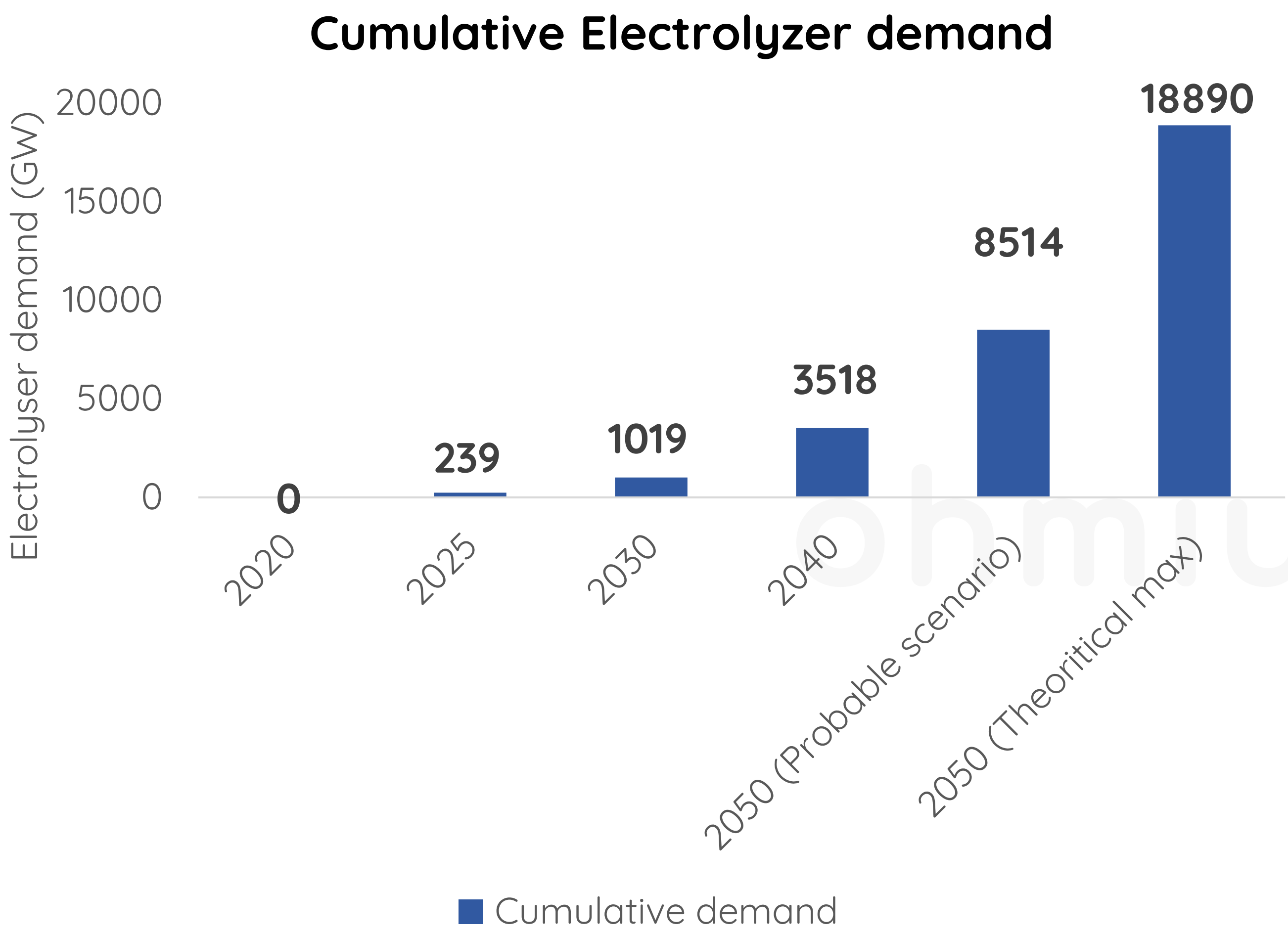
Of world's energy in 2050 would be met with hydrogen

$2 - $5 trillion/year

Of economic impact worldwide by 2050

Source: Hydrogen Insights 2021 (Hydrogen Council, McKinsey & Company, Bloomberg, Ohmium estimates

Market opportunity for Electrolyzers



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

~ 3 GW

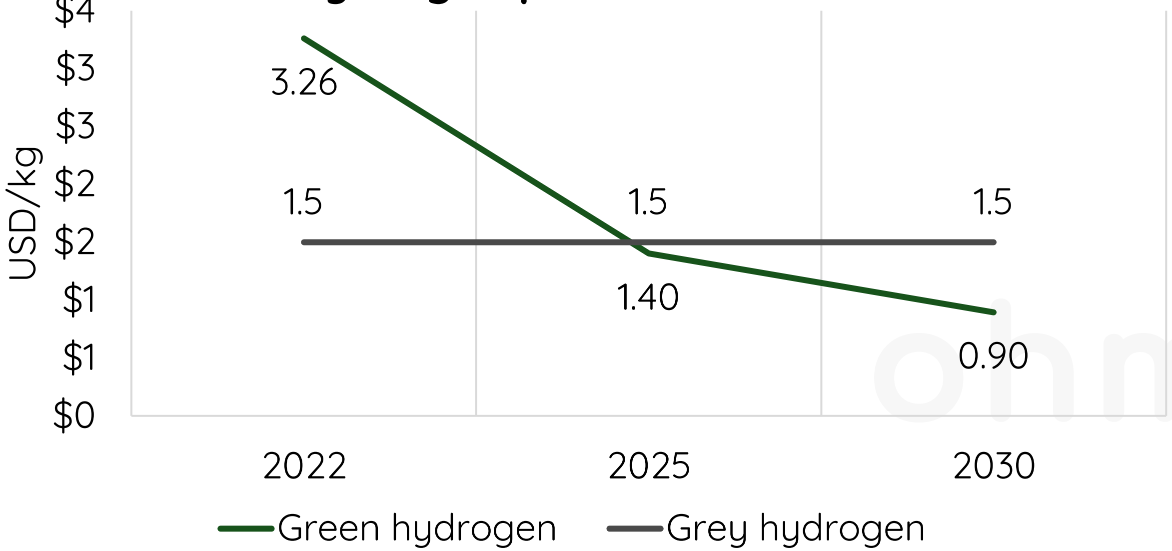
Note:

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

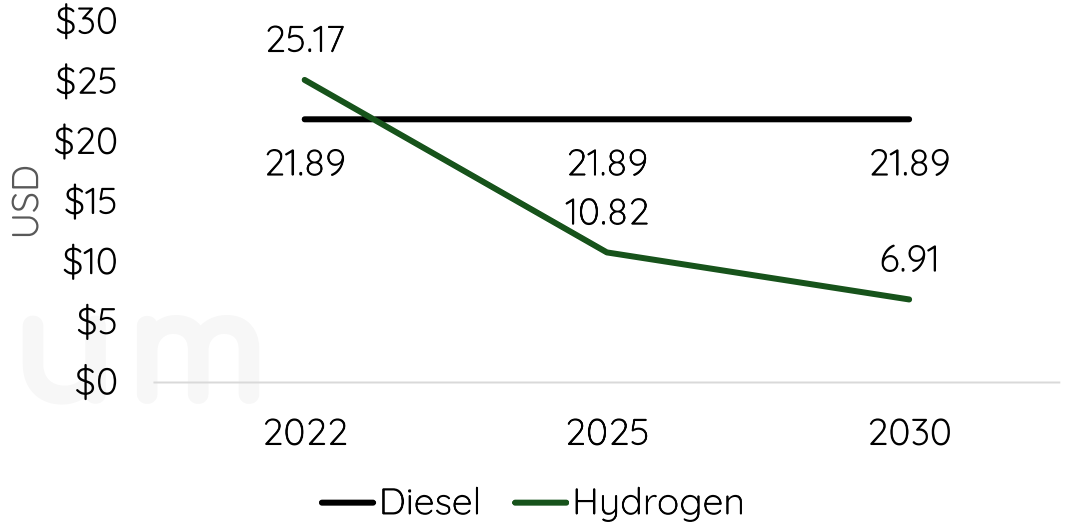
Source: Global Hydrogen Review, pg. 44, IEA 2021; State of the Hydrogen Market: Key Trends and Cost Analysis, REGLOBAL, 2020

Hydrogen can be highly competitive in India before 2025

Price of green hydrogen compared to grey hydrogen possible in India



Refuelling price for 100 km for a long-haul truck



Considerations made:

- Estimated delivered cost of installed solar in India in 2025 is $ 0.012/kWh; Estimated cost of installed solar in India in 2030 is $ 0.006/kWh
- 55kW is needed for 1 kg of H2 – assuming 0.029 USD/kWh, this is $ 1.62
- For a long-haul truck,100 km distance, 40L of diesel required; Equivalent hydrogen required - 7.72kg
- Pricing is without taxes (both state & central)
- Dealer's margin removed

Green H_2 fuel will be cost competitive with diesel by 2023
Green H_2 will be cost competitive with grey H_2 before 2025

Proposed policies such as a) dollar denominated RE tariffs, b) zero RE transmission charges, and c) PLI subsidy will rapidly reduce the green hydrogen costs in India

About Ohmium

Mission

Ohmium is making Green Hydrogen a reality today. The company's suite of innovative electrochemical products enables customers to achieve their sustainable energy goals in industrial, transportation and energy projects.

Highlights

- Deep domain expertise in electrolyzer, fuel cell and renewable energy industries.
- R&D Centers in San Francisco Bay, United States and Bangalore, India.
- Manufacturing capacity of 500 MW and ramping toward 2+ GW in India.
- Diverse team of about 300 people.
- Global presence focused on Europe, North America, Middle East, India and Australia.

Product Advantages

- **Advanced Technology**: Interlocking modular proton exchange membrane (PEM) technology with American IP and Indian based manufacturing cost structure.
- **Scalable:** Rapidly installed standard interlocking modular units to expand projects from MWs to Gigawatts without technology scaling risk.
- **High Performance**: Optimized supply chain and roadmap resulting in low Levelized Cost of Hydrogen (LCOH).
- **Dynamic Operation**: Fully compatible with renewable energy resources with PEM safety.
- **Proprietary Power Electronics:** Flexible and dynamic power electronics for an enhanced operation.
- **Efficient Land Utilization**: Flexible standard modular design for project layout optimization and stacking.
- **Short Production Downtime:** Rack-in/rack-out design for minimum maintenance downtime.

Short downtime

Low installation cost

Operation flexibility

Efficient land use

Scalable standard modular units

Construction in phases

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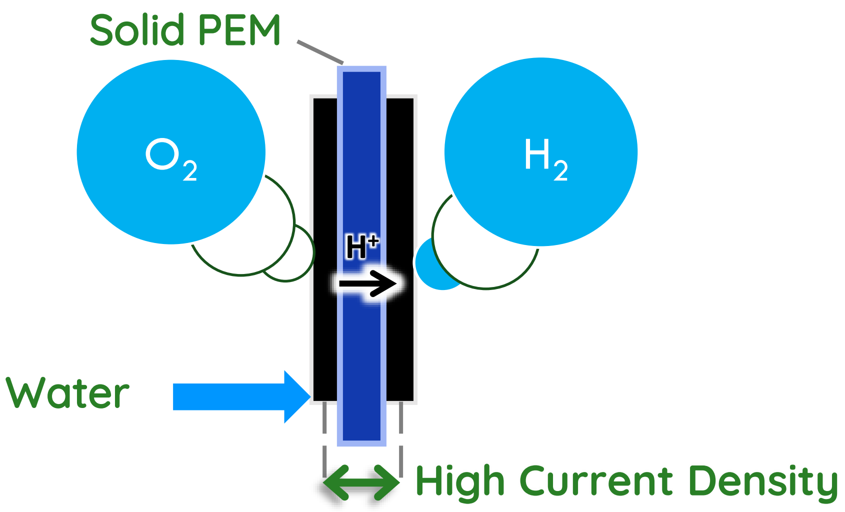
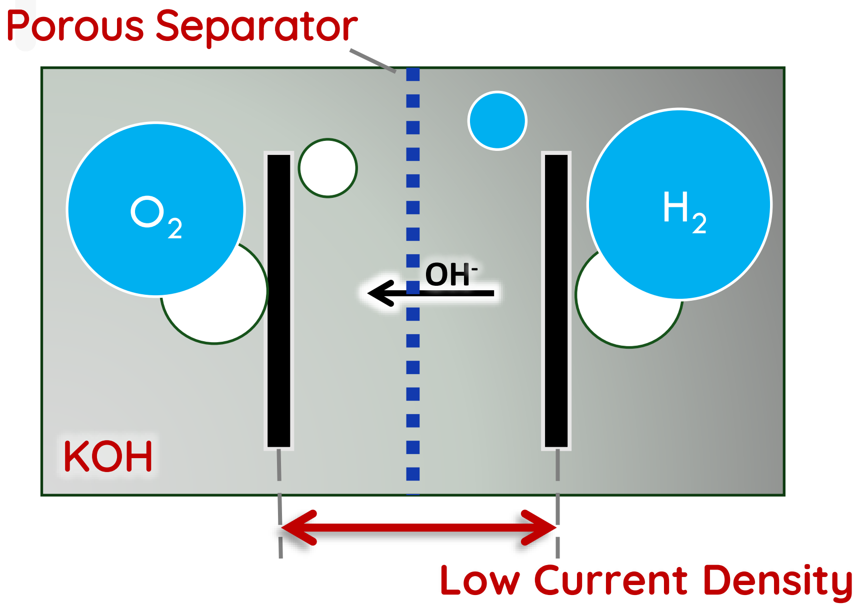
PEM versus Alkaline

A brief technology comparison

PEM Value

	Characteristic	Alkaline	PEM
Safety	Proton Conductor	30 wt% KOH	Solid Polymer
	Water and Gas Carrier	30 wt% KOH	DI Water
	Chemical Compatibility	KOH Corrosion	Noncorrosive
	Operating Mode	Isobaric Required	Differential Pressure
Renewable	Startup Time	60 + Mins	15 mins
	Turn Down Ratio	2.5 : 1	10 : 1
	Operating Temp. (˚C)	80 - 90	50 - 80
LCOH	Volume / Weight	X	1/3 X
	Elec. Required (kWh/kg)	50 to 73	50 to 73
	Electrode Materials	Non-Precious	Precious Metal
	Current Density (A/cm2)	0.2 – 0.7	1.0 – 2.2
	Cell Ion Conductor (Electrolyte)	Available Caustic Liquid	Solid Polymer





References: Yujing Guo et al, Earth and Environmental Science 371 (2019) 042022, Mark Ruth et al, 2017 Fuel Cell Seminar

Ohmium Interlocking Module PEM Design

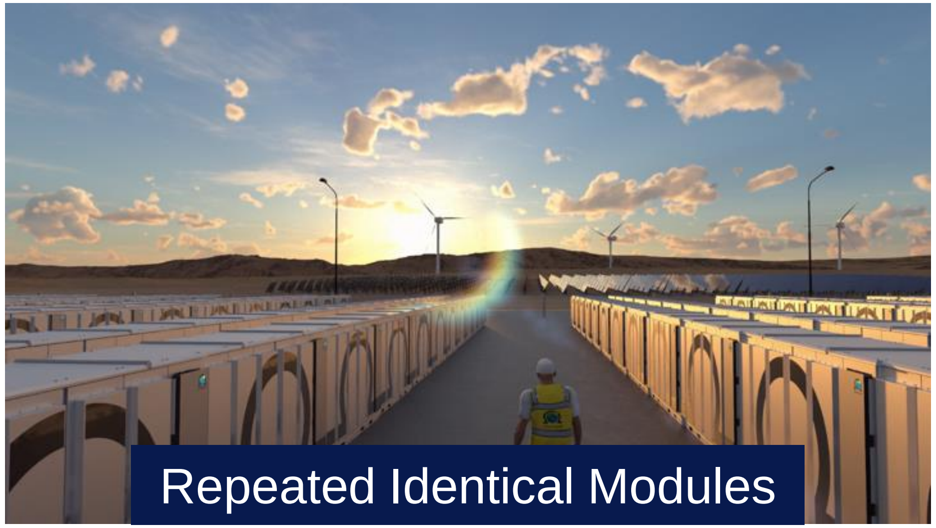
Ohmium Interlocking Modular PEM Design

Design & Construction:

- Standard block design & construction (repeatable identical modules)
- Ease of installation (human-scale design)
- Low construction cost (short installation period)
- Phased construction (build as market grows)
- Efficient use of land (layout optimization & stacking)

Operation & Maintenance:

- Flexible to operate & maintain (interlocking modules)
- Short production downtime (rack-in/rack-out)

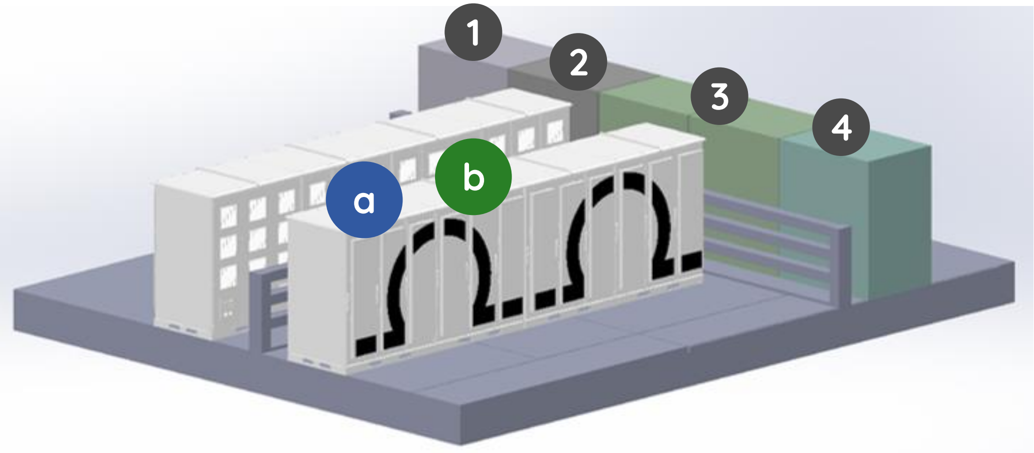

Repeated Identical Modules

Rack Out / Rack In Service

Comprehensive Hydrogen Solution

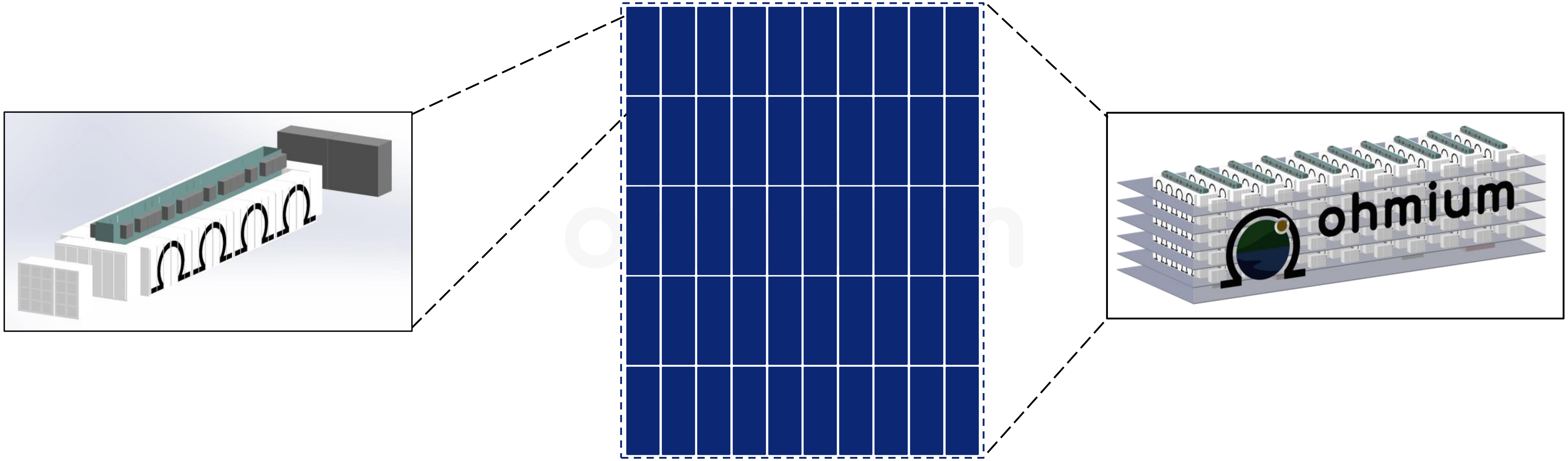
Production Specs	
H_2 Production	4 x 6.0 kg/hr
H_2 pressure	Up to 27 bar (electrochemical)
H_2 purity	≥ 99.99% (high purity)
Output dynamic range	10% - 100%
Ramp-up time	5 sec
O_2 Production	Optional
Inputs	
Power	4 x 300kW_{dc} 480VAC or 415VAC 3phase 50 Hz or 60 Hz
Water	4 x 1.4 SLM DI water Or 4 x 2.7 SLM City water
Other	
Ambient temp.	-20 ˚C to 50 ˚C
Dimensions (LWH)	4 x (2) Cabinets (1.8 x 1.3 x 1.8 m) Auxiliary Cabinets (1.8 x 1.3 x 1.8 m)
SCADA & Controls	Fully compatible
Comm Interface	TCP/IP, RS485
Conformity	Designed to UL 2264A

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



- a — Power Electronics Module
- b — Hydrogen Module
- 1 — Telecom Module
- 2 — Power Distribution Module
- 3 — Cooling Module
- 4 — Water Module

Standard Block Architecture



Rapid design, installation and maintenance for large scale projects

Proprietary stacking design for efficient land utilization

Key steps for making India a leader in the hydrogen economy

1. Define bold targets for green hydrogen usage across the sectors for 2030
    a. 20 million tonnes of green H2 by 2030 is an attainable goal
    b. Our targets shouldn't be constrained only be domestic demand

2. For India to become a hub, all global electrolyser companies need to set up their bases for R&D and manufacturing in India early on

3. Provide PLI support to manufacturers for at least 5 years
    a. Eligibility should be minimum of 60% domestic content
    b. Extend PLI support to promote manufacturing of value chain components such as storage tanks, compressors, and dispensers etc.

4. Rationalise trade duties to boost local manufacturing and value addition
    a. Impose/increase duties on finished products and stacks (7.5% to 25%)
    b. Reduce duties for raw materials and critical components such as membrane and semiconductors where India doesn't have a competitive advantage

Thank You

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