6th

WORLD HYDROGEN EXPO 2025

Conference

Program Book

Dec 4(Thu) – Dec 7(Sun), 2025

Kintex, S. Korea

Hydrogen Pioneers :
Innovate, Unite, and Accelerate

HYUNDAI MOTOR GROUP

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HTWO

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Hydrogen, Beyond Mobility, New Energy for Society

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지난 30여 년간 기술 투자를 이어오며, 이동수단을 넘어 수소의 생산, 저장, 운송, 활용까지
전 과정을 포괄하는 종합적인 밸류체인을 구축해 나가고 있습니다.

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Hyundai Motor Group is committed to leading the global energy transition, mobilizing sustainable energy for humanity.

As the world's first to commercialize hydrogen fuel cell vehicles, Hyundai Motor Group has continued investing in hydrogen technologies for almost three decades, built on a steadfast belief in hydrogen. Going beyond mobility, Hyundai Motor Group is building a comprehensive hydrogen value chain that encompasses production, storage, transportation, and utilization.

By integrating its capabilities, Hyundai Motor Group introduced HTWO, its hydrogen business brand and business platform, to deliver end-to-end solutions across the entire hydrogen value chain. HTWO serves as an open platform for collaboration, partnership, and investment, continuously evolving and growing to drive the acceleration of a sustainable hydrogen society.

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이노베이션으로 답하다

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'Global No. 1'을 모토로 글로벌 환경과 미래까지 생각하는 효성은 끊임없는 도전과 혁신을 통해 글로벌 시장을 이끌어 나가고 있습니다.

HYOSUNG HEAVY INDUSTRIES

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- Creating a viable market for green hydrogen and ammonia

Timetable

Leadership & Market Insight

December 4 (THU), 13:30-16:05 **Venue : Hall 6C, KINTEX II**

Time		Program	Title / Speaker
Keynote			
13:30-13:40	10'	Speech	Korea's Hydrogen Economy: Current Status and Policy Direction **Deokyeol Park** (Director General, Ministry of Climate, Energy and Environment)
13:40-13:50	10'		Clean Hydrogen Standardization Strategy and Recommendations **Sunghwan Cho** (President, International Organization for Standardization (ISO))
Leadership Insight			
13:50-14:05	15'	Speech	Germany's Hydrogen Economy: Current Status and Policy Direction (EU RED III implementation, national hydrogen strategy) **Axel Bree** (Deputy Director General for Hydrogen Ramp-up and Energy Research, Federal Ministry for Economic Affairs and Energy
14:05-14:20	15'		Japan's Hydrogen Economy: Current Status and Policy Direction (national hydrogen strategy, industry initiatives) **Masahiro Tachibana** (Counsellor, Embassy of Japan In the Republic of Korea)
14:20-14:35	15'		Canada's Hydrogen Economy: Current Status and Policy Direction (Hydrogen Strategy for Canada) **Sunny Park** (Senior Economic Officer, Embassy of Canada to the Republic of Korea)
14:35-14:50	15'		Fueling the transition to a Net Zero future - New South Wales Government investment in clean energy **Penny Sharpe** (Minister for Energy, NSW Geovernment)
14:50-15:05	15'	**Break Time**	
Market Insight			
15:05-15:20	15'	Speech	Helping Accelerate the Hydrogen Economy: Scaling Innovation Through Materials Science **Mark Copman** (President – New Growth Ventures, 3M)
15:20-15:35	15'		Hydrogen mobility activation: lessons learnt from Europe and Korea **Erwin Penfornis** (Vice President, Air Liquide)
15:35-15:50	15'		Latin America's Clean Hydrogen Ecosystem and Business Development Trends **Juan Antonio Gutierrez** (Technical Advisor, H2PERU)
15:50-16:05	15'		Northeast Asia's Clean Hydrogen Ecosystem and Business Development Trends **Audrey MA** (Vice President, Refire)

Hydrogen Deep Dive I : Global Hydrogen Outlook

December 5 (FRI), 13:30-16:00 **Venue : Hall 6C, KINTEX II**

Time		Program	Title / Speaker
Global Business Outlook			
09:30-09:45	15'	Speech	Global State of Play of Hydrogen **Ivana Jemelkova** (Chief Executive Officer, Hydrogen Council)
09:45-10:00	15'		Global Hydrogen Policy and Market Trends **Neal Won** (Principal Analyst, S&P Global)
10:00-10:15	15'		Hydrogen for Development: 10 GW Lighthouse Initiative **Myoe Myint** (Senior Energy Specialist, World Bank)
10:15-10:30	15'		Overview of the Northeast Asia Clean Hydrogen Power Generation Market **Lim Yeon Yi** (Senior Manager, KPX)
10:30-10:45	15'		H2Global: A Novel Financing Mechanism to Accelerate Global Clean Hydrogen Trade **Markus Exenberger** (Executive Director, H2Global Foundation)
10:45-11:15	30'	Panel Discussion	Investment and Market Growth Outlook of Global Clean Hydrogen Projects Moderator : **Neal Won** (Principal Analyst, S&P Global) Panelists : **Myoe Myint** (Senior Energy Specialist, World Bank) **Lim Yeon Yi** (Senior Manager, KPX) **Markus Exenberger** (Executive Director, H2Global Foundation)
11:15-13:30	135'	**Lunch Break**	
Global Demand Outlook			
13:30-13:45	15'	Speech	LH2-based Global Hydrogen Supply Chain Development and Demand Expansion Strategy **Kenji Yoshimura** (Kawasaki Heavy Industries)
13:45-14:00	15'		Hydrogen sector in Spain **Javier Brey** (President, Spanish Hydrogen Association (AeH2))
14:00-14:15	15'		POSCO HyREX Development Status **Jang Hoi Choi** (General Manager, Posco Holdings)
14:15-14:30	15'		Power Transition in Data Centers **Inki Choi** (Senior Manager of Strategy and Marketing, Bloom Energy Korea)
14:30-14:45	15'		Green Hydrogen and Regional Decarbonisation: Helios Project at Port Augusta to Support Local Superpower Industries **Jong Hwa Lee** (Head of Ammonia Hydrogen Business and Executive Vice President, Hanwha Impact)
14:45-15:00	15'	**Break Time**	
15:00-15:15	15'	Speech	Mobility Sector Hydrogen Demand and Market Outlook **Yong Tae Kimm** (Vice President, Hyundai Motor)
15:15-15:30	15'		India's Industrial Hydrogen Demand and Market Growth Outlook **Nishaanth Balashanmugam** (CEO, GH2 India)
15:30-16:00	30'	Panel Discussion	Hydrogen Price Stability and Its Impact on Global Demand Expansion Moderator : **Nishaanth Balashanmugam** (CEO, GH2 India) Panelists : **Kenji Yoshimura** (Kawasaki Heavy Industries) **Jang Hoi Choi** (General Manager, Posco Holdings) **Inki Choi** (Senior Manager of Strategy and Marketing, Bloom Energy Korea) **Jong Hwa Lee** (Head of Ammonia Hydrogen Business and Executive Vice President, Hanwha Impact) **Yong Tae Kimm** (Vice President, Hyundai Motor) **Ralph Foong** (Chief Hgydrogen Officer, City Energy)

Hydrogen Deep Dive II : International Hydrogen Technology Standardization

December 5 (FRI), 10:00-11:15 **Venue : Room 301, KINTEX II**

Time		Program	Title / Speaker
Global Clean Hydrogen Technology Standardization Strategy			
10:00-10:15	15'	Speech	Proposed US Regulations and Impact on Global Hydrogen Compliance and Certification **Frank Wolak** (President, Fuel Cell and Hydrogen Energy Association)
10:15-10:30	15'		Status and Strategy of Korea's Hydrogen Fuel Cell Standardization (IEC/TC 105) **Hong-Ki Lee** (Chair, IEC/TC 105) (Vice President, Woosuk University)
10:30-10:45	15'		Global Clean Hydrogen Technology Standardization Strategy **Laurent Antoni** (Executive Director, IPHE)
10:45-11:00	15'		Hydrogen Technology Standardization in Europe and Germany : A Catalyst to Drive Green Hydrogen Solutions **Klemens Ilse** (Deputy Director, Fraunhofer IWMS)
11:00-11:15	15'		Commercial Hydrogen Measurement Standards Development of United States & California **Kevin Schnepp** (Director, California Department of Food and Agriculture)
11:15-11:45	30'	Panel Discussion	Investment and Market Growth Outlook of Global Clean Hydrogen Projects Moderator : **Laurent Antoni** (Executive Director, IPHE) Panelists : **Hong-Ki Lee** (Chair, IEC/TC 105) (Vice President, Woosuk University) **Klemens Ilse** (Deputy Director, Fraunhofer IWMS) **Kevin Schnepp** (Director, California Department of Food and Agriculture)

Hydrogen Deep Dive III : Clean Ammonia

December 5 (FRI), 10:00-11:15 **Venue : Room 302, KINTEX II**

Time		Program	Title / Speaker
Global Technology and Policy Trends for the Expansion of Clean Ammonia			
10:00-10:15	15'	Speech	Global Clean Ammonia Market and Outlook **Alexander Oliver Bower** (Global Head of Marketing & Sales, Gentari Hydrogen Sdn Bhd)
10:15-10:30	15'		Ammonia Cracking Technologies: Status and Outlook **SeongHoon Woo** (CEO, Amogy)
10:30-10:45	15'		Development of Ammonia Fuel System for Marine Applications **HoKi Lee** (Vice President, Samsung Heavy Industries)
10:45-11:00	15'		Progress and Outlook of the Green Ammonia Project by Hive Energy **Colin Loubser** (CEO, Hive Energy Africa)
11:00-11:15	15'		Investment Strategy for Green Ammonia Infrastructure in Korea **KwangJun Kim** (Senior Executive Director, Saman Corporation)
11:15-11:30	15'		Ammonia Adsorbents as Key Enabling Technologies for a Clean Ammonia Society **KwangBok Yi** (Professor, Chungnam National University)
11:30-12:00	30'	Panel Discussion	Technological and Economic Challenges for Clean Ammonia Utilization Moderator : **KwangBok Yi** (Professor, Chungnam National University) Panelists : **Alexander Oliver Bower** (Global Head of Marketing & Sales, Gentari Hydrogen Sdn Bhd) **SeongHoon Woo** (CEO, Amogy) **HoKi Lee** (Vice President, Samsung Heavy Industries) **Colin Loubser** (CEO, Hive Energy Africa) **KwangJun Kim** (Senior Executive Director, Saman Corporation)

Hydrogen Deep Dive V : Hydrogen : Future to TECH

December 5 (FRI), 13:00-16:15 **Venue : Room 302, KINTEX II**

Time		Program	Title / Speaker
Breakthroughs in Hydrogen Production Techniques			
13:00-13:15	15'	Speech	From Waste to Value: CCUS & Sustainable Hydrogen Pathways for Industrial Decarbonization **Marat Mayan** (Founder & CEO, Airovation Technologies)
13:15-13:30	15'		Project Helios - Cement Production Decarbonisation through Green Hydrogen **Robert Saunders** (Managing Director, Elecseed)
13:30-13:45	15'		Catalyzed heat exchanger for fuel processing **Amin Mehdipoor** (Business Development Manager, Catator AB)
13:45-14:00	15'		Precision hydrogen flow measurement in SOFC and SOEC applications **Peter Brouwer** (Market Developer Renewable Energy, Bronkhorst High-Tech B.V.)
14:00-14:15	15'		Accelerating clean hydrogen solutions with High-efficiency heat exchangers **MyoungSoo Shin** (Professional of Sales Manager,Alfa Laval)
14:15-14:30	15'		Scaling Economic Industrial Decarbonization: How Utility Global H2Gen® Technology is delivering Decarbonization without Compromise for the Hard-to-Abate Sectors **Vladimir Novak** (Chief Commercial Officer, Utility Global, Inc.)
14:30-14:45	15'	**Break Time**	
Exploring New Hydrogen Storage and Distribution Solutions			
14:45-15:00	15'	Speech	Materials challenges in the Hydrogen Economy **Jens Eichler** (Hydrogen Technology and Business Architect, 3M)
15:00-15:15	15'		Large-scale liquid hydrogen technologies enabling intercontinental hydrogen transportation:Techno-readiness & economic assessment **Sébastien Lichtle** (Director of LH2 Product Line,Air Liquide E&C)
15:15-15:30	15'		BEYOND THE BOND, ADHESIVE SOLUTION FOR HYDROGEN APPLICATION **Hyunseob Shim** (Lead Application Engineer, Henkel Korea)
15:30-15:45	15'		Case Study & Research for Hydrogen Refueling Station Performance Test Apparatus **Moonbeom Heo** (Team Leader, TÜV SÜD KOREA)
15:45-16:00	15'		"Industrializing Hydrogen Storage for Global Mobility" How OPmobility is enabling the next generation of zero-emission transport **Chanjoo Park** (Asia Managing Director, Opmobility)
16:00-16:15	15'		TBD **Mikaa Blugeon-Mered**

Country Day : Australia Day

December 4 (THU), 13:30-16:10 **Venue : Room 306**

Time		Program	Title / Speaker
13:30-14:00	30'		Registration & Networking
Session I. Opening Function			
14:00-14:03	3'	MC	Opening Comment **Dane Richmond** (Trade Commissioner, Austrade)
14:03-14:10	7'		Opening speech **Jeff Robinson** (Australian Ambassador,)
14:10-14:30	20'	Speaker	"Key-note Speech Australia's cleantech & hydrogen industry – a turning point for Australia?" **Dr. Nigel Nambhujun** (Senior Analyst, Rystad Energy)
Session II. NSW State Government			
14:30-14:32	2'	MC	Opening Comment **Sunah Kim** (Associate Directo, Investment NSW Seoul)
14:32-14:39	7'	Speaker	Accelerate the clean fuel transition of carbon-intensive industry: Direct injection dual-fuel technology **Dongchan Kim** (Engineering Lead, Decarice)
14:39-14:46	7'	Speaker	"Port of Newcastle: Australia's most advanced hydrogen export project " **Sheena Martin** (Senior Manager Government Relations, Port of New Castle)
14:46-14:53	7'	Speaker	"Beating Diesel: How Rux Energy's Advanced Metal Organic Framework (MOF) Storage Materials will slashthe cost of Hydrogen" **Jehan Kanga** (Founder and CEO, Rux Energy)
14:53-15:00	7'		How Fugu is Pairing Hydrogen and DAC to Produce Green Methanol At Scale **Luke Marshall** (CEO & Co-Founder, Fugu)
Session III. SA State Government			
15:00-15:10	10'	MC	"Driving the Energy Transition South Australia's gateway for innovation and investment" **Sally Townsend** (Regional Director, MC of SA session)
15:10-15:20	10'	Speaker	Green Hydrogen and Regional Decarbonisation: Helios Project at Port Augusta to Support Local Superpower Industries **Kyu Hong Lee** (Chief Strategy Officer, Elecseed)
15:20-15:30	10'	Speaker	Policies, Market Challenges and Collaboration Opportunities in Clean Tech and Renewables between Korea and Australia **Neil Thompson**
Session IV. WA State Government			
15:30	-	MC	Opening comment **Ryan Yi** (Business Development Manager, MC of WA Session)
15:30-15:40	10'	Speaker	The Cardinia CCS Project: A Carbon Storage Solution for the Hard-To-Abate Industries **Peter Hoiles** (General Manager, InCapture)
15:40-15:50	10'	Speaker	Change the future of decarbonization, without changing your engines **Mark Burke** (Group Corporate Development Manager, Hy-Boost Technology)
15:50-16:00	10'	Speaker	Australian Natural Hydrogen Exploration **Krista Davies** (Chief Operating Officer, Prominence Energy)
16:00	-		Closing & Group photo

Country Day : Canada Day

December 4 (THU), 13:30-16:00 **Venue : Room 307**

Time		Program	Title / Speaker
13:30 - 13:35	5'		Opening by TCS / B.C. Korea
13:35 - 13:50	15'		Canada's Hydrogen Roadmap: Building an Economically Prosperous, Low-Carbon Future **Nicolas Hilario** (Vice-President, Operations, Canadian Hydrogen Association)
13:50 - 14:05	15'		Hydrogen Opportunities from Alberta in the AI Era: New Potential for Korea–Canada Cooperation. **Victor Lee** (Counsellor, Alberta Government Representative in Korea)
14:05 - 14:20	15'		Introduction to AVL Fuel Cell Canada **Nam Gi Kim** (Mechanical Engineer, AVL Fuel Cell Canada
14:20 - 14:35	15'		Infrastructure Independent Energy with H2M's Innovative Hydrogen Storage Material **Grace Quan** (President and CEO, Hydrogen In Motion Inc. (H2M))
14:35 - 14:50	15'		Advanced Fast-Cycle Rotary Valve PSA for High-Purity Hydrogen Purification **John Li** (Director-PSA Sales, Ivys Adsorption)
14:50 - 15:05	15'		Powertech Labs Introduction **Tanja Smutny** (Engineering Team Lead, "Hydrogen Industry Technology and Testing Group, Powertech Labs")
15:05 - 15:10	5'		Closing by TCS / B.C. Korea

Country Day : UK Day

December 5 (FRI), 10:30-12:00 **Venue : Room 306**

Time		Program	Title / Speaker
10:30 - 10:50	20'	Speaker	Gas Detection Solutions in the Hydrogen Industry **Jarod Lim** (Area Sales Manager, Crowcon Detection Instruments)
10:50 - 11:10	20'	Speaker	Innovative Sealing Solutions Enabling Safe and Reliable Hydrogen Applications **Alesssandro Cavalli** (New Energy Business Development Manager, Flexitallic UK Ltd.)
11:10 - 11:30	20'	Speaker	Role of Dual Fuel Hydrogen in the transition to Net Zero - Dual Fuel Hydrogen Combustion **Paul Turner** (Technical Director, ULEMCO Ltd.)
11:30 - 11:50	20'	Speaker	Creating a viable market for green hydrogen and ammonia **Youngsun Om** (Business Development Analyst, Yamna)

WORLD HYDROGEN EXPO 2025 6th
Conference

Leadership & Market Insight

WORLD HYDROGEN EXPO 2025 6th Conference

Keynote

Keynote 1

Korea's Hydrogen Economy: Current Status and Policy Direction



Deokyeol Park
Director General, Ministry of Climate,
Energy and Environment

Education

· B.A. in Economics, Korea University
· Current: Director General, Hydrogen and Heat Industry Policy Bureau, Ministry of Climate, Energy and Environment (MCEE)
· Former: Director, Petroleum Industry Division, Ministry of Trade, Industry and Energy (MOTIE)
· Former: Director, Gas Industry Division, Ministry of Trade, Industry and Energy (MOTIE)

Keynote 2

Clean Hydrogen Standardization Strategy and Recommendations



Sunghwan Cho
President, International Organization for Standardization (ISO)

Education

· 1993 — Stanford University, Ph.D., Mechanical Engineering
· 1986 — Seoul National University, M.S., Mechanical Engineering
· 1984 — Seoul National University, B.S., Mechanical Engineering

Professional Career

· 2024 – Present — President, ISO
· 2020 – 2023 — President & CEO, Hyundai Mobis
· 2019 – 2020 — Executive Vice President, Head of R&D Division, Hyundai Mobis
· 2018 – 2019 — Executive Vice President, Head of R&D Division, Hyundai Motor Company
· 2017 – 2018 — CEO & Executive Vice President, Hyundai Autron
· 2015 – 2017 — Senior Vice President, Head of R&D Planning & Coordination, Hyundai Motor Company
· 2012 – 2015 — Senior Vice President, Head of Hyundai America Technical Center, Hyundai Motor Company
· 1994 – Senior Researcher, Hyundai Motor Company

Company Introduction

The International Organization for Standardization (ISO) is an independent, non-governmental global organization that brings together national standards bodies from 170 countries. ISO develops voluntary, consensus-based international standards created by experts from industry, government, academia, and civil society. These standards provide solutions to real-world challenges by supporting quality, safety, efficiency, and sustainability across sectors. Through globally recognized standards, ISO enables smoother international trade, strengthens consumer trust, and helps organizations innovate responsibly. By connecting global expertise and building common frameworks, ISO contributes to a safer, more reliable, and more resilient world.



ISO/TC 197 – Hydrogen technologies

Hydrogen serves as a clean energy carrier across industries, transportation and power generation

ISO/TC 197 develops standards to:

- Ensure safe production, storage and transport of hydrogen
- Support the integration of hydrogen into energy systems
- Foster innovation in hydrogen technologies

2



ISO/TC 197's Objectives

Science-based Standards

Develop internationally harmonized standards grounded in rigorous scientific research and real-world testing

Safety & Reliability

Ensure safety, reliability, and interoperability across all hydrogen applications and systems

Building Trust

Build confidence among governments, industry stakeholders, and end-users through transparent standards

Energy Transition

Advance the global clean energy transition with frameworks that enable sustainable hydrogen deployment

3



4

Why their work matters

- Infrastructure investments define energy trade
- Must pace with technological advances
- ISO/TC 197 in 2025:
  - 9 published standards
  - 16 documents in development
- New technologies implemented with clarity and speed
- Industry confidence to scale, investor assurance to commit capital



A milestone for hydrogen

ISO/TS 19870 from ISO/TC 197/SC 1 establishes a **global method for calculating greenhouse gas emissions** throughout the hydrogen lifecycle – from production to consumption.



- Enhances transparency in the hydrogen economy
- Builds investor confidence and consumer trust
- Provides a methodology for low-emission hydrogen
- Increases competition between different hydrogen pathways
- Supports decisions on hydrogen deployment
- Facilitates certification and sustainability assessment

Partnerships

- ISO provides a platform for cross-sectoral cooperation
- Partnerships harmonize the standards landscape and lay the foundation for meaningful climate action

UNIDO
International Energy Agency
IRENA International Renewable Energy Agency
GREENHOUSE GAS PROTOCOL
Hydrogen Council
ISO

7

ISO and GHG Protocol

GREENHOUSE GAS PROTOCOL

- Harmonize our existing portfolios and co-develop new standards



- A common language for emissions accounting
  - Simplify processes, increase consistency and reduce measurement and reporting burdens
    - Standards that support robust, science-based decarbonization – reducing market confusion

8

ISO and Hydrogen Council

- Advancing global standards for hydrogen and its derivatives across the value chain
- Awareness raising, capacity building, stakeholder engagement
- Accelerate the safe, efficient and widespread deployment of hydrogen and its derivatives through harmonized International Standards

9





10

International participation (1)

- International participation in standards development is essential:
  - Hydrogen standards must reflect all perspectives, particularly those of developing countries
  - Industry innovation benefits from harmonized international approaches
  - Climate goals demand coordinated action across borders

International participation (2)

- ISO standards are consensus-based, with input from across sectors
- The active participation of ISO's 175 members ensures broad acceptance
- 44 countries actively participate in ISO's hydrogen committee, representing both developing and developed countries

11



Contributing to standards development

- Expert input to working groups shapes hydrogen technologies
- Real-world experience refines standards and accelerates their adoption
- National needs reflected in global decisions
- Emerging scientific and technical knowledge helps standards keep pace with rapid innovation

12



Standards adoption benefits

- Guaranteed safety, easier market access and lower deployment costs
- Harmonized regulation and seamless international trade
- Reduced risk and quicker market acceptance
- Scalability and compatibility as markets grow

13





How to engage

- ISO members can join our hydrogen committee, ISO/TC 197
- Industry experts can engage with their national standards body to participate in working groups

Key takeaways

- The hydrogen economy is at a decisive moment
- International Standards are the bridge between ambition and achievement, innovation and trust
- Let’s ensure that hydrogen fulfils its promise as a cornerstone of the clean energy transition

15



Thank you.

Making lives *easier*, *safer* and *better*.

KATS Strategy & Planning Team for ISO President

ISO

WORLD HYDROGEN EXPO 2025 6th Conference

Leadership Insight

WORLD HYDROGEN EXPO 2025 6th Conference

Leadership Insight 2

Germany's Hydrogen Economy: Current Status and Policy Direction

(EU RED III implementation, national hydrogen strategy)



Axel Bree

Deputy Director General for Hydrogen Ramp-up and Energy Research, Federal Ministry for Economic Affairs and Energy

Education

1996-1997, Ph.D., Law, Georg-August-Universität, Göttingen, Germany
1998, Master of Laws - LLM, International Law, American University, Washington DC, United States
1987-1993, Law, State Exam, Universität zu Köln, Köln, Germany

Professional Career

After several years in a private law firm, Axel Bree joined the German Federal Ministry for Economic Affairs in 2002. Between 2005 and 2011, he worked in the Federal Chancellery, at the German Embassy in Washington DC (US) and for the World Future Council in London (UK). Since 2011, he held various positions at the Federal Ministry for Economic Affairs, among others being responsible for mining law, industry aspects of energy policy, the hydrogen ramp-up and energy research. Since October 2025, he is in charge of the Sub-Directorate for "International Energy Policy, Federal-State Coordination and Energy Efficiency"

Research Interest

Hydrogen: Global ramp-up, infrastructure, regulation, etc.
International Energy Policy
Energy Efficiency

Speech Summary

Germany's Hydrogen Economy: Current Status and Policy Direction (EU RED III implementation, national hydrogen strategy)
##The speech is currently under preparation. Summary and presentation will be forwarded as soon they are fully prepared.

Company Introduction

The Federal Ministry for Economic Affairs and Energy (BMWE) is a German ministry responsible for economic affairs and energy.

Federal Ministry for Economic Affairs and Energy

H_2 in Germany: Current Status and Policies

World Hydrogen Expo, 04 December 2025

Dr. Axel Bree, Deputy Director General

Marius Strotjohann, Energy Partnership Division

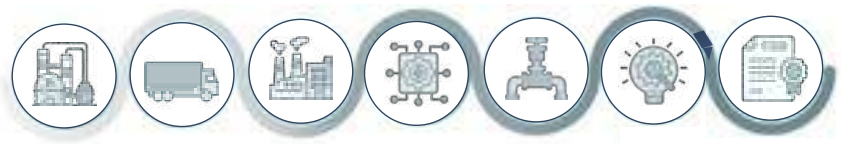
Germany's hydrogen strategy covers a number of sectors and fields of action

Hydrogen (H_2) production & imports
Total demand is currently re-evaluated

Industry
Funding within IPCEI projects and Carbon Contracts for Difference

Infrastructure & supply
European Hydrogen Backbone
Shipping

Certification & approval
Simplification and acceleration in H_2 generation, transport and infrastructure



Transport Sector
H_2 applications stimulated in heavy vehicles
E-fuels as an alternative with focus on maritime and aviation

Electricity
Grid-bound H_2 for energy storage and transport

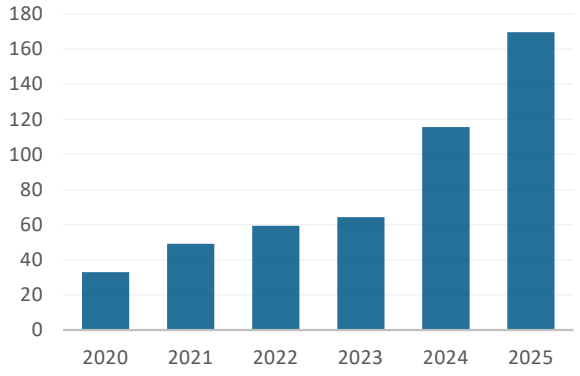
Research, education and innovation
Promotion of R&D and training of specialists
Technology and innovation roadmap

Source: Guidehouse, September 2023 based on BMWK 2023; Icons from flaticon.com

Federal Ministry for Economic Affairs and Energy

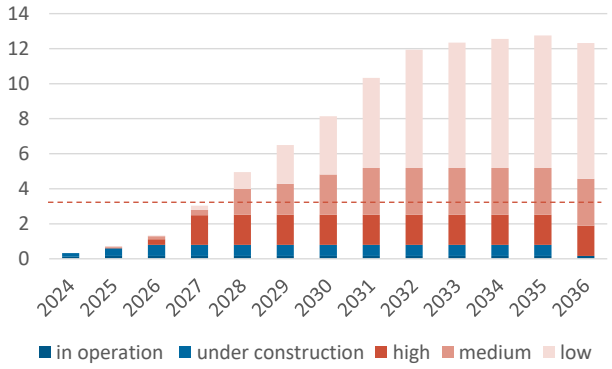
The H2 ramp-up is taking up pace, but many projects fail due to high costs and missing offtake

Electrolysis capacity in MW



Capacity of electrolysis projects in GW

Project status and **probability of realisation**



Source: dena, 25.11.2025

Federal Ministry for Economic Affairs and Energy

The new German government is committed to a pragmatic and flexible H2 ramp-up

Measures derived from the German Energy Transition monitoring

- Flexible and technology-neutral ramp-up
- Concentrate on markets with **high willingness to pay**
- **Production** will be scaled up with clear demand signals
- **Infrastructure** will be developed step by step in close coordination with the demand side
- **More flexible rules** and definition can bring down production costs significantly

Source: BMWE, 25.11.2025

Federal Ministry for Economic Affairs and Energy

The hydrogen core network is the backbone of Germany's H_2 infrastructure

- **Objective of the core network:** To connect key hydrogen locations across Germany (production, storage, import, demand centers).
- According to the approval by BNetzA, **9,040 km of hydrogen pipelines** are planned to go operational between 2025 and 2032, **~60% repurposing** of existing natural gas pipelines, total CAPEX 18.9 bn EUR.
- **Planned capacity for the target year 2032:** entry capacity of approx. 101 GW_{th}, exit capacity approx. 87 GW_{th}.
- **Amortization account** established as financing tool (Inter-Temporal Cost Allocation Mechanism). In July 2025, BNetzA set a **ramp-up fee of 25 EUR/kWh/h/a** for the hydrogen core network.



Source: FNB Gas e.V.

Instruments of the EU / GER to support the H2 ramp-up

- **IPCEI:** Support for projects along the European value chain.
- **European Hydrogen Bank (EHB)**: Financing hydrogen production in the EU through an auction-based mechanism
- **H2Global:** Double-sided auction mechanism matching global supply with EU demand
- **Carbon Contracts for Difference (CCfDs):** Supporting industrial companies in investing in CO_2-neutral production facilities in Germany.
- **Lead markets:** Strengthening demand for climate-friendly basic materials such as steel through public procurement and potentially quotas

Source: BMWE, 25.11.2025

Federal Ministry for Economic Affairs and Energy

Lead markets strengthen demand for climate-friendly materials such as cement and steel

Why?

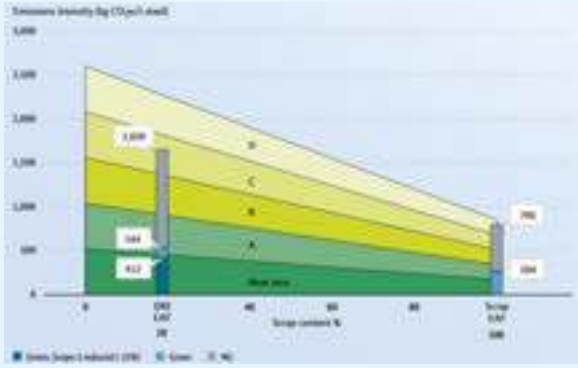
- To incentive investments additionally and increase planning security
- To reduce the need for state funding in the long run and strengthen the effect of carbon pricing
- To support the competitiveness of the new products until they are the "standard" in 2045/ 2050

How?

- Information and labelling requirements regarding the CO2 emissions
- Sustainable public procurement
- Environmental requirements in terms of CO2 emission intensity for the materials put on the market (producers and importers)
- Pricing of scope 3 emission, e.g. from the extraction of raw materials or/and fuels

Climate-friendly steel as example

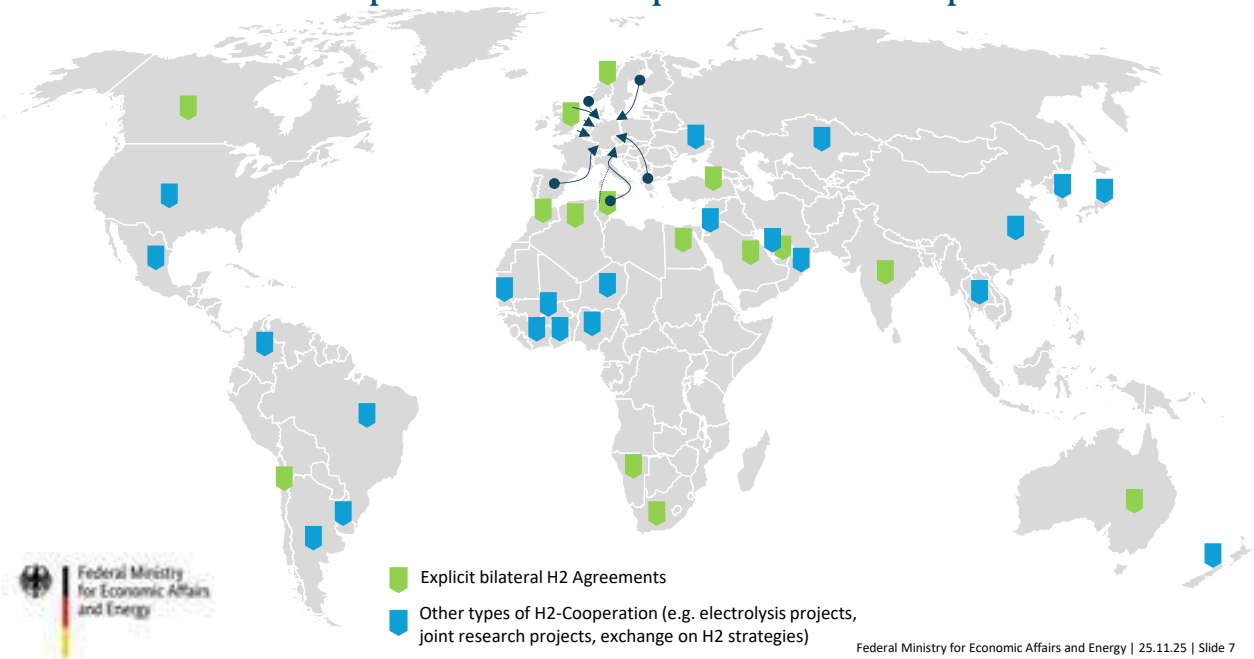
Threshold values for climate-friendly high-grade steel and classification of selected reference plants



Source: Guidehouse, Fraunhofer ISI, Wuppertal Institut (2024)

Federal Ministry for Economic Affairs and Energy

Bilateral H2-Cooperation and Pipeline-based import corridors



Federal Ministry for Economic Affairs and Energy

Explicit bilateral H2 Agreements

Other types of H2-Cooperation (e.g. electrolysis projects, joint research projects, exchange on H2 strategies)

Federal Ministry for Economic Affairs and Energy

Thank you for your attention!

Contact details
Bundesministerium für Wirtschaft und Energie
Scharnhorststr. 34-37
10115 Berlin

Dr. Axel Bree,
Deputy Director General
www.bundeswirtschaftsministerium.de

The import strategy is an integral part of Germany's H2 market development

Goals:

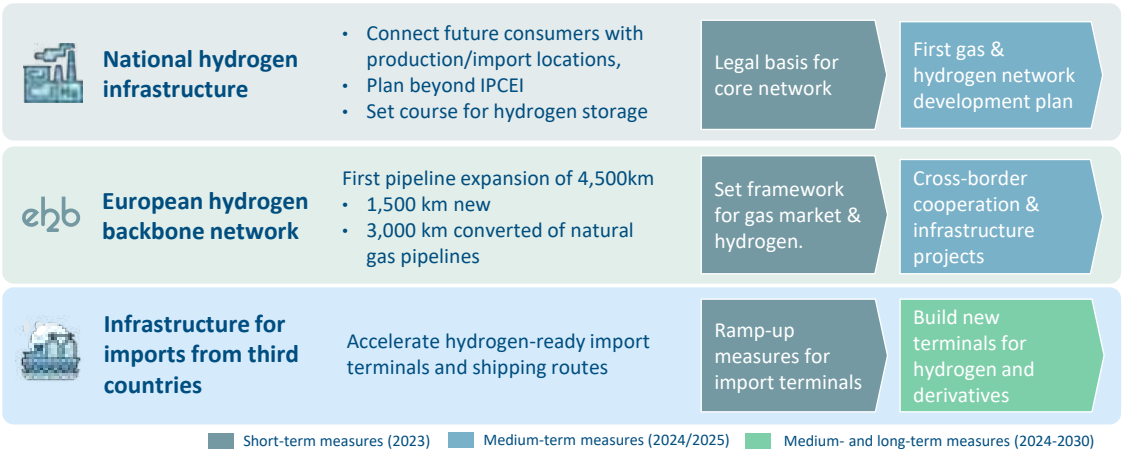
- Ensuring a **reliable supply** of hydrogen and ist derivatives.
- **Informing market participants and partners** about objectives and framework conditions for H2 imports to Germany.
- **Increasing investment security** for H2 production import infrastructure



Measures:

- Strengthening **reliable demand** in Germany, complemented by supply-side support
- **Accelerating infrastructure development** in Germany and the EU
- Establishing of **harmonised certification and product requirements**
- **Deepening EU and international cooperation** on hydrogen
- Supporting the international market ramp-up through targeted R&D policy

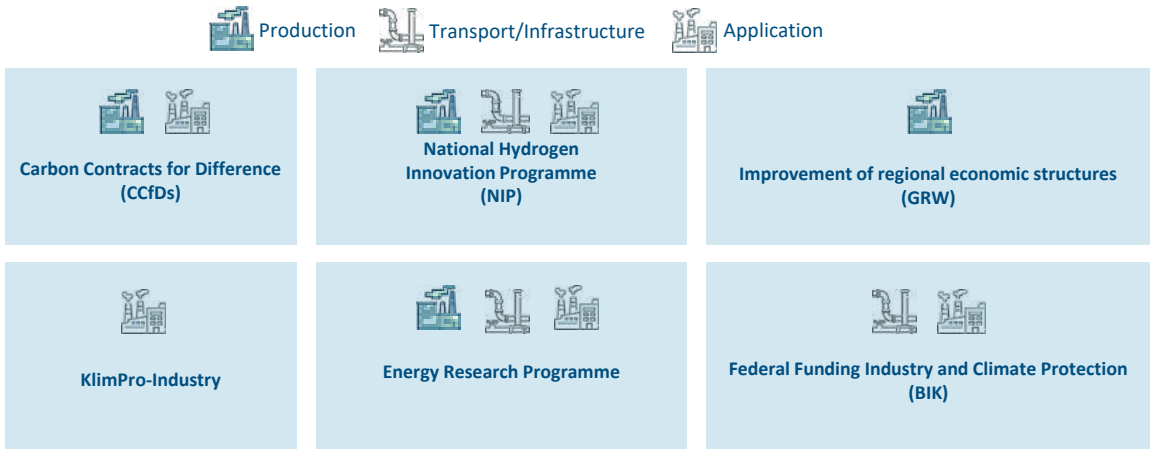
Roadmap to Germany's hydrogen core network



Source: Guidehouse based on BMWK 2023; Graphic: flaticon.com

Federal Ministry for Economic Affairs and Energy | Slide Deck: Energy Transition | 10.10.2025 | Slide 11

Germany supports the H_2-ramp-up as a funder, insurer, and an enabler for innovation



Source: GIZ based on Federal Government 2025 & BMWK 2024; Graphic: flaticon.com

Germany and EU's targeted funding instruments to support green hydrogen projects worldwide

Germany's H_2 funding schemes

- PtX Development Fund
- H2Global
- H2Uppp
- National Funding Guideline

EU's H_2 funding schemes

- European Hydrogen Bank
- Connecting Europe Facility Programme
- Clean Hydrogen Partnership
- IPCEI Hydrogen

Source: GIZ based on BMWE 2025 & European Commission 2025

Leadership Insight

Japan's Hydrogen Economy: Current Status and Policy Direction
(national hydrogen strategy, industry initiatives)



Masahiro Tachibana
Counsellor, Embassy of Japan In the Republic of Korea

Mr Masahiro Tachibana has been Counsellor at Embassy of Japan in ROK since July 2024. Being seconded from Japan's Ministry of Economy, Trade and Industry (METI), he also has been serving as a commercial attache at the Embassy. The scope of his responsibility at the Embassy is essentially encompassed by that of METI, covering a range of topics such as trade, investment, energy, minerals, economic security, SME, start-up and so on.

Mr Tachibana has served as a government official for over 20 years with a wide range of mandates and responsibilities at METI. During his carrier to date, he also served at the government-related organization and the international organization.

Recently, Mr Tachibana assumed Director of International Investment Control Office where he led several significant works in the area of FDI screening, leading both screening individual cases and inter-governmental discussions towards updating the screening policy and mechanism. He also served as a team leader in charge of different areas within METI, including trade negotiators for market access of goods, negotiations and designs of rules of origin applicable to FTAs, bilateral trade relationship with Canada and Mexico, and international cooperation in the power sector before taking over the current position. He also worked for the International Atomic Energy Agency (IAEA) for 3 years as Public Communication Specialist until July 2020 where he led several important projects with tangible outcomes.

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Leadership Insight 4

Canada's Hydrogen Economy: Current Status and Policy Direction
(Hydrogen Strategy for Canada)



Sunny Park
Senior Economic Officer,
Embassy of Canada to the Republic of Korea

Education
1997 – 2001, Korea University, B.A. in Mass Communication and Journalism

Professional Career
Currently serving as a Senior Economic Officer at the Embassy of Canada in Seoul, representing Natural Resources Canada, her focus is on policy monitoring and investment promotion within the dynamic Korean energy and natural resources sectors. This current role builds upon nearly a decade of impactful public service, which included her tenure as a Commercial Specialist for the U.S. Department of Commerce at the U.S. Embassy in Seoul, where she specialized in commercial diplomacy, trade advocacy, and market access for U.S. firms in the Energy, Aerospace, and Defense industries. This extensive track record is grounded in over ten years of diverse professional experience across major multinational companies, including Bloom Energy , DNV , British American Tobacco , Unilever Korea , and AC Nielsen Korea , where she developed expertise in strategy, marketing, and external affairs.

Speech Summary
Canada is positioning itself as a clean energy and mineral security supplier for the Indo-Pacific region. The Hydrogen Strategy for Canada is driving significant growth in low-carbon hydrogen projects. Western Canada offers advantages like cost-friendly feedstock, high ESG standards, and shorter shipping times to Asia. Canada is supporting this through investment tax credits and financing (Canada Growth Fund, EDC, CIB) to establish international hydrogen corridors.

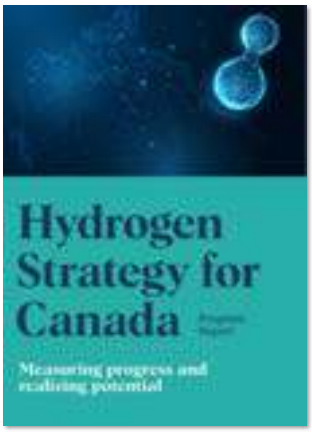
Company Introduction
The Embassy of Canada fosters Canada-Korea relations. Natural Resources Canada (NRCan) promotes the sustainable development of Canada's natural resources, energy, and minerals.


Canada's Hydrogen Opportunity
World Hydrogen Expo 2025
Natural Resources Canada
Ressources naturelles Canada
Canada


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Geopolitical Context
• Current geopolitical context places energy and mineral security as a top priority for government and business leaders.
o Need to secure reliable supplies of energy and minerals
o Need to pursue action to meet net zero goals
• Canada is positioning itself to support the Indo-Pacific region in its transition to a low-carbon footprint using clean energy.
Geopolitical Context
Energy & Mineral Security
Climate Change
Natural Resources Canada
Ressources naturelles Canada
Canada

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3

Hydrogen Strategy Progress Report



- Canada's first Progress Report on the *Hydrogen Strategy for Canada (December 2020)*
- Highlights major project and policy developments
- Describes key market developments across the hydrogen value chain
- Forecasts hydrogen's role in Canada's net-zero objectives by 2050
- Provides a roadmap of next steps

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4

Significant growth across Canada's value chain



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Western Canadian Hydrogen Value Proposition

Western Canada offers advantages as a supplier of world-leading hydrogen and fuel cell sector expertise

- Cost friendly natural gas/electricity feedstock
- High ESG standards and regulatory credibility
- Robust federal and provincial support for hydrogen industry
- Shorter shipping times to Asian markets than US/Qatar
- A full value proposition beyond production, including technology, services, R&D, and IP
- Established fuel cell leadership, testing capacity, and a skilled workforce with decades of sector experience



Low-carbon hydrogen export production from Alberta

- There are currently 2 active low-carbon ammonia projects in Alberta representing over C$8B of potential investment; however, there is currently no clear path forward to transport production from inland to the coast

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Canada is Supporting Competitiveness

- ✓ Clean Hydrogen and Clean Technology Investment Tax Credits (ITCs) – Budget 2025 expands availability of CH ITC to include methane pyrolysis
- ✓ Canada Growth Fund – potential equity financing and investments to support domestic end-use development
- ✓ Export Development Canada – able to provided credit and debt financing for export projects to help de-risk their development
- ✓ Canada Infrastructure Bank – potential debt financing and may provide support for FEEDs (Project Acceleration), expanded under Budget 2025
- ✓ Alignment of production and demand incentives to establish international hydrogen corridors

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Recent Initiatives between Canada and South Korea



British Columbia and Alberta are advancing heavy-duty transportation solutions, collaborating with Hyundai for deploying its XCIENT fuel cell trucks with HTEC, Innovate B.C., and Edmonton Global



In 2024, Ulsan Free Economic Zone Authority signed two MOUs in Alberta, with Alberta's Industrial Heartland Association and Edmonton Global for collaboration on hydrogen.



In 2025, Trigon Pacific Terminals at the Port of Prince Rupert, BC, and Ulsan Free Economic Zone Authority signed an MoU to expand collaboration on hydrogen-as-ammonia exports from Canada to South Korea.

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Thank you!

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Canada

WORLD HYDROGEN EXPO 2025 6th Conference

Leadership Insight

Fueling the transition to a Net Zero future - New South Wales Government investment in clean energy



Penny Sharpe
Minister for Energy, NSW Geovernment

Professional Career

Penny Sharpe is the Leader of the Government in the Legislative Council, Minister for Climate Change, Minister for Energy, Minister for the Environment and Minister for Heritage. First elected to NSW Legislative Council in 2005, Penny has held a variety of Government and Opposition portfolios including Heritage, Transport and Planning, Family and Community Services, as well as Disability Inclusion. Penny is passionate about the care of our environment and making sure that NSW takes serious action to tackle climate change.

Speech Summary

The NSW Government is leading the charge to net zero and building a reliable energy system. Leveraging partnerships and expertise our strategies are designed to drive investment in projects that deliver reliable power, cut emissions, create jobs, and unlock global export opportunities - positioning NSW as a clean energy leader.

Company Introduction

NSW has the largest economy of any Australian state and makes up about a third of Australia's total economy. NSW has a globally connected and investment-ready economy, well positioned to seize new opportunities in a rapidly changing world. As industries transform and global markets shift, NSW must diversify its economy through trade partnerships and by attracting strategic investment especially for the energy transition.
Source: https://www.nsw.gov.au/departments-and-agencies/investment-nsw/resources/nsw-trade-and-investment-strategy

Department of Climate Change, Energy, Environment and Water (DCCEEW)

Clean Energy in NSW

Penny Sharpe MLC
Minister for Climate Change, Minister for Energy
Minister for the Environment, Minister for Heritage

World Hydrogen Expo

December 2025

NSW GOVERNMENT

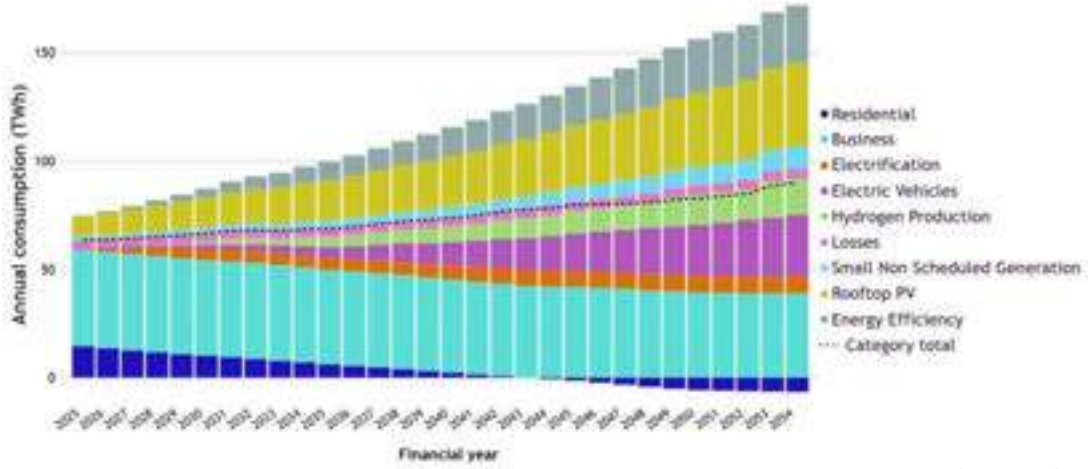
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NSW energy demand forecast

Ready to support green hydrogen production

NSW GOVERNMENT



Source: Australian Energy Market Operator (AEMO) 2024 Electricity Statement of Opportunities

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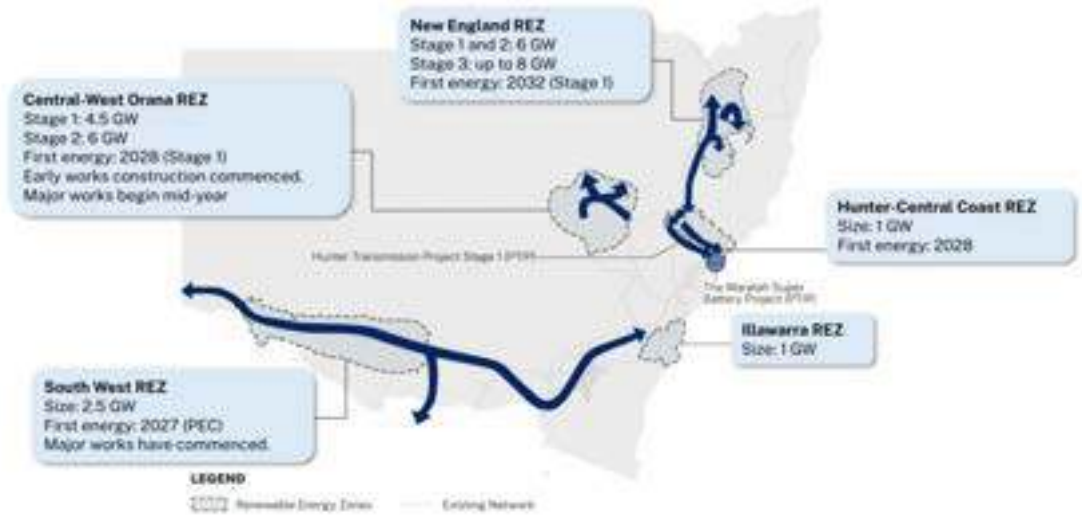
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Renewable electricity in NSW

Leading Australia's first declared Renewable Energy Zones

NSW GOVERNMENT



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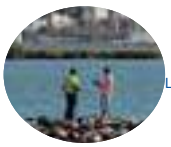
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Hydrogen in NSW

Combining natural strengths with world-leading policy

NSW GOVERNMENT



PEOPLE

Largest economy & skilled workforce



INFRASTRUCTURE

Extensive road, rail, port and grid infrastructure



ENERGY

World-leading renewable energ development



NSW-UNIQUE INCENTIVES

Totalling up to $4 per kilo

ENERGY DISCOUNTS

Up to 90% discounts on network charges

SPURRING DEMAND

Australia's first legislated hydrogen target

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WORLD HYDROGEN EXPO 2025 6th Conference

Market Insight

Market Insight 1

Helping Accelerate the Hydrogen Economy: Scaling Innovation Through Materials Science



Mark Copman
President – New Growth Ventures, 3M

Education
Mark holds B.S. degrees in Mechanical Engineering and Political Science from MIT and an M.B.A. from Harvard University.

Professional Career
Mark Copman leads the New Growth Ventures (NGV) organization at 3M. NGV is responsible for internal and external venture investments. Mark joined 3M in 2003 and has held various senior leadership roles throughout the company. Prior to 3M, Mark served in the US Navy and was an investment banker. Outside of 3M, Mark is on the board of directors for Twin Cities Habitat for Humanity and the Minnesota Orchestra.

Research Interests
Advanced materials (technical ceramics, glass bubbles, thermal insulation, catalysts, stable isotopes, polymers, coating, adhesives, etc.) for a variety of energy and automotive applications. Segments of interest within energy include, upstream exploration & production, midstream pipelines, downstream chemicals, carbon capture, geothermal, hydrogen, nuclear, and renewables (wind, battery storage, direct lithium extraction)

Speech Summary
The global H2 market is evolving from an existing 150+ billion$ fossil-based industry to a lower carbon future. However, significant cost reductions in low carbon alternatives are needed to accelerate this transition. In this talk, we will highlight how 3M is leveraging its 49 technology platforms and materials science expertise to develop innovative products that address critical pain points across the production, storage & transportation, as well as end use of low carbon H2. We will also highlight how we are working across the value chain with OEMs, government agencies, etc. to advance the different building blocks needed for a hydrogen economy

Company Introduction
3M is a diversified global technology company with a core expertise in materials science, delivering innovative products for almost any industry you can imagine e.g., auto, consumer, electronics, energy, etc.



"More with less" driving overall energy investments today

Need for more energy and energy derivatives... → ... with less CO_2e and waste

Electricity	Oil & Gas	Petrochemicals	Decarbonization	Waste mgmt.
Demand to nearly double by 2050[1]	Demand stays strong through 2050[1, 2]	Demand to nearly double by 2050[3]	CO_2e to peak by 2030; <2 °C requires action	Bringing MSW[4] under control requires action
~$2.5 T/y Investment thru 2035	**~$0.7 T/y** Investment thru 2035	**~$0.3 T/y** Investment thru 2035	**~$2.5 T/y** Investment thru 2035	**~$0.1 T/y** Investment thru 2035[5]

1. Based on the conservative IEA Stated Policies (STEPS) Scenario 2. Maintaining current levels of O&G production will require continuous capital investments to explore and develop new reserves 3. Includes ethylene, propylene, methanol, ammonia, benzene, toluene, and xylene 4. MSW refers to municipal solid waste 5. Represents capex investments for new recycling, landfill, waste to energy, collection, and dumping facilities
Source: IEA World Energy Investment 2025; Cefic Chemdata International; UNEP

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Where hydrogen matters the most

Chemical Production
(e.g., Ammonia, Methanol)



Refining



Iron & Steel Production



Heavy-Duty Transport
(e.g., Bus, Truck, Train)



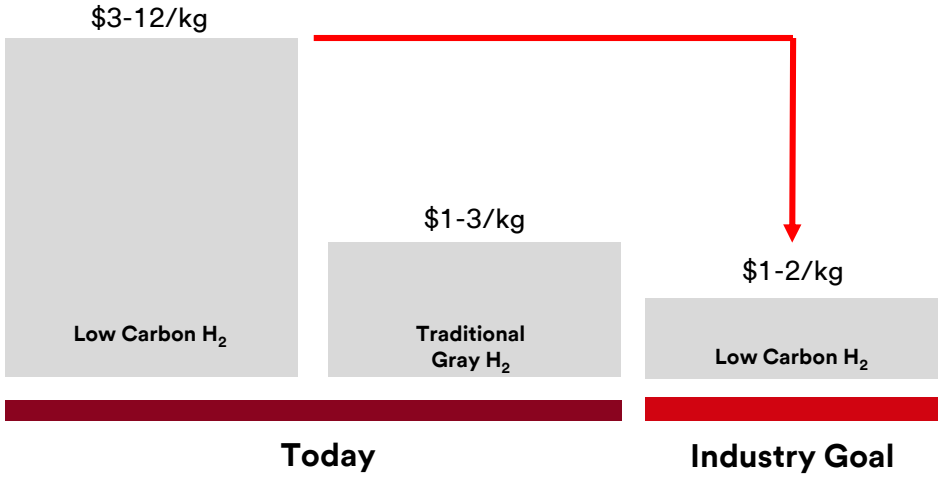
~23%
of global carbon emissions represented by these sectors

Source: IEA

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3M

However, cost-out is essential to scale low-carbon hydrogen

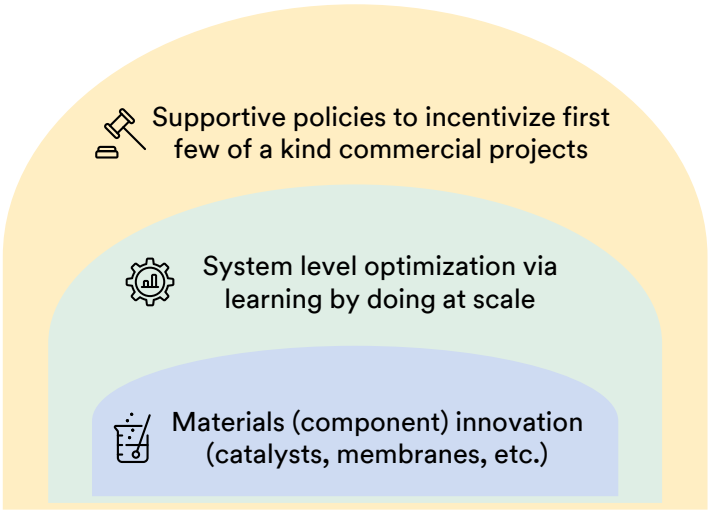


Source: BNEF, S&P, US Dept. of Energy

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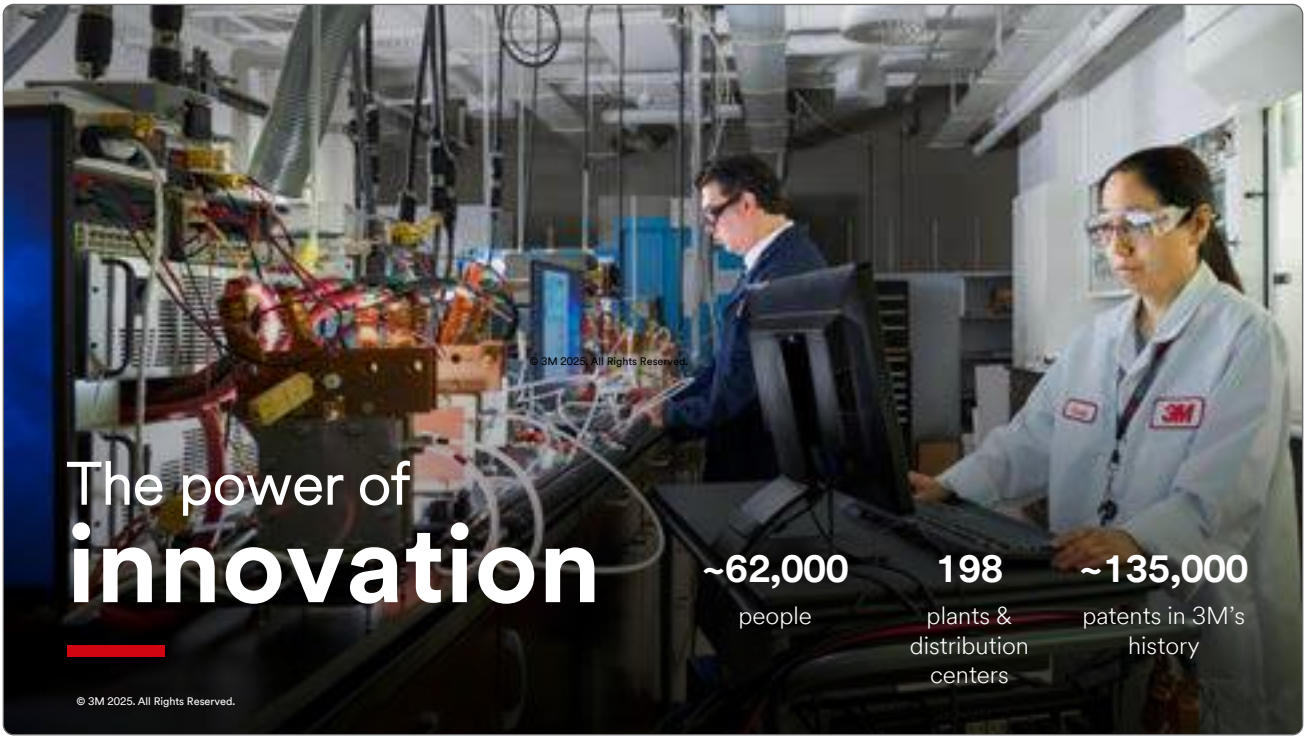
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The future of hydrogen will be built together



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At 3M, we believe that materials science can help customers unlock the scalability, reliability, affordability, and resilience the hydrogen economy needs to thrive



Working to advance a thriving energy system

As energy demand evolves, 3M is uniquely positioned to deliver a portfolio of solutions that **help customers improve safety and reliability, drive productivity, reduce costs, increase efficiencies, and deliver stability to the energy infrastructure.**



Generation

- Hydrogen production & storage
- Nuclear generation
- Solar & wind generation
- Geothermal
- Oil & Gas production (incl. carbon capture to mitigate emissions)

Transmission

- Hydrogen transport
- Conduction efficiency

Distribution

- Smart grid sensing
- Resilient cable accessories
- Grid stability for RE transition

Consumption

- Data centers
- Electronics & appliance
- Built environment – commercial & homes
- Agriculture
- EVs

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3M

Engineered solutions that span the value chain

	Generation (upstream)		Storage and transportation (midstream)		
Topic	**Electrolyzers**	**Nat gas reformers, SOEC/SOFCs**	**Pumps and compressors**	**Liquid H_2 supply chain**	**Compressed H_2 (Type IV) tanks**
Materials science challenge	 Iridium scarcity and durability; Adhesives and sealant durability	 Durable materials that withstand >850 °C and harsh environments	 Materials to handle scavenging, leakage, high stress, etc.	 Durable insulation materials that help minimize boiloff losses	 Materials to light-weight and reduce thickness of tanks
Potential 3M solution	**3M™ Nano-structured Iridium Catalyst Powder*, 3M™ Adhesives & Sealants**	**3M™ Nextel™ Fibers and Fabrics**	**3M™ Silicon Carbide Gas Seal Rings, 3M™ Silicon Carbide Mechanical Seal Rings, 3M™ Silicon Carbide Sliding Bearings**	**3M™ Glass Bubbles**	**3M™ Matrix Resins***

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3M

**Developmental product. Available for sampling under CDAs*

Cross-value-chain collaboration helps unlock speed & scale

Real projects, real results



Customer: NASA

One of the largest liquid hydrogen storage tanks in the world and user of 3M™ Glass Bubbles: 1.25M gallons (4732 m^3)**, developed for Artemis missions



Customer: HD KSOE

Joint research project agreement to develop large liquid hydrogen storage tanks for shipping application using 3M™ Glass Bubbles

*Note: This information is based on tests performed by a third-party at their facility and may be based on a limited sample size. Your results may vary due to differences in test types, conditions, systems, and facilities. See www. https://ntrs.nasa.gov/citations/20180006604 for more information.

**Source: NASA, 2022. https://ntrs.nasa.gov/citations/20220004276

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3M



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WORLD HYDROGEN EXPO 2025 6th Conference

Market Insight 2

Hydrogen mobility activation: lessons learnt from Europe and Korea



Erwin Penfornis
Vice President, Air Liquide

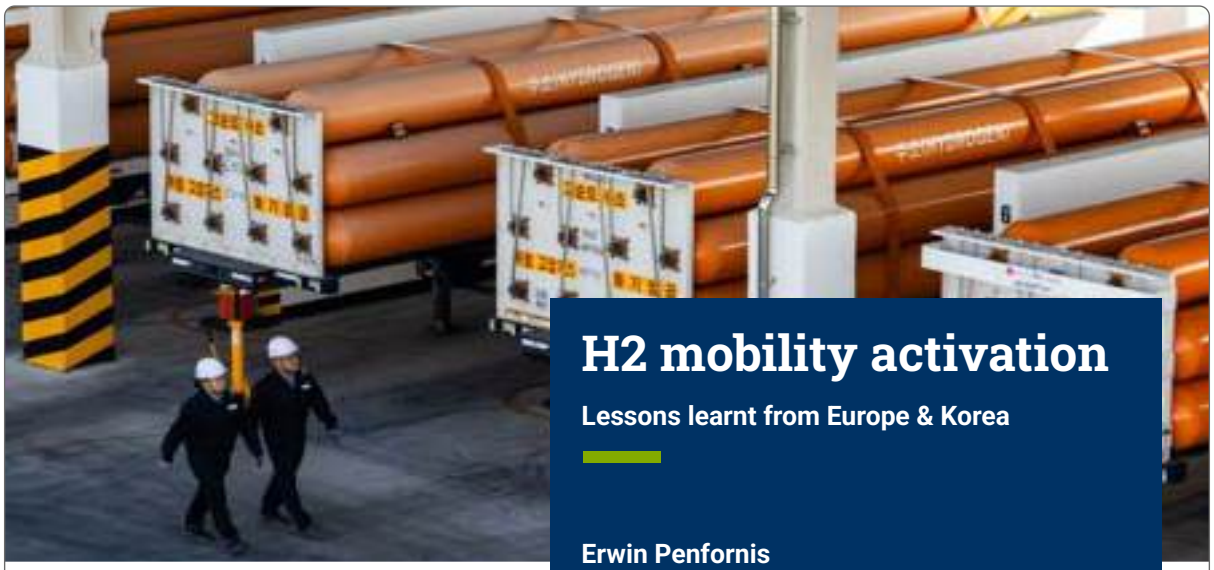
Education
1997-2000 Ecole Centrale - Engineering Master Degree

Professional Career
2021-Present Vice President, Hydrogen Energy World Business Line, Air Liquide
2019-2021 Vice President, Hydrogen Energy, Asia Pacific, Air Liquide
2018-2019 Vice President Hydrogen Energy world business unit, Air Liquide
2015-2018 Vice President Hydrogen Energy Market, Air Liquide
2013-2015 Business Development Director, Air Liquide
2010-2013 Business Development Manager, Air Liquide
2009-2010 Operations Control Manager, Air Liquide
2006-2009 Project Development Manager, Air Liquide
2000-2006 R&D Project Manager, Air Liquide

Research Interest
Development of hydrogen mobility
Hydrogen technologies
Standards
Required policie

Speech Summary
While Europe has established world-leading regulatory frameworks like AFIR, the race is now on to convert policy into steel and wheels. This session explores how Europe is moving from ambition to market activation, focusing on synchronizing infrastructure with vehicle rollout. Drawing parallels with Korea's dynamic ecosystem, we discuss how government-industry pragmatism can bridge the TCO gap and accelerate the heavy-duty transport transition.

Company Introduction
Air Liquide is a world leader in gases, technologies and services for industry and healthcare. Present in 60 countries with approximately 66,500 employees, the Group serves more than 4 million customers and patients.



H2 mobility activation

Lessons learnt from Europe & Korea

Erwin Penfornis
Vice President Hydrogen Energy business line

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Introducing Air Liquide

66,500 employees

60 countries

4 M Customers & Patients

€27.6 bn Revenue

€3.1 bn Net profit (Group share)



Large industries
Industrial gases in large quantities in the framework of long-term partnerships

Refining, Chemicals, Metals



Industrial Merchant
Industrial gases in small and medium quantities, related application technologies, equipment and services

Energy, Fabrication, Food & Pharma, Technology, Craftsmen...



Healthcare
Medical gases, products and services to support patients and customers in hospital and at home

Hospitals, Home healthcare, Specialty ingredients



Electronics
Ultra-pure gases in large quantities and development of new molecules

Semiconductors, Flat panels, Photovoltaic



Engineering & Technologies
Plants and equipments for industrial gas production but also equipment and services for energy transition and deep tech

A world leader in gases, technologies and services for Industry and Health

Hydrogen Energy | Air Liquide

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Air Liquide and hydrogen in a nutshell

60+ years of expertise

1.2 Mt annual production

€2.2 bn annual sales

~1,000 employees in hydrogen

240+ stations delivered

HARD-TO-ABATE INDUSTRIES



Hydrogen to decarbonize Refining, Metals, Chemicals

HEAVY-DUTY MOBILITY



Hydrogen for sustainable transport

Hydrogen Energy Air Liquide

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H2 is a key fuel for the future of zero-emission transport



Trucks & Buses



Maritime

H_2

As a complement to BEV



Intensive fleets

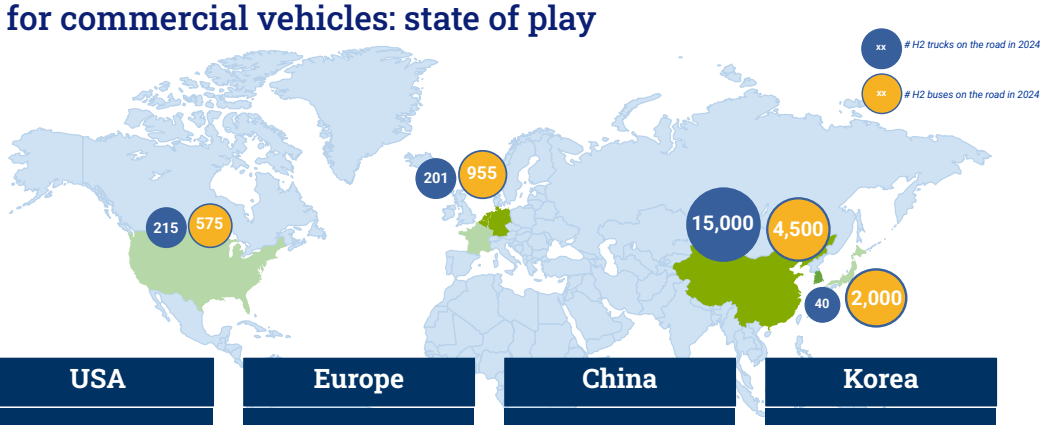


Aviation

Hydrogen Energy Air Liquide

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H2 for commercial vehicles: state of play



USA	Europe	China	Korea
Uncertain environment State of California remains committed Transit market preparing the ground for HD trucks	Key OEM's lined up and some infrastructure initiatives but complex policy landscape Pivotal moment in terms of public support	Strong momentum with government support Thousands of H2 HD trucks in targeted clusters Rapid infrastructure growth	Synchronized action between government and industry Rapid infrastructure growth around main metropolitan areas

Hydrogen Energy | Air Liquide

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Europe: Air Liquide's drive to activate the market

Production

The Group operates a first 20 MW electrolyzer in Germany…

And we're scaling-up!

200 MW

In France In the Netherlands



Gigafactory with

Retail infrastructure

JV with TotalEnergies developing and operating a European HRS network, primarily for heavy-duty trucks

Building and operating a public HRS network for passenger cars and commercial vehicles across Germany

A pioneering French hydrogen mobility company that offers an integrated "Mobility as a Service" solution: (700+ taxis on the road)

Supply



Extensive fleet of state-of-the-art high pressure trailers

INTRODUCING OUR FIRST HYDROGEN POWERED TRUCKS IN OUR LOGISTICS STARTING 2026!

Hydrogen Energy | Air Liquide

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Europe: a strong potential but still failing to activate



What works

Decarbonization mandates & systems
Emission reduction standards, ETS2, Road toll exemption

OEM's lined up
HYUNDAI VOLVO

Technology ready
Molecule: Electrolysis, Low-carbon H2
Supply: High-pressure GH2, LH2
Infrastructure: First ecosystems, Standardization
Vehicles: FCEV, H2 ICE

Opportunities for the energy system
Import, storage, grid balancing

What does not work

Uncompetitive TCO
Expensive vehicles, High H2 price

Insufficient refueling infrastructure
"chicken-and-egg" deadlock between vehicles & stations

Vehicles
Limited availability

Inefficient policy support
Complex, unstable & inconsistent support schemes across EU countries
Not properly adressing the initial TCO gap

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Stronger together: the Global Hydrogen Mobility Alliance

Global Hydrogen Mobility Alliance

July 2025
official launch with Europe focus

CEO led
all signing the "call to action letter

40+
participating companies

Hydrogen Energy Air Liquide
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Korea: Multiple best practices from the Korean strategy & policy

What works

- **Comprehensive support schemes** fully bridging the initial cost gap
- **Proper sizing of public support** (~800M€ in 2025)
- **Maximum agility and pragmatism** with annual revision of funding priorities & schemes
- **Market activation synchronized** ecosystem partnerships

What 's next

- **Refuelling network extension**
- **Heavy duty trucks acceleration**



H2 mobility in Korea today

250 HRS
35,000 cars
2,000 buses
First trucks

F/C CAPEX support	HRS CAPEX support	H2 OPEX subsidy	FCEV subsidy
~ 40% of CAPEX / site	50~70% of CAPEX / site Opex Subsidy/site (80% of annual deficit)	35 ~ 50 % of fuel cost No constraint on H2 origin At parity with diesel	70 % of FCEV purchase At parity with diesel vehicles

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Lotte-Air Liquide Ener'Hy



17 tpd capacity, 10 loading bays



New high-pressure trailers



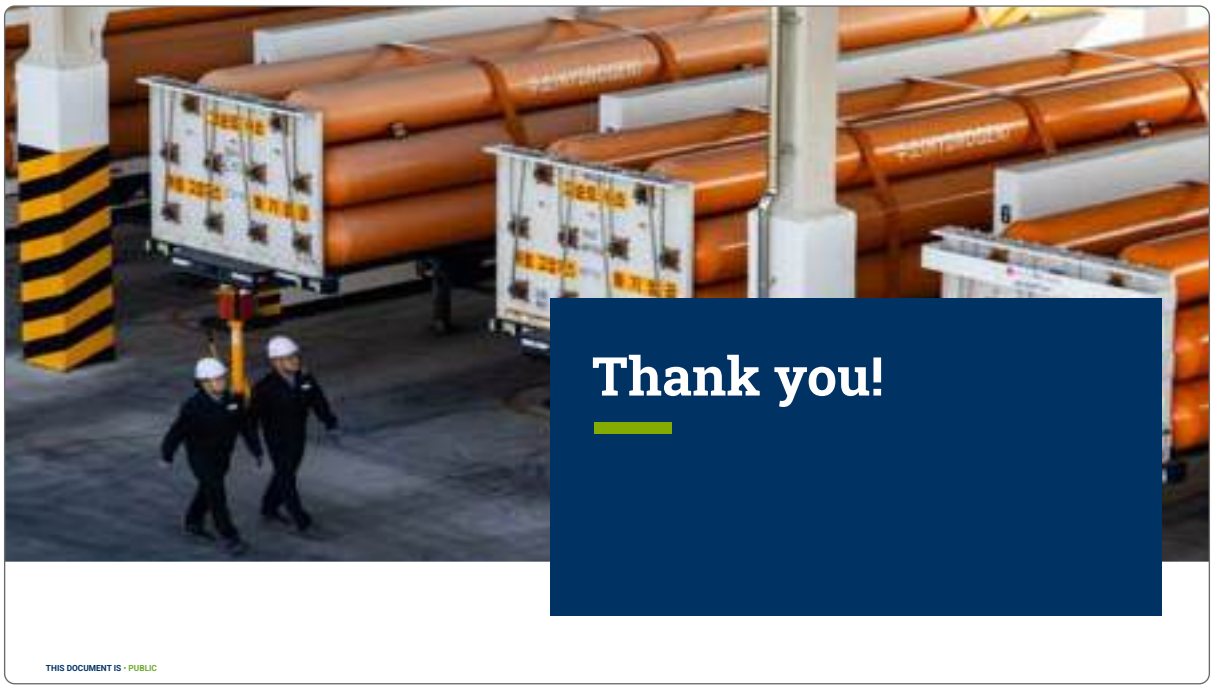
Stable supply in the Greater Seoul area



Supporting the momentum in Korea

Hydrogen Energy | Air Liquide

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This is the time to prove hydrogen mobility works – leveraging current molecule flexibility to unlock economics and future network scaling

Current phase

1 Activation price & molecule flexibility

ALL COLOURS WELCOME TO KICK-START

Today

2030

- Geographical focus to **drive local infrastructure development**
- **viable ecosystems with well-loaded HRS in high traffic areas**
- **Derisked economics** and supply enabled by molecule flexibility
- **Activation cost** of €8/kg supported by targeted policies
- HD (truck, bus, coach) unlock other applications (e.g., LCV, cars, maritime)

2 Connect ecosystems

CREATE CORE NETWORKS

Mid-2030s

- Expand geographical coverage by connecting HRS ecosystems to create core transport routes (e.g., TEN-T)
- **Decarbonize H2** in line with other industries and with BEV charging
- Capacity payments for infrastructure decarbonization
- **Fleet demand** and **vehicle OEMs driving commercial scale**
- **Shift towards low-carbon and renewable hydrogen**, including from imports

3 Full deployment

COMPREHENSIVE NETWORKS

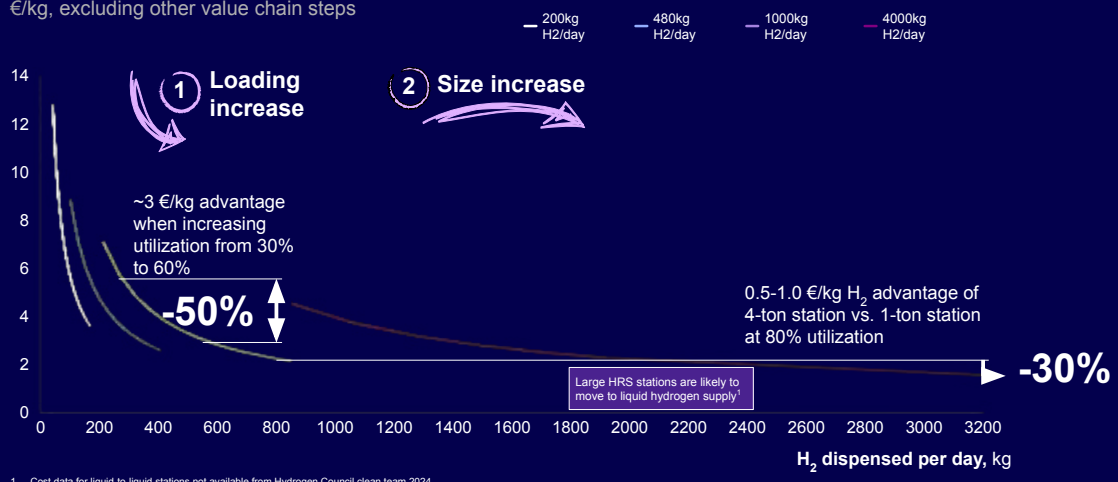
2040

- **Comprehensive HRS network** matching today's usability
- **Scaling H2 adoption** across relevant use cases
- **Focus on renewable or low-carbon hydrogen,** at scale

Global Hydrogen Mobility Alliance 12

HRS | Scale and utilization are essential to reduce H_2 cost at the pump, with most competitive cost position reached above 2t per day

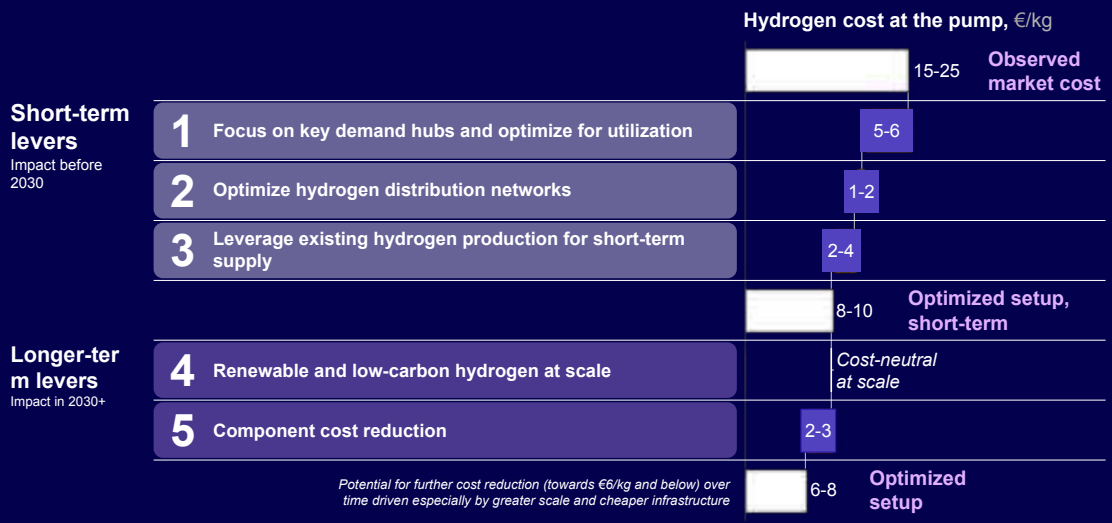
Hydrogen Refueling Station cost per H_2 dispensed
€/kg, excluding other value chain steps



1. Cost data for liquid-to-liquid stations not available from Hydrogen Council clean team 2024

Source: Hydrogen Council clean team (2024)

An optimized hydrogen supply chain can already achieve meaningful cost reductions already in the short-term



Note: Excluding subsidies, incentives and credits by 2030

Source: Hydrogen Council clean team (2024)

If the specific tipping points of scale and demand certainty are met, hydrogen in road transport can already be competitive today

H2 Mobility Setup, H2 cost at the pump[2]			Production	Conversion / Storage Distribution	HRS[1]	Vehicle
Step 0: Today		15-25 €/kg	Local sources	300 kg	250-500 kg / day 10-20%	~100 units/y
Step 1: Activation price & molecule flexibility	5-10 ecosystems of 10 HRS with 100-300 trucks around existing H2 sources	8-12 €/kg	Mix of sources	950+ kg	1,000+ kg / day 50-60%	100-500 units/y
Step 2: Connect ecosystems	Linked ecosystems of 100-200 HRS with 5k-10k trucks and decarbonizing H2 sources	7-9 €/kg	Shift to low-carbon & renewables	Shift to LH2: 4,000 kg	2,000+ kg / day 60-70%	~5,000 units/y
Step 3: Full deployment	Comprehensive network of 1,000+ HRS with 100k+ trucks using low-carbon / renewable H2 sources	6-8 €/kg *further improvements may be possible in long-term*	Low carbon & renewable	4,000 kg Pipelines	4,000+ kg / day 60-80%	10,000+ units/y

1. Hydrogen Refueling Stations
2. Without incentives or credits

Source: Hydrogen Council clean team (2024)

Key policy asks

Enabling conditions BEV = H2

Recognise the complementarity of BEV and H2 mobility



Level playing field for BEV and H2 on the upcoming EU policy from the Automotive Action Plan

- Eurovignette amendment
- Transport corridors
- Greening of corporate fleets

Flexibility to use whatever H2 is available to kickstart H2 mobility



Independent measures to activate H2 mobility and decarbonize H2 (BEV approach)

- The target is to meet 8€ per kg at the nozzle (and below)
- Gradual adoption of low-carbon and renewable H2

Bridge the cost gap

SWiM type of funding for HRS and vehicles



Specific program for H2 mobility & flexible granting conditions

- "Consortias" HRS + Fleets
- Secure 50% min loading (coupled with capacity payment for HRS in corridors)
- Techno neutral approach H2, HRS and vehicles

Swift implementation of ETS and Eurovignette



Swift Implementation of existing EU policy and extended longevity

- Eurovignette free tolls for ZEV
- ETS2 fossil fuel tax for road transport and ETD exemption for H2 ICE
- Other enabling elements: clean ports and public procurement

Introducing Air Liquide



Present in **60 countries** with **66,500 employees**, the Group serves more than 4 million customers and patients.

Oxygen, nitrogen and hydrogen are **essential small molecules** for life, matter and energy. They embody Air Liquide's scientific territory and have been at the core of the company's activities since its creation in **1902**.

A WORLD LEADER IN GASES, TECHNOLOGIES AND SERVICES FOR INDUSTRY AND HEALTH

Hydrogen Energy Air Liquide

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Market Insight 3

Latin America's Clean Hydrogen Ecosystem and Business Development Trends



Juan Antonio Gutierrez
Technical Advisor, H2PERU

Education
- B.Sc. in Chemical Engineering, National Autonomous University of Mexico (UNAM), Faculty of Chemistry, Mexico City, Mexico (2010–2015).
- European Energy Manager (EUREM), AHK – Mexico-Germany Chamber of Commerce (2019)
- Renewable Energy Co-Benefits Specialist, Renewable Energy Academy (RENAC), Berlin (online, 2020–2021)
- Certificate of Knowledge in Hydrogen & Fuel Cells for Transport Applications, Universidad San Jorge – KnowHy, Spain (2017)

Professional Career
- Energy Transition Solutions Manager – Fotowatio Renewable Ventures (FRV)
  Madrid, Spain – Nov 2023 – Present
- Senior Technical Advisor – Peruvian Hydrogen Association (H2 Perú)
  Lima, Peru – Oct 2022 – Present
- Business Strategy Associate – NTT DATA
  Mexico City, Mexico – Feb 2022 – Sep 2023
- Hydrogen Consultant – Hinicio
  Mexico City, Mexico – Nov 2019 – Jan 2022
- Product Specialist – PEM Electrolysis, Leman Instruments
  Mexico City, Mexico – Apr 2014 – Nov 2019

Research Interest
- Renewable hydrogen and Power-to-X (PtX): Green hydrogen production, derivatives such as green ammonia and e-fuels, and their deployment in industry, mobility and power systems.
- Energy systems and multi-energy integration: Modeling off-grid and grid-connected systems (PV, batteries, thermal generation, hydrogen) for industrial sites and data centers; energy storage and multifluid systems.
- Techno-economics and project development: LCOH/LCOE/LCOA modelling, investment cases, and project structuring from concept and pre-FEED through tenders and basic engineering.
- Energy transition policy and roadmaps: National and regional hydrogen strategies, regulatory frameworks and just-transition aspects in Latin America and the Caribbean.

Speech Summary
This talk explores how Latin America is building a competitive clean hydrogen ecosystem: emerging hubs, policy and financing shifts, landmark projects, regional value chains, and what developers and investors must do now to turn today's opportunities into bankable businesses.

Company Introduction
H2 Perú, the Peruvian Hydrogen Association, is a non-profit industry association created in 2020 and formally registered in early 2021. It acts as a collaborative platform to accelerate the decarbonization of Peru's economy through renewable and low-emission hydrogen.

The association brings together more than 70 members, including companies, professionals, academic institutions and strategic partners, who share a long-term vision of a green-hydrogen-based, resilient and sustainable economy for Peru.



Latin America: Clean Hydrogen Ecosystem Development and Business Growth Trends

Juan Antonio Gutierrez
Senior Technical Advisor
4 december 2025

H2 PERU Asociación Peruana de Hidrógeno

75
Associates and Allies

We have a strong network of corporate and strategic partners who share our vision of a decarbonized economy. Additionally, we actively collaborate with international associations and promote platforms for exchange to share visions, knowledge, and experiences.

Corporate Associates

Energía

Industria, minería y transporte

Ingeniería y servicios de tecnología

Allies

Strategic Partners

Media Allies

Professional Partners

15

Peru's Potential to Offer Competitive LCOH

Levelized Cost of Hydrogen for the Second Half of the Year from Photovoltaic and Onshore Wind Systems up to 2050



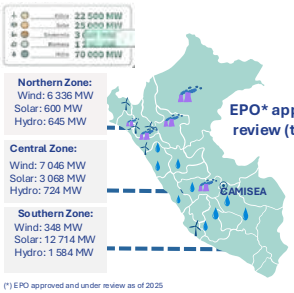
Renewable potential of 125.5 GW, **which represents 9 times the current installed capacity in the country (13.8 GW).**

Peru is well-positioned globally to develop a low-cost hydrogen economy, with production costs identified among the top 10 worldwide.

By 2040, renewable and low-emission hydrogen is expected to be the most competitive option, driven by lower electricity prices, Peru's strong renewable potential and falling technology costs.

High Renewable

Renewable Potential



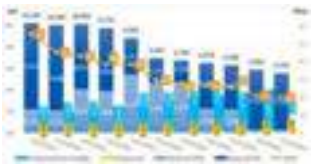
(*) EPO approved and under review as of 2025

Peru's total electricity demand reached approximately **64 TWh in 2024**.

EPO* approved and under review (total): 33 067 MW

In **combination, natural gas** and **renewables** could contribute to the production of renewable and low-emission hydrogen to **boost Peru's energy transition**.

Natural Gas



According to OSINERGMIN, Lot 88 has a reserves-to-production (R/P) ratio of **20 years**. If **Lot 58** enters commercial operation and is directed to the domestic market, it would extend supply. Together, Camisea could secure Peru's natural gas supply for **around 30 years.**

Regulatory and Strategic Landscape of Hydrogen in Latin America

Brazil
- Strategy: National Hydrogen Program (PNH2, 2022).
- Laws: Law No. 14.990/2024
- Incentives: Tax credits, financial support, and direct incentives for low-emission hydrogen projects.

Colombia
- Strategy: Hydrogen Roadmap of Colombia (2021).
- Laws: Law 2099 of 2021 (extends Law 1715)
- Incentives: Through Laws 2099/1715 (processed via UPME) (february 2025)

Chile
- Strategy: National Green Hydrogen Strategy (2020).
- Framework Law and broader energy regulations.
- Incentives: CORFO instruments and R&D/investment funds applicable to hydrogen projects.

Uruguay
- Strategy: Green Hydrogen Roadmap of Uruguay and H2U Program (2022)
- Incentives: General Investment Promotion Regime (Law 16,906, COMAP): exemptions from Corporate Income Tax (IRAE), VAT (refund/credit)

Peru
- Laws: Law No. 31992; Draft Regulation
- Incentives: Enables future promotional and tax mechanisms; details to be defined in the upcoming regulation.



Ecuador
- Strategy: Green Hydrogen Roadmap of Ecuador (2023).

Paraguay
- Strategy: National Strategy for the Hydrogen Economy (2025).
- Incentives: Carbon credits Law No. 7190/23 and its Regulatory Decree No. 3369/25

Argentina:
- Strategy: National Strategy for the Development of the Hydrogen Economy (ENH, 2023).
- Laws: Draft Law for the Promotion of Low-Emission Hydrogen (2024).

Panama
- Strategy: National Strategy for Green Hydrogen and Derivatives (ENHIVE) (draft 2023).
- Incentives: Linked to the country's green hub and logistics role; still being consolidated.

Costa Rica
- Strategy: National Green Hydrogen Strategy of Costa Rica (2023)
- Laws: Draft Law for the Promotion and Implementation of a Green Hydrogen Economy (Bill No. 22.392).

México
Strategy: Clean Hydrogen Industrial Strategy of Mexico 2024 (led by AMH2/private sector).
- Laws: No federal hydrogen law yet

Hydrogen & Derivatives Project Pipeline in Latin America

Country	Project / Hub	Companies/ Promoters	Reference scale (electrolysis ≥100 MW)	Highest public milestone achieved
Argentina	Patagonia H_2 projects (e.g., FFI Río Negro)	Fortescue and others	Multi-GW (≥100 MW)	Prefeasibility / framework agreements
Brazil	Pecém H_2V Hub	Various (FRV, Fortescue, AES, etc.)	Blocks ≥100 MW	Pre-FEED / studies; MoUs, port agreements
	Suape / NE Brazil Hubs	Various	≥100 MW	Pre-FEED
Chile	H_2 Green Mining – Calama	Susterra / H_2 Green Mining	~200 MW	EIA approved (RCA); awaiting FID
	H_2 Magallanes	TE H_2 / TotalEnergies	Multi-GW (≥100 MW in 1st phase)	Pre-FEED/FEED; EIA submitted; partial concessions
	HNH Energy – Magallanes	HNH Energy	>100 MW	Pre-FEED/FEED; EIA under evaluation
Mexico	Sonora projects / industrial hubs	Various	≥100 MW	Pre-FEED
Peru	Horizonte de Verano Green H2 & NH3, Arequipa	Verano Energy / Grenergy	>100 MW (project includes up to 5.85 GWp PV)	**EIA-d approved in 2025** by the Ministry of Production : "Environmental Authorization" granted; pre-FID
	Hub H2 Arequipa	Arequipa Goverment	>100 MW	Prefeasibility Study
Uruguay	Tambor Green Hydrogen Hub	Enertrag / partners	~150 MW	Pre-FEED / studies

Key barriers to hydrogen project development in Latin America

01

Lack of market demand and bankable contracts

There are still few industrial or energy off-takers willing to sign long-term hydrogen or ammonia purchase agreements (HPAs/PPAs), making financing and FID difficult.

02

Regulatory gaps and institutional delays

Many countries have hydrogen laws or strategies but lack clear regulations on certification, incentives, grid access, or permitting, creating legal uncertainty.

03

Infrastructure and grid limitations

Regions with the best renewable resources often lack adequate transmission lines, port facilities, and logistics for large-scale hydrogen export.

04

High costs and competitiveness gap

Green hydrogen remains more expensive than fossil alternatives, and without carbon pricing or subsidies, cost parity is still out of reach.

05

Technical and social challenges

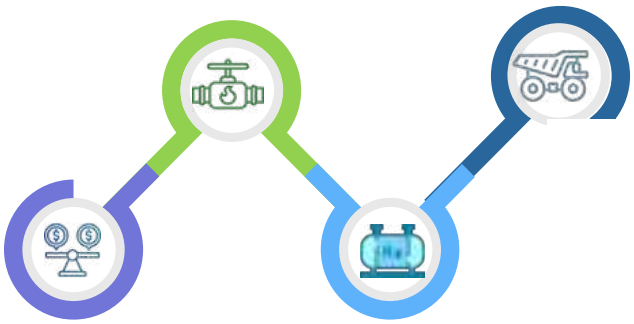
Limited local expertise in large-scale hydrogen projects and social concerns over water use and community engagement often delay approvals and project execution.

Asociación Peruana de Hidrógeno

STRENGTHS FOR THE DEVELOPMENT OF A HYDROGEN INDUSTRY IN PERU

02 EXPERIENCE IN NATURAL GAS EXPORTATION

04 MINING SECTOR WITH DECARBONIZATION OBJECTIVES



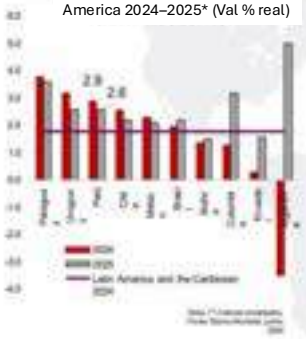
01 MACROECONOMIC STABILITY

03 EXPERIENCE WITH RENEWABLE HYDROGEN PRODUCTION

01 MACROECONOMIC STABILITY

Leadership in economic growth for 2024 and 2025

Economic growth in Latin America 2024–2025* (Val % real)



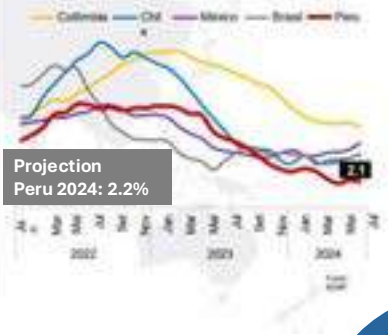
2nd best country risk in the region

Interest rates: EMBIG (variation in bps) Spread, 2022 – May 2024 in Latin America



The lowest inflation rate in the region

Inflation in Latin America 2022 – May 2024 (annual % change)

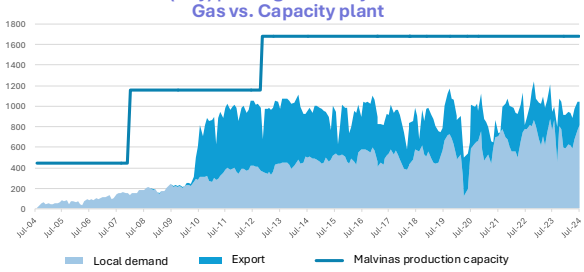


Projection Peru 2024: 2.2%

Peru is a macroeconomically resilient country

02 EXPERIENCE IN NATURAL GAS EXPORTATION

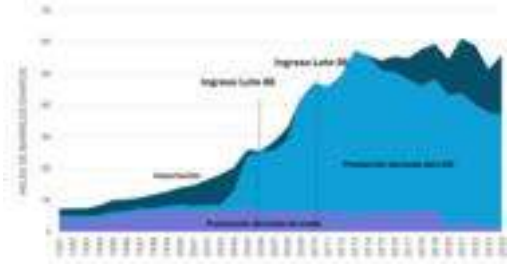
2004 – 2024 (July) | Average monthly sales of Natural Gas vs. Capacity plant



- Production capacity: 1,680 MMPCD
- Reinjection: 250 – 350 MMPCD
- Average local market: 550 – 750 MMPCD
- Average LNG production (L88): 50 MBbl/d
- Average export: 650 – 800 MMPCD
- Average LPG production (L56 & L57): 28 MBbl/d

Fuente: Hunt Oil 2024. Demanda local, capacidad de producción y exportación

LPG Supply in Peru



NG | MMPCD



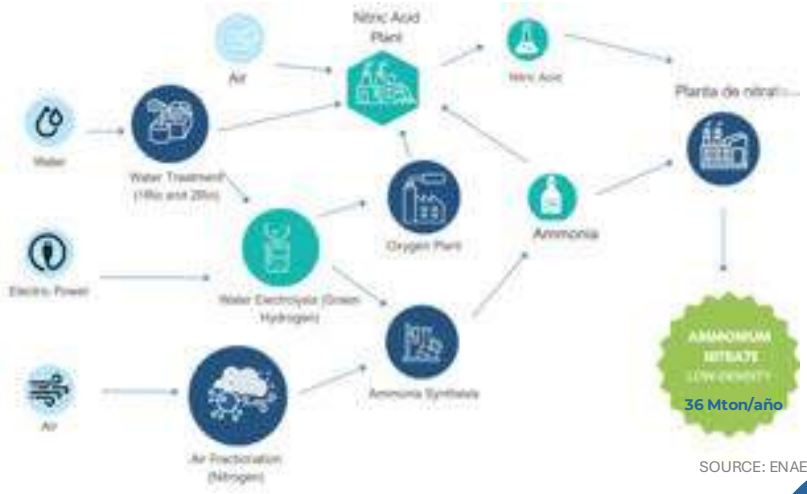
Malvinas production capacity

03 EXPERIENCE WITH RENEWABLE HYDROGEN PRODUCTION





- **Location:** Cusco, Peru
- **In operation since:** 1965
- **Technology:** 7 alkaline electrolyzers (23 MW)
- **Production:** 8.6 tons of renewable hydrogen per day for ammonium nitrate, used in the production of mining explosives
- **Energy source:** powered by 100% certified renewable energy (in partnership with Engie Energía Perú)



SOURCE: ENAEX

Renewable Hydrogen Pioneers in Peru: Industrias Cachimayo Leading Since 60 Years Ago

04 MINING SECTOR WITH DECARBONIZATION OBJECTIVES

Portfolio of mining investment projects planned until 2034



Source: Mining Investment Project Portfolio 2024.

The mining sector in Peru is one of **the largest energy consumers** in the country, accounting for approximately **30% of total electricity demand**, with an average annual consumption of 17 terawatt-hours (TWh).

Hydrogen can decarbonize **various mining processes**. In the country, mineral transportation alone could **require between 5GW and 7GW** of new renewable capacity.

Hydrogen as an Enabler for Critical Mineral Extraction

1. Hydrogen in Metallurgical Processes
Used as a reducing agent to replace carbon in mineral refining

2. Hydrogen for Low-Carbon Explosives
Essential for producing ammonium nitrate-based explosives.

3. Hydrogen-Powered Drilling & Processing
Used in hydrogen fuel cells to power drilling and crushing equipment.

4. Facilitating the Energy Transition
Supports the sustainable extraction of minerals essential for EV batteries, wind turbines, and solar panels.

Hydrogen is crucial for reducing emissions and driving the transition to a more sustainable economy in industries such as cement, steel, fertilizers, and transportation.

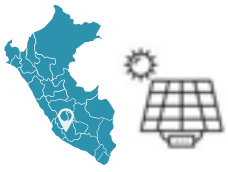
Arequipa: The Future Gateway for Green Hydrogen and Derivatives from Peru to Asia

Economic Profile
Arequipa contributes approximately **5–5.5% of Peru's national GDP (2023)** and is the **second-largest regional economy** in the country.

World-class mining hub
Arequipa hosts Sociedad **Minera Cerro Verde**, one of the largest **copper complexes in the world**, positioning the region as a strategic anchor for Peru's copper exports.

Diversified industrial base
Beyond mining, Arequipa has a **solid industrial ecosystem:** Cement (Yura), Steel (Aceros Arequipa), food processing, and light chemicals.

Strategic Export Gateway for Green Molecules
Corio is a planned deep-water, multi-purpose megaport in Arequipa. **Matarani and rail links** to the Interoceanic Highway and the Southern Railway, it forms a strategic logistics corridor for southern Peru.



Solar potential
Arequipa has **exceptional solar radiation**, averaging **~6.0–6.5 kWh/m^2/day**, among the best in the world for photovoltaics, with more than **300 clear days per year**.

Natural gas and associated infrastructure
Transportadora de Gas del Perú (TGP) has proposed a **coastal gas pipeline** running from **Humay (Ica)** to **Mollendo, Arequipa, and Ilo (Moquegua)** to reinforce natural gas supply in the southern region.

Arequipa: The Emerging Hub for Hydrogen and Green Molecules in Latin America

Cooperation Agreement between H2 Peru and the Regional Government of Arequipa

MoU with the British Embassy in Lima: Joint efforts to develop regulatory frameworks, promote investment, and foster pilot projects, including support for regional hydrogen hubs.

• Led to the *Proposed Regulation of the Green Hydrogen Promotion Law* (2025), covering certification, safety, and export frameworks.
• Currently supports the governance study and stakeholder mapping for the **Arequipa Hydrogen Hub**, in collaboration with the Regional Government.



Main objectives of the agreement:

•Conduct baseline studies, including stakeholder mapping and governance analysis to enable the hub.

•Develop a roadmap to guide the progressive implementation of the hydrogen ecosystem in Arequipa.

•Promote pilot projects and investments that bring together industry, academia, the public sector, and international cooperation.

Arequipa brings together the perfect mix of resources, industry, and infrastructure to lead Peru's transition into a green export economy. The Arequipa Green Molecules Hub is not just a project it's a vision to turn the region's mining and energy strengths into a global gateway for clean molecules.

Peru's H_2 vision moves ahead with regulatory clarity, safety standards, and an integrated national ecosystem

Strategy & roadmap

According to H2 Peru's roadmap, this is how the country's hydrogen industry is expected to develop in the coming years. These are the key milestones.

2030
- **1 GW** of installed electrolyzers
- **$20 M** for replicable pilot projects
- **$3 B** in private investment
- **≥ 40 %** participation of local talent
- Sustainable transport with fuel-cell vehicles and H_2-V fleets

2040
- **6GW** of electrolyzer cap acity
- H_2V cost **< 5.15 USD/kg**
- **75 %** fossil fuel reduction
- **80 %** less imports of H_2-derived fuels

01 03 02 04

Harmonise policies & safety standards

Technical Committee for Hydrogen Technology Standardization (CTN 175)

H2 Perú, as technical secretariat, is leading the adaptation of ISO 19870 and ISO 15916 in Peru, bringing together public sector, private sector, and academia to align feedback and ensure the standards are legitimate and practical for national use.

Building a Legal Framework to Power the Hydrogen Economy

Key Aspects

Policy and Planning · Tax Incentives · Origin Certification · Scientific Research

Hydrogen Promotion Law and its Regulation under Review

The regulation is developed based on four fundamental principles:
•Full Integration of the Hydrogen Value Chain
• Enabling Criteria for the Operation of Plants
•Hydrogen Certification and Export
•General and Specific Safety Aspects for Hydrogen

Connect supply chains & infrastructure

Arequipa and H2 Perú have joined forces to promote the **first Hydrogen and Derivatives Hub**, starting with a **key study on stakeholder mapping and governance.** This will then feed into **Arequipa's Hydrogen Hub Roadmap and Macroeconomic Impact Study.**

WHY IN AREQUIPA?

- **Outstanding renewable potential**
- **Existing strategic infrastructure: 14,000 ha of available land.**
- **Concentration of mining and energy-intensive industries**
- **Arequipa has formally declared hydrogen a regional priority**

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Latin America: Clean Hydrogen Ecosystem Development and Business Growth Trends



WORLD HYDROGEN EXPO 2025 6th Conference

Market Insight 4

Northeast Asia's Clean Hydrogen Ecosystem and Business Development Trends



Audrey MA
Vice President, Refire

Education
2008-2012, M.S., Urban Design, University of Hong Kong., Hong Kong, China
2004-2008, B.S., Architecture, Carleton University, Ottawa, Canada

Professional Career
2020-Present, Executive Director of the Board, Vice President of International Business, Shanghai REFIRE Group Limited, Shanghai, China
2017-2020, Director of Marketing and Business Development, Shanghai REFIRE Technology Co., Ltd, Shanghai, China
2015-2017, Vice President, SINOSYNERGY Hong Kong Limited, Hong Kong, China

Research Interests
Next-Generation Electrolysis Technologies for Green Hydrogen Production
Hydrogen-Powered Heavy-Duty Truck Commercialization
Strategic Expansion in Overseas Hydrogen Markets

Speech Summary
1. Opening Remarks: The Strategic Significance of Northeast Asia
   - Regional Leadership: Northeast Asia (China, Japan, South Korea) accounts for 40%+ of global hydrogen investments, positioning it as the "epicenter of clean energy transition".
   - REFIRE's Vision: As a pioneer in fuel cell technology, REFIRE is committed to accelerating cross-border collaboration to build interconnected hydrogen ecosystems.

2. Market Status: Growth Drivers and Regional Dynamics
   2.1 Key Market Indicators-China
   2.2 REFIRE's Market Impact

3. Regional Cooperation: Case Studies in Ecosystem Integration
   3.1 Cross-Border Infrastructure
   3.2 REFIRE's Flagship Projects
   - Taiyangshan, Ningxia
   - Megawatt-Level Power Generation

4. Technology Innovation: Advancing the Hydrogen Value Chain
   4.1 Breakthroughs in Fuel Cell Systems
   - Cost Reduction
   - Durability
   4.2 Ecosystem Integration
   - Wind-Solar-Hydrogen Storage
   - Solid-State Storage

5. Policy Environment: Catalysts for Growth
   5.1 Regional Policy Landscapes
   - China
   - EU-Asia Synergies
   5.2 Regulatory Challenges
   - Standardization Gaps

6. Closing: Toward a Decarbonized Northeast Asia
   - Shared Vision: "Hydrogen is not just an energy carrier but a bridge to regional prosperity and climate security."
   - Next Steps

Company Introduction
Shanghai REFIRE Group Limited (HKEX Code: 02570, referred to as "REFIRE ") is a global leader in the hydrogen technology sector, dedicated to the R&D of hydrogen solutions, establishment of industrial ecosystems, and the promotion of hydrogen commercial applications. Founded in 2015 and headquartered in Shanghai, the company operates with a market-oriented approach and a global perspective. REFIRE's business encompasses the holistic hydrogen industry chain, from upstream hydrogen production equipment to downstream fuel cell systems, providing solutions for diverse application scenarios such as road transportation, rail transit, construction machinery, power generation, off-grid supercharging, and green hydrogen production. The company has also pioneered the innovative "electricity-hydrogen-electricity" business model.

WORLD HYDROGEN EXPO 2025 6th
Conference

Hydrogen Deep Dive I：
Global HydrogenOutlook

WORLD HYDROGEN EXPO 2025 6th
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Global Business Outlook

Global Business Outlook 1

Global State of Play of Hydrogen



Ivana Jemelkova
Chief Executive Officer, Hydrogen Council

Education
• Charles University, Master's Degree in European Studies
• Charles University, Bachelor's Degree in International Affairs

Professional Career
• Chief Executive Officer, Hydrogen Council, Jun 2024 - Present
• Senior Managing Director, FTI Consulting, 2017 – 2024, Washington, District of Columbia, United States

Speech Summary
Highlighting hydrogen's role in decarbonization, Ivana will outline industry progress, investment needs, and key insights from the Global Hydrogen Compass Report 2025 showing accelerating deployment, falling costs, and growing readiness across value chains.

Company Introduction
The Hydrogen Council is a global, CEO-led initiative that brings together leading companies with a united vision and long-term ambition for hydrogen to foster the clean energy transition.

The Council believes that hydrogen has a key role to play in reaching our global decarbonization goals by helping to diversify energy sources worldwide, foster business and technological innovation as drivers for long-term economic growth, and decarbonize hard-to-abate sectors.

Using its global reach to promote collaboration between governments, industry and investors, the Council provides guidance on accelerating the deployment of hydrogen solutions around the world. It also acts as a business marketplace, bringing together a diverse group of 140+ companies based in 20+ countries and across the entire hydrogen value chain, including large multinationals, innovative SMEs, and investors.

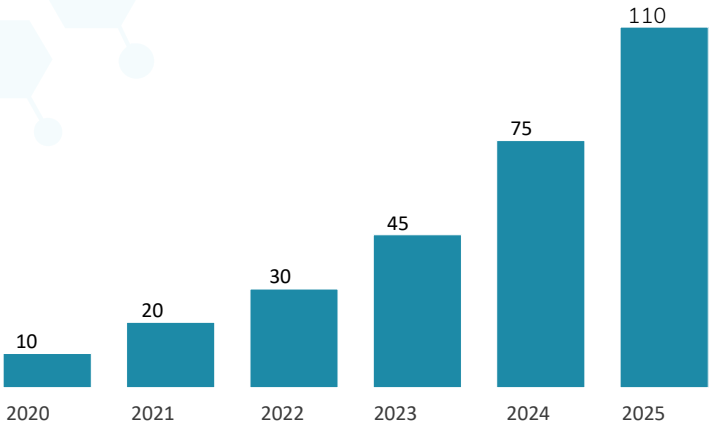
The Hydrogen Council also serves as a resource for safety standards and an interlocutor for the investment community, while identifying opportunities for regulatory advocacy in key geographies.



Global hydrogen industry has surpassed USD 110 billion in committed investment

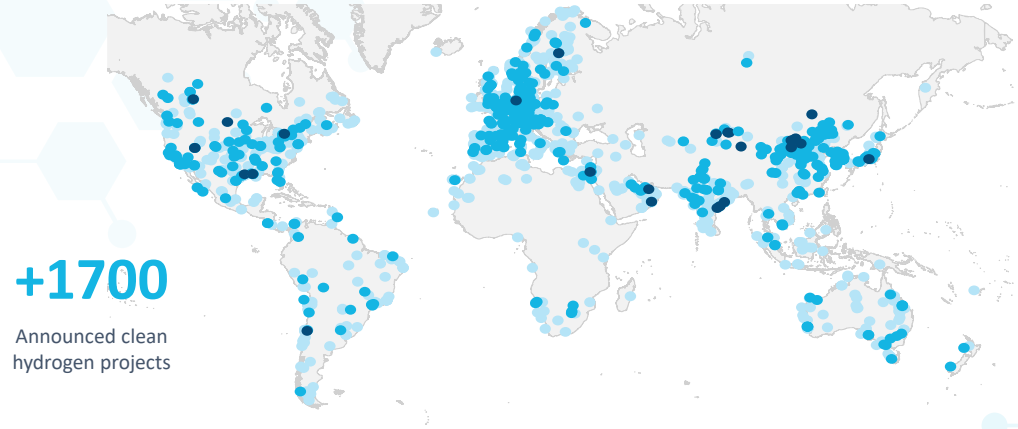
Hydrogen Council

Global cumulative committed (FID+) investment in clean hydrogen projects by 2030, $ billion



There are 510 committed (FID+) projects globally (+83 since May 2024)

Hydrogen Council



+1700

Announced clean hydrogen projects

Pre-committed projects

Committed (FID+) projects with investment less than $1 billion

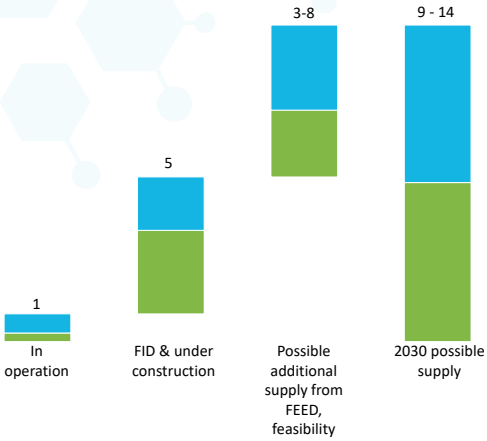
Committed (FID+) projects with investment greater than $1 billion

Supply is ready to scale, and demand is starting to materialise

Hydrogen Council

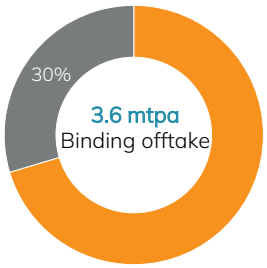
Global clean hydrogen capacity by 2030, mtpa

Low-carbon Renewable



Binding offtake by end use sector, %

New end-uses (e.g., power, steel, road mobility, maritime)



Existing end uses (e.g., ammonia, refining)

Potential 2030 demand in key regions, mtpa



2+ mtpa
Anticipated additional demand in China, India, Canada and other regions

8 mpta
Policy-enabled demand in EU, US, East Asia

China has emerged as a dominant player, followed by North America and Europe

Hydrogen Council

Committed investment by 2030

China
$33 billion
Global leader in electrolysis deployment, supported almost exclusively by domestic market

North America
$23 billion
Global leader in low-carbon production and exports, with limited domestic demand-side policies

European Union
$19 billion
Policy-backed renewable demand center with emerging regulatory clarity

Industry CEOs have a unified message of confidence, clarity, and urgency

Hydrogen Council

75%
CEOs report stable or increased investment appetite

97%
CEOs believe hydrogen is a critical solution for hard-to-abate sectors

65%
Across economy

83%
CEOs expect growth to continue



Learn more:
compass.hydrogencouncil.com



Global Business Outlook 2

Global Hydrogen Policy and Market Trends



Neal Won
Principal Analyst, S&P Global

Education
B.A., Urban Systems, McGill University, Montreal, Canada

Professional Career
Principal analyst at S&P Global Energy's Gas, Power and Climate Solutions team under CERA, based in Seoul. Focused on South Korea's evolving power market fundamentals, the energy transition toward renewables in conjunction with nuclear, and the policy frameworks shaping them. Delivers strategic insight that bridges macro policy shifts with operational realities, supporting institutional and corporate decision-making in a decarbonizing landscape.
Previous experiences include leading Asia-Pacific energy market analysis at Siemens Energy's Gas Services division and providing global macro and renewable market intelligence at Hanwha Solutions while simultaneously performing a freelancer job at S&P Global Market Intelligence covering the Korean Peninsula's geopolitical risks. Served as an intelligence officer at some of the highest echelons of Republic of Korea's military, overseeing real-time missile operations, supporting diplomatic efforts, and arms sales.
Holds a degree in urban systems and philosophy from McGill University. Fluent in English and Korean, with some passive knowledge in French. Growing focus is on the intersection of power, energy, and capital across the global energy industry.

Research Interest
- South Korea Power and Renewables market
- Global LNG Market Dynamics
- APAC LNG and Natural Gas generation
- Global Hydrogen Market Dynamics
- APAC Hydrogen and Ammonia co-firing

Speech Summary
Explore global hydrogen trends, policy frameworks, and market dynamics. Highlight emerging offtake agreements and price insights. Discuss long-term hydrogen outlooks, emphasizing the role of coordinated global policy in advancing clean hydrogen adoption across sectors by 2050.

Company Introduction
At S&P Global Energy we deliver a comprehensive view of global energy and commodities markets that enables you to make superior decisions and create long-term sustainable value for your business.
Our four core capabilities bring clarity to the kinetic: S&P Global Energy Platts delivers pricing and news; S&P Global Energy CERA delivers research and advisory; S&P Global Energy Horizons delivers energy expansion and sustainability solutions; S&P Global Energy Events deliver unparalleled thought leadership and industry collaboration. Together, these resources empower those who power the world.

S&P Global Energy

Global Clean Energy Technology

Global hydrogen policy and market trends

World Hydrogen Expo 2025



Neal Won / Global Power and Renewables / Principal Analyst

December 5, 2025.

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Global policy frameworks have come together despite political challenges

Most markets globally established basic definitions and processes needed for low-carbon hydrogen markets

		Clean hydrogen definition	Certification process	Demand mechanism	Financial support
ASIA-PACIFIC	Australia	✓	✓	✓	✓
	China	✓	✓	✓	✓
	India	✓	✓	✓	✓
	Japan	✓	✓	✓	✓
	South Korea	✓	✓	✓	✓
EUROPE	European Union	✓	✓	✓	✓
	United Kingdom	✓	✓	✓	✓
NORTH AMERICA	United States	✓	✓	✗	✓
	Canada	✓	✗	✓	✓

Legend: ✗ Conceptual → ✓ Fully defined

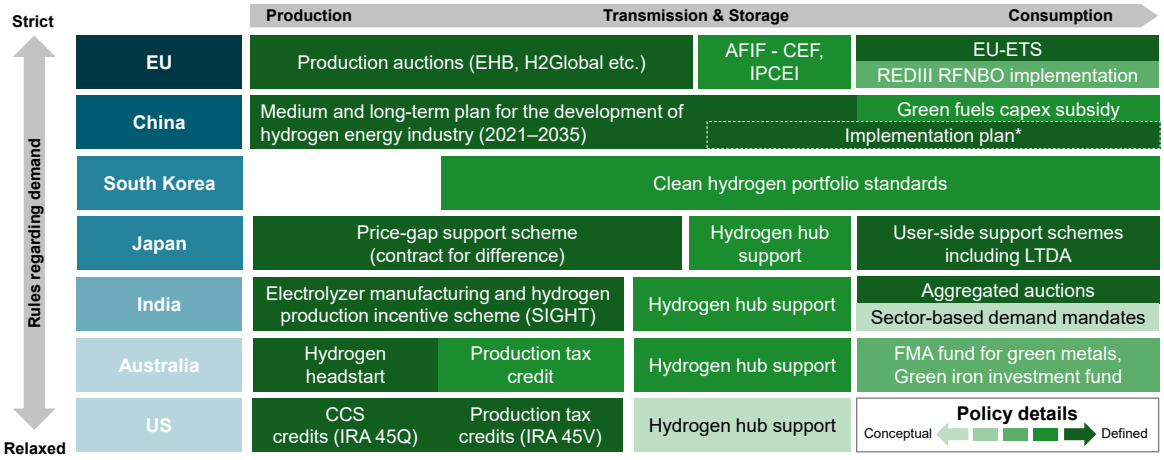
Data compiled Jul. 15, 2025
Source: S&P Global Commodity Insights.

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Support policy frameworks are advancing across the supply chain in key markets

Hydrogen support policy landscape in key markets



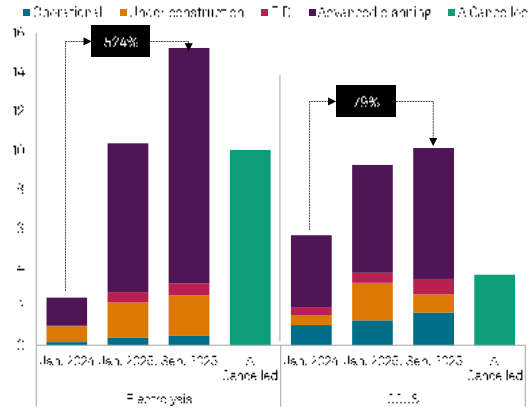
As of September 2025.
EHB = European Hydrogen Bank; AFIF – CEF: Alternative Fuels Infrastructure Facility under Connecting Europe Facility funding; IPCEI = Important Projects for Common European Interest; EU-ETS = European Union emission trading scheme; REDIII = renewable energy directive; RFNBO = renewable fuels of non-biological origin; LTDA = long-term decarbonized-power auction; CCS = carbon capture and storage; FMA = Future Made in Australia.
*Implementation Plan on Accelerating the Deployment of Clean and Low-Carbon Hydrogen in the Industrial Sector, and so on.
Source: S&P Global Commodity Insights.

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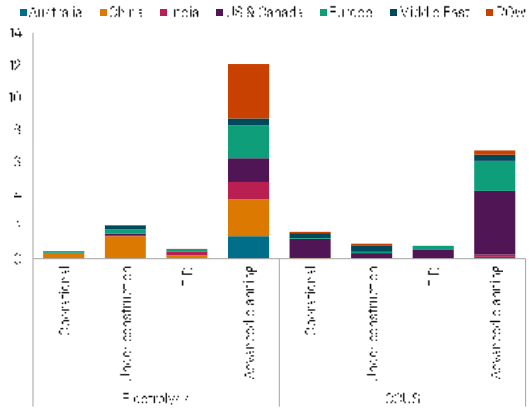
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The clean hydrogen project pipeline is maturing even amid geopolitical tensions, with Asia Pacific leading electrolysis and US leading CCS

Advanced and canceled clean hydrogen project capacity, January 2024 to today (MMt/y H_2-e)



Advanced clean hydrogen project capacity, by current status, technology and region (MMt/y H_2-e)



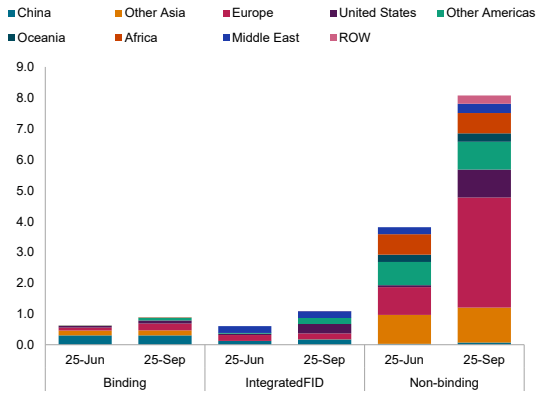
Data compiled Sept. 1, 2025.
MMt/y H_2-e = million metric tons of hydrogen equivalent including derivatives per annum; CCUS = carbon capture utilization and storage; FID = Final Investment Decision; ROW = rest of the world.
Δ Canceled refers to projects canceled" between January 2024 – September 2025. Canceled projects include projects announced as "canceled" or "on hold" by the developers and "dormant" projects where no announcements have been made in over 36 months.
Source: S&P Global Commodity Insights.

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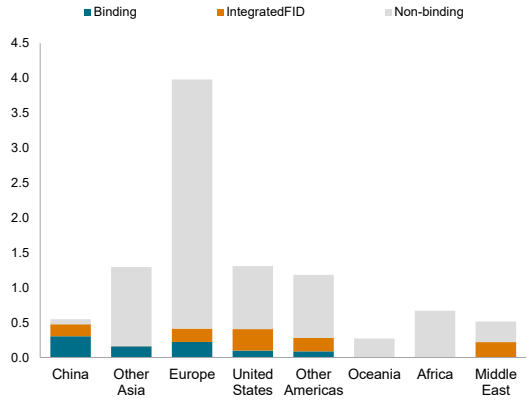
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Observations from offtake agreements: Capacities are increasing with Europe leading overall and China leading the most committed agreements

Offtake agreement volumes by production country or region by status (MMt/y H_2)



Offtake agreement volumes by country or region - September 2025 (MMt/y H_2)



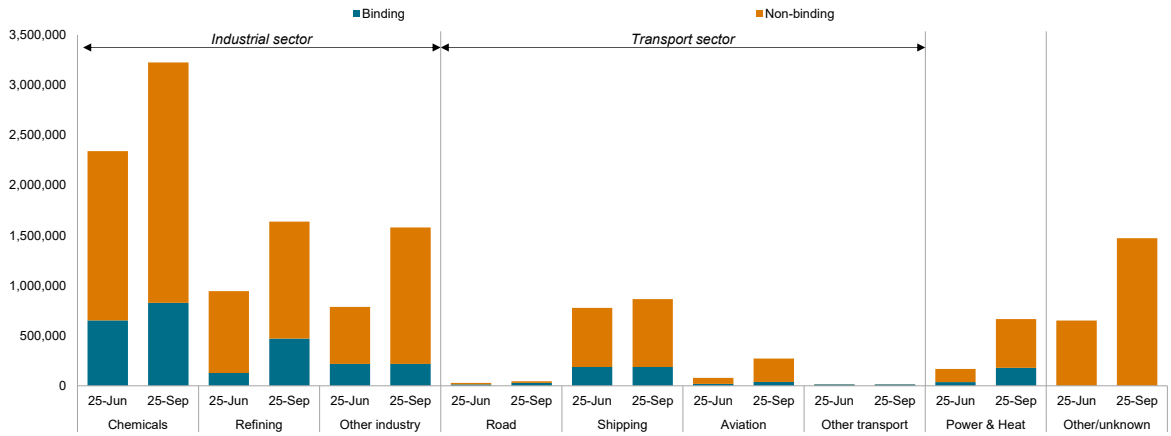
Data compiled Sept. 18, 2025.
Source: S&P Global Commodity Insights Clean Hydrogen Offtake Database.

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Offtake agreements in industrial applications continues to lead the absolute volume and the growth in volume

Offtake agreement volumes by end-use sector (MMt/y H_2)



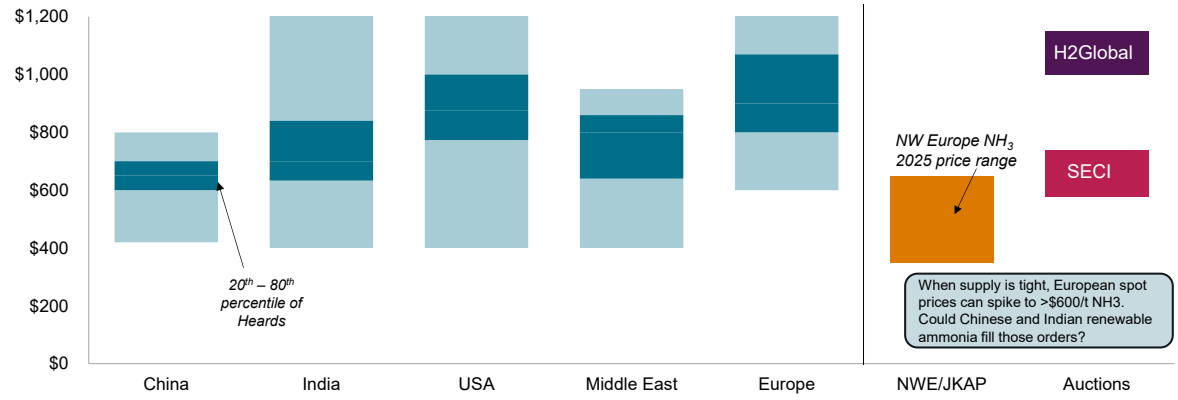
Data compiled Sept. 18, 2025.
* Offtake volumes are attributed to the producing country or region to match production capacity projections. Conversion from gigawatt capacity assumes a 50% average capacity factor in China and 60% globally.
Source: S&P Global Commodity Insights Clean Hydrogen Offtake Database.

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Renewable ammonia indicative prices from China and India at around $600 – 800/t NH_3 – below cost projections and auction results in the US and Europe

Indicative price Heards and auction results for renewable ammonia compared with traditional ammonia market ($/mt NH_3)



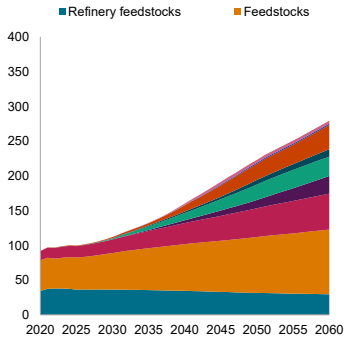
Data compiled October 7, 2025
Graph shows indicative Heards, not traded prices. Indicative Heards are generally "at-the-gate" and do not include transportation and delivery costs. H2Global range due to fluctuating Euro-to-dollar exchange range.
Source: S&P Global Commodity Insights

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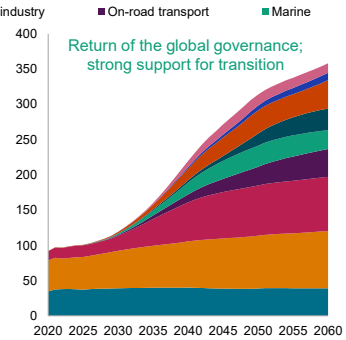
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Long-term demand outlook differ significantly across scenarios – adoption in new sectors will require a coordinated global support for transition

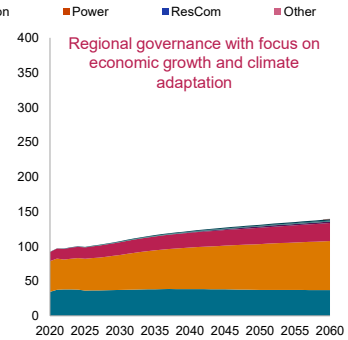
Global hydrogen demand by sector — CI Base Case (MMt)



Global hydrogen demand by sector — Renaissance (MMt)



Global hydrogen demand by sector — Adaptation (MMt)



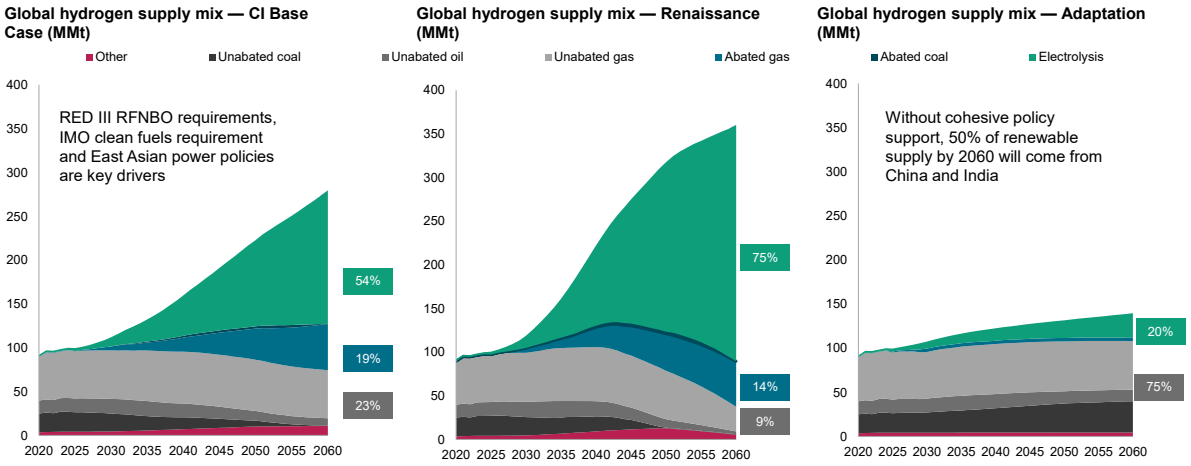
Global GDP (CAGR 2024–60)	2.4%	2.8%	2.8%
GHG emissions (vs. 2024)	-31%	-71%	+1%
Global temperature (by 2100)	2.5°C	1.9°C	3.2°C

Data compiled July 2025.
ResCom = Residential and commercial. Other consists of hydrogen demand for gas grid blending.
Source: S&P Global Commodity Insights.

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Currently discussed policies could see low-carbon hydrogen grow to 60% of the supply mix in 2050, but cessation of support could see this drop dramatically



Data compiled July 2025.
RED III RFNBO = Renewable Energy Directive III Renewable Fuels of Non-Biological Origin; IMO = International Maritime Organization.
Other consists of hydrogen produced as a byproduct from other chemical production processes, including ethylene cracking byproducts, propane dehydrogenation and ethylbenzene dehydrogenation.
Source: S&P Global Commodity Insights.

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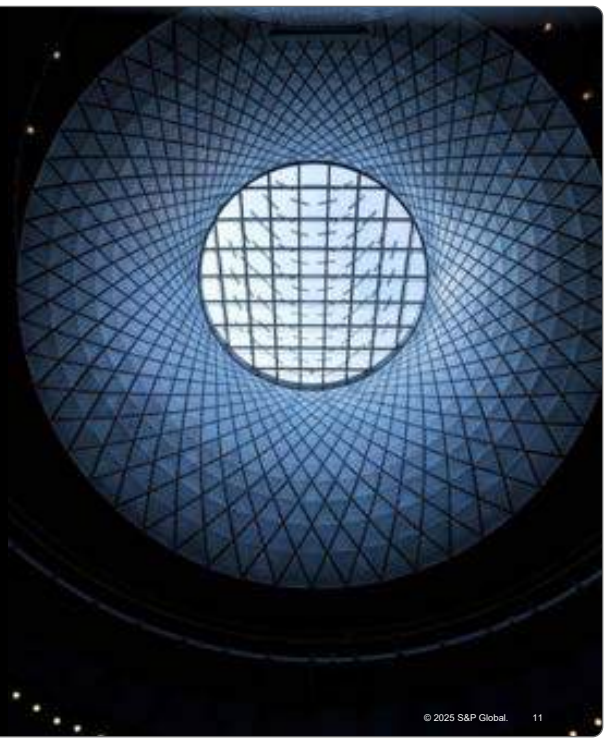
Key messages

- **The policy and regulatory frameworks for the low-carbon hydrogen market have developed in most major markets,** with auctions, grants, and tax credits facilitating project advancements. In the near term, China is expected to dominate renewable electrolysis hydrogen production.
- **Today, binding and non-binding offtake agreements primarily target incumbent sectors,** driven by policy direction, a higher willingness to pay, and ease of implementation.
- **By 2050, hydrogen demand outlooks vary widely depending on the scenario.** Globally coordinated policy will be crucial for the adoption and growth of clean hydrogen consumption in non-traditional sectors.

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S&P Global Energy

Global Business Outlook 3

Hydrogen for Development: 10 GW Lighthouse Initiative



Myoe Myint
Senior Energy Specialist, World Bank

Education
2006-2007, MPA, International Energy Management and Policy, Columbia University, New York, USA
1999-2001, MBA, Yangon Institute of Economics, Yangon, Myanmar
1986-1995, B.E., Yangon Institute of Technology, Yangon, Myanmar

Professional Career
2015-Present, Senior Energy Specialist, The World Bank, Songdo, Korea
2003-2014, Energy Analyst, ITOCHU International Inc., New York, USA

Research Interest
Myoe Myint serves as Senior Energy Specialist and plays a pivotal role on the World Bank Korea energy team. He oversees initiatives to facilitate the sharing of Korea's development experience and technical expertise with developing countries throughout the East Asia and Pacific region. As the task team leader, he is responsible for the implementation of World Bank energy operations in Korea, Myanmar, Micronesia, and the Marshall Islands, as well as providing support for regional energy transition initiatives in the East Asia and Pacific region. Myoe is involved in multiple World Bank initiatives across the region, including projects in the Solomon Islands, Papua New Guinea, the Philippines, Thailand, and other Pacific Island countries.
Myoe has approximately 25 years of professional experience working in energy project development across Southeast Asia, Latin America, and North America. His expertise includes research on energy sector development in these regions. Myoe Myint is a World Bank scholar with a Master of Public Administration focused on International Energy Management and Policy from Columbia University (2007), an MBA from Yangon Institute of Economics (2001), and a Bachelor of Engineering in Electronics from Yangon Institute of Technology (1995).

Speech Summary
The 10 GW Hydrogen Lighthouse Initiative is a World Bank–led ESMAP program launched at COP28 to accelerate clean (renewable) hydrogen in emerging markets and developing countries by de-risking and financing a first wave of mid- to large-scale projects (roughly 100 MW to 1 GW each) totaling about 10 GW of electrolyzer capacity. It aims to prove commercial viability, lower costs, and create replicable models for hard-to-decarbonize sectors like steel and long-haul transport, using tailored risk mitigation instruments and coordinated support from development finance institutions and private investors.
One of the most significant barriers to clean hydrogen's growth is its high production and financing costs, particularly in developing countries. World Bank role includes designing financing mechanisms to reduce these costs and de-risk projects. By addressing uncertainties around future buyers, pricing, and regulatory conditions, the World Bank aims to attract investment and encourage the development of clean hydrogen infrastructure. World Bank is particularly focused on lowering financial risks, working with its partners to make clean hydrogen projects more commercially viable and thus paving the way for broader adoption. In FY2024 the World Bank approved 1.6 billion in funding for renewable hydrogen loans, in addition to the $1.65 billion approved in FY2023, bringing the total loan amount for hydrogen activities to $3.25 billion. Investments up to $3 billion are currently in preparation.
In partnership with other stakeholders, World Bank is also developing a digital hub to support knowledge sharing, training, and technical assistance. The platform will serve as a resource for countries and stakeholders looking to implement clean hydrogen projects. It will also help connect governments, investors, and technical experts, promoting collaboration and enabling stakeholders to benefit from shared knowledge and expertise.

Company Introduction
The World Bank is a global development bank providing finance, knowledge to reduce poverty and boost prosperity.
https://www.worldbank.org/ext/en/home

Global Business Outlook 4

Overview of the Northeast Asia Clean Hydrogen Power Generation Market



Lim Yeon Yi
Senior Manager, KPX

Education
2016-2021, Ph.D., Economics, SoongSil University, Seoul, Korea
2014-2016, M.S. Economics, SoongSil University, Seoul, Korea
2010-2014, B.S., Economics, SoongSil University, Seoul, Korea

Professional Career
2022-Present, Hydrogen Market Team, Market Innovation Department, KPX, Jeollanam-do, Korea

Research Interest
Hydrogen Policy and Clean Hydrogen Power Market Design
Energy Markets and Power System Economics
Climate and Decarbonization Policy
Energy Price Analysis

Speech Summary
This Speech provides an overview of Korea's clean hydrogen power generation bidding market and Japan's long-term decarbonized capacity auction. It outlines policy backgrounds, market design principles, bidding and evaluation structures. Through this, it offers insights into policy trends and future institutional directions for the Northeast Asian hydrogen power market.

Company Introduction
KPX is Korea's independent system and market operator, ensuring transparent electricity markets and reliable grid operations. As Asia's first ISO-style power exchange, KPX is at the forefront of the global energy transition, connecting Korea to international standards.
The Hydrogen Council also serves as a resource for safety standards and an interlocutor for the investment community, while identifying opportunities for regulatory advocacy in key geographies.

Overview of the Northeast Asia Clean Hydrogen Power Generation Market



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2025.12.05.



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Korea's Hydrogen Power Generation Bidding Market Overview

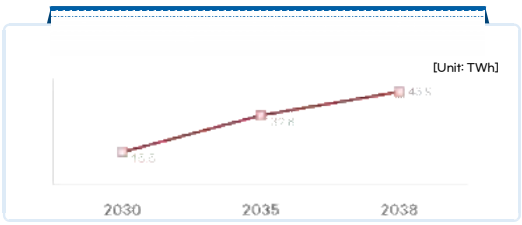
KOREA POWEREX

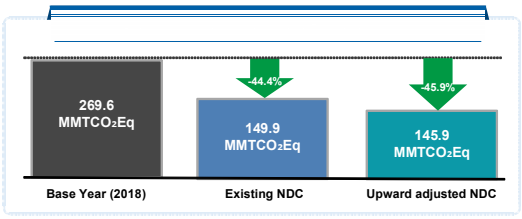
Background

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Reduction of Greenhouse Gases in the Power Generation Sector

- Use clean hydrogen as fuel to generate electricity
  →Achieving carbon neutrality through carbon-free power sources such as nuclear power and renewable energy





Establishing a Full Hydrogen Value Chain

- Complementing the limitations of the existing RPS scheme to expand hydrogen-using power plants and create stable hydrogen fuel demand
- Foster related industries and build the foundation for a hydrogen economy by generating large-scale clean hydrogen demand and ensuring stable investment and cost recovery for businesses through long-term fixed-price contracts

	Renewable Portfolio Standard	Hydrogen Power Generation Bidding Market
Legal Basis	Article 12-5 of the Renewable Energy Act	Article 25-6 of the Hydrogen Act
Subject of Trade	Renewable energy certificate (REC)	Electricity generation by Hydrogen power(kWh)
Obligated Party	Power generators	Power Sales Companies
Settlement Method	SMP + REC	Fixed price contract
Contract Duration	20 years	20 or 15 years
Competitive Factors	Price + non-price factors	Price + non-price factors

Progress and Foundation

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Feb. 2021	Nov. 2021	June 2022	Nov. 2022	Dec. 2022	Jan. 2023	May 2023	June 2023	May 2024
Enforcement of the Hydrogen Act	Establishment of the first basic plan for transiting to a hydrogen economy	Amendment of the Hydrogen Act	Establishment of a plan to create a clean hydrogen ecosystem	Amendment of the Enforcement Decree and Enforcement Regulations	Designation of a management agency for the bidding market	Announcement of purchase volume and enactment of management regulations	The first opening of a market for general hydrogen power	The first opening of a market for clean hydrogen power

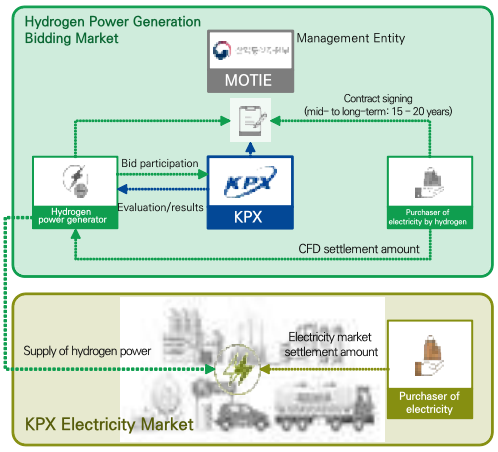
Legal Basis

Opening of Hydrogen Power Generation Bidding Market (MOTIE)

- **Article 25-6 of the Hydrogen Act (Purchase or Supply of Amounts of Hydrogen-Generated Electricity)**
  The Minister of Trade, Industry and Energy may establish a bidding market for hydrogen power generation (hereinafter referred to as "bidding market") to facilitate the implementation of the hydrogen economy. In such cases, a successful bidder in the bidding market shall be determined from among hydrogen power generation business entities meeting the standards prescribed by the Presidential Decree, such as resident acceptance.

Management Agency for the Bidding Market (KPX)

- **Article 25-7 (Designation of Agencies Managing Bidding Market)**
  To efficiently operate a bidding market, the Minister of Trade, Industry and Energy may designate an institution, an organization, or a corporation related to hydrogen business or electricity transactions that meet the standards prescribed by the Presidential Decree, such as facilities and human resources, as an agency managing a bidding market (hereinafter referred to as "management agency").



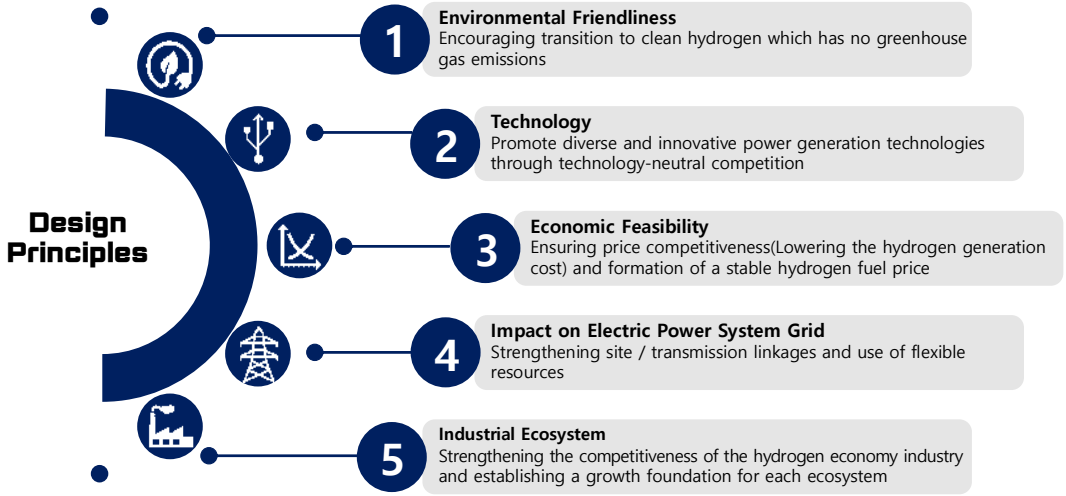
Market Segmentation

While making unnecessary classification of the market should be avoided to promote the competition of businesses, the market should be classified into a general and clean hydrogen market per policy objectives.

	General Hydrogen Market	Clean Hydrogen Market
Purpose	Maximizing the role of **distributed generation expansion**	**Reducing greenhouse gas emissions** through **mandatory clean hydrogen use**
Subject of Participation	**Technology-neutral**	
	New hydrogen firing plant (RPS-unregistered)	**New clean hydrogen firing and co-firing plants** (RPS-unregistered)
Fuels Used	**Clean hydrogen** Allows **reformed(grey) and by-product hydrogen**	**Clean hydrogen**
Features	▪ Opened considering the limitations of the initial introduction of clean hydrogen ▪ After the stabilization of clean hydrogen production and introduction in the future, the **general hydrogen market will be closed.**	▪ Since the beginning, the bidding market was established targeting power producers that **use clean hydrogen**

Basic Design Principles

To achieve the objectives of the Hydrogen Act, five basic principles are comprehensively considered: environmental friendliness, technology, economic feasibility, impact on electric power system, and industrial ecosystem



Basic Operational Framework

Application of the operating rules of the hydrogen power generation bidding market

- Market opening
- Evaluation of bids and selection of successful bidder
- Contract signing and Construction management

Application of the *Electricity Market Management Regulations*

- Commencement of commercial operation
- Linkage with spot market
- Metering, settlement, and payment

Decision-making through a committee of experts

Hydrogen Power Generation Bidding Market Committee
Making decisions on key matters such as market opening, management, contracts, and post-management, and enactment/amendment of management regulations

Working Council
Discussions on key matters related to the management of the bidding market

Design WG
Gathering the opinions of external experts related to the design of the bidding market

Evaluation Committee
Random selection from the expert pool
Evaluation of business proposals and Selection of successful bidder fairly and transparently

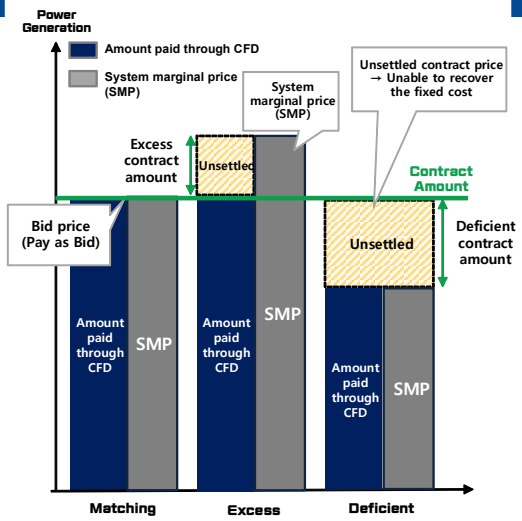
Transparent and fair management of the bidding market through multilateral decision-making.

Basic Operational Framework

1 Market opening

Volume	based on annual purchase notification in the hydrogen power generation bidding market
Contract Duration	Preparation : 3 years (up to 1-year grace period) Trading : 15 years
Require-ments	(Facility) obtained a power plant license (Financial) Credit rating, Paid-in capital etc. (Environmental) Using Clean hydrogen, at least 20% co-firing ratio etc.
Bid Amounts	Annual hydrogen power generation
Bid Price	LCOE for clean hydrogen power generation Fuel costs can be linked to the exchange rate and Henry-Hub price
Contract	A contract for difference(CfD)

Dealing with Excess/Deficient contract amount



Basic Operational Framework

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2 Evaluation of bids and selection of successful bidder

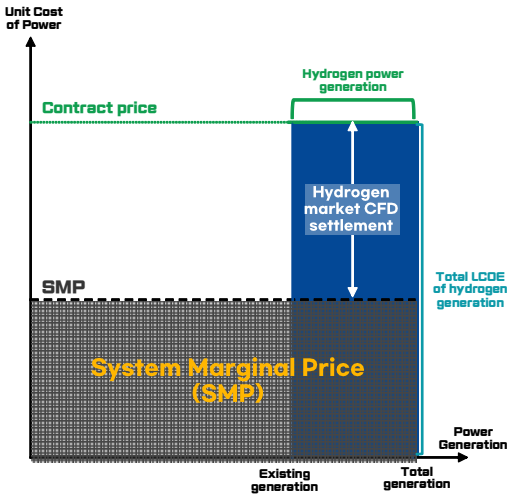
- Evaluating bid proposals meeting participation requirements and within the ceiling price
- A successful bidder is selected by comprehensively evaluating price (60%) and non-price factors (40%)
  - (Price evaluation) Evaluation based on the price proposed by the bidder within the ceiling price
  - (Non-price evaluation) Forming a separate committee to ensure the objectivity of quantitative and qualitative evaluations
- Selection of successful bidders in order of highest total score

※ Tie-breakers : Price → Environmental contribution → Fuel Supply Stability

Price (60%)	Based on lowest price(*)	- Fixed costs + operating costs + fuel costs - Calculated as (Lowest bid price / Given bid price) × 60
Non-price (40%)	Quantitative and Qualitative Evaluations	- Calculated as [Overall evaluation score × 0.4] - Considering the market's purpose, greater weight is given to environmental contribution categories - Pass-fail system to ensure business capability

(*) Excluding bid prices of businesses that exceed the ceiling price or fail in non-price evaluation

3 Settlement of Hydrogen Power Generation

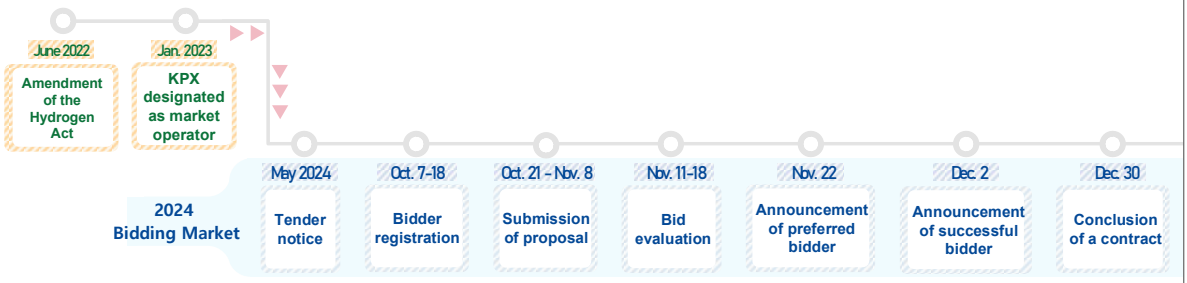


'24 Clean Hydrogen Power Generation Bidding Market Results

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First Bidding Market Opening Progress

- After the formation of a task force for the clean hydrogen power generation bidding market in June 2023, working council management and design, working council review, and committee resolution took place, after which the first clean hydrogen power generation bidding market opened in May 2024.



Acceptance of Bids and Successful Bid Results

- Six power plants (five companies) participated in the bid with volume of 6,172 GWh, and one power plant with 750 GWh was selected as the final successful bidder.

Announced Amount	# of Participating Companies	# of Bids	Total Bid Amount	Proposal Acceptance Rate	Successful Bidder Amount
6,500 GWh	5	6	6,172 GWh	0.95 : 1	750 GWh (1 bid)

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smart KPX 전력거래소 KOREA POWER EXCHANGE

Japan's Long-term decarbonized Power Generation Capacity Auction Overvie

K O R E A P X

Background

smart KPX 전력거래소

K O R E A P X C H A N G E K P O W E R E X K O R E A P O W E R E X

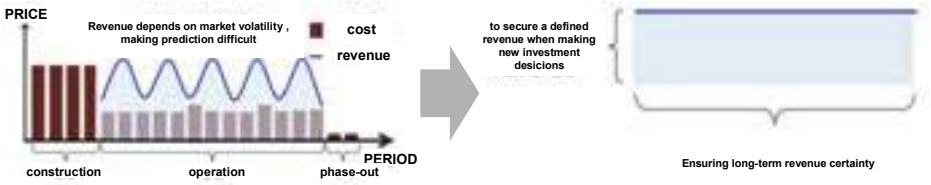
Securing supply capacity through decarbonized power sources is necessary to achieve carbon neutrality by 2050

- The capacity market was bifurcated into **the general capacity market** and **the long-term decarbonized capacity market** according to its purpose and function.

General capacity market	To secure the supply capacity required for demand in a future specified period(single year), the auction is conducted 4years prior to the actual delivery year(real supply-demand year)

Promoting new investment in decarbonized power sources

- When investing in new power sources, investors require a level of **revenue predictability** that allows for long-term cost recovery.
- By providing producers with greater long-term predictability for investment recovery than existing schemes, **investment in decarbonized power sources is promoted.**

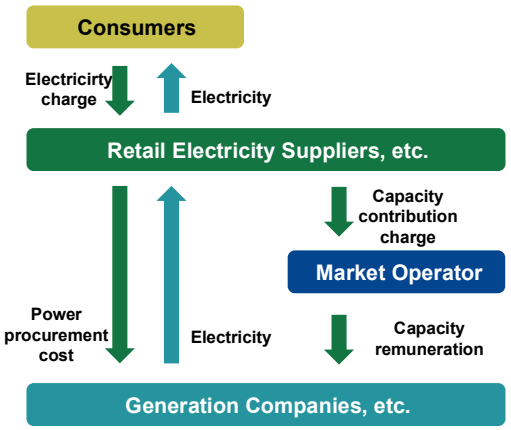


Progress and Operating Framework

Oct. 2023	Jan. 2024	Apr. 2024	Jan. 2025	Apr. 2025
Registration of participants for the first auction	The fist opening an auction	Selection of awardees in the first auction NH3/H2 820MW	Announcement of the second aution	Selection of awardees in the second auction NH3/H2 94MW

Operating framework

- The central capacity market is operated **by OCCTO**, the cross-regional transmission system operator.
- OCCTO invoices and collects capacity contribution **charges from retail electricity suppliers, general transmission and distribution operators**, and then disburses **the payments to generation companies**.
- The costs associated with securing capacity are ultimately **passed on to end consumers**.



Fundamental elements of market design

Bidding process

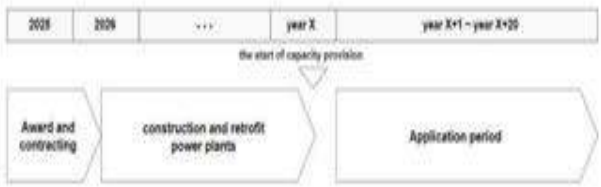
Market opening → Submission of bid proposals → Evaluation and selection of successful bidders → Contract execution → Obligation fulfillment and settlement

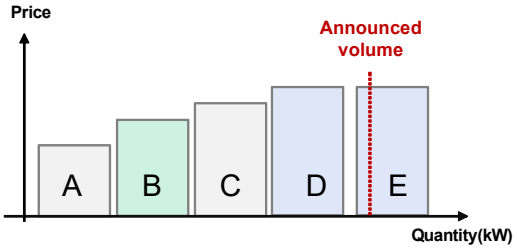
Market opening(based on the second auction market round)

Volume	The total capacity : 5GW Decarbonized thermal capacity* : 500MW * Ammonia/Hydrogen(co-firing and full-firing), CCS
Eligible Entities	Decarbonized stable/variable power LNG dedicated firing is temporarily included
Bid Capacity	For each generator unit, the operator sets the supply capacity(kW) New/replacement Hydrogen full-firing : 100MW or more Retrofit Hydrogen co-firing : 50MW or more Ammonia full or co-firing : 50MW or more

Fundamental elements of market design

Bid price	▪ Based on capital cost, O&M costs, and project margins(yen/kW/year) ▪ Decarbonized thermal plants(NH3/H2 dedicated or co-firing, CCS) may include variable costs(e.g., fuel) in their bid prices. ※ Limited to the fuel cost differential vs. LNG/coal, Capacity factor capped at 40%
Contract period	20-year period(beginning in the year following the start of capacity provision) While 20-year period is the standard across all resource types, participants may request a longer application period, in one-year increments, if desired.
Evaluation	Awarding proceeds from the lowest bid until the volume is filled To minimize the burden on consumers, ceiling prices are applied by power source and by category (new/replacement or retrofit).
Contract/Settlement	Pay-as-bid





Thank you.

Power business convergence platform that leads an eco-friendly future

KOREA POWER EXCHANGE

Global Business Outlook 5

H2Global: A Novel Financing Mechanism to Accelerate Global Clean Hydrogen Trade



Markus Exenberger
Executive Director, H2Global Foundation

Education
He studied business administration, commercial law and supply engineering at the universities of Cologne and Hamburg.

Professional Career
Worked for Bechtel Corporation and Multiplex in Hong Kong, Singapore, Australia, and the United States.
Consultant for large companies in Germany in the field of energy transformation.
2001–2021: Senior roles at the German Federal Government (GIZ) in South-East Europe, South-East Asia, East Africa, and Brazil; managed major energy programs and advised governments on energy transition and funding mechanisms.
Co-founder and co-developer of the H2Global mechanism.
Chairman of the Executive Board of the H2Global Foundation since establishment.

Research Interest
Clean hydrogen market development
Energy transition policy and funding mechanisms
International energy cooperation
Market-based support instruments for next-generation fuels

Speech Summary
With around USD 6 billion in funding commitments from four governments, H2Global is currently the world's largest green hydrogen trading platform. This keynote will introduce the H2Global model — an innovative price gap financing instrument designed to bridge price gaps between supply and demand, de-risk early market transactions, and accelerate international hydrogen trade. The presentation will also highlight lessons learned from the European experience and explore how the mechanism can support clean hydrogen market development in other regions.

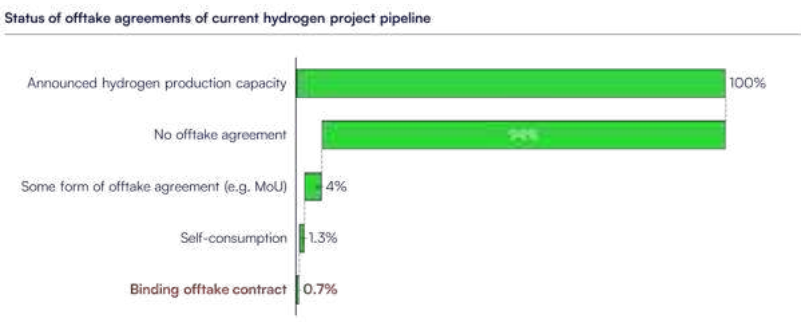
Company Introduction
The H2Global Foundation is a non-profit organization dedicated to creating a global market for clean hydrogen and other low-emission fuels. By promoting a double-auction mechanism, the foundation facilitates the efficient and transparent trade of clean fuels, helping to accelerate the energy transition.



H2Global: A Novel Financing Mechanism to Accelerate Global Clean Hydrogen Trade
December 2025

H2Global

The challenge — Billions in planned low-carbon hydrogen projects remain unbuilt due to missing buyers



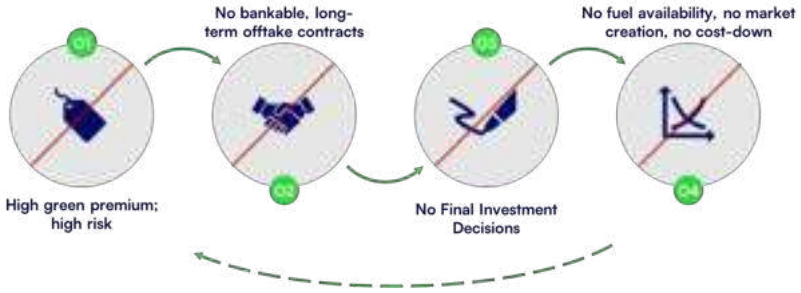
Producers face high upfront costs and long payback periods, but buyers are unwilling to sign long-term, fixed-price offtake contracts.
As a result, **nearly all announced hydrogen capacity has no binding buyer — leaving projects unable to reach Final Investment Decision.**

Page 2

Source: BNEF Hydrogen Tracker (2025)

H2Global

The challenge — Structural market failures prevent low-carbon projects to move forward

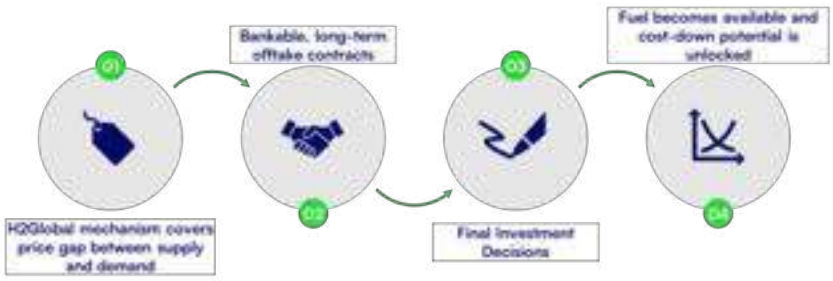


Even when governments set ambitious decarbonization targets, **private actors face too much price risk**.
Without a smart and efficient mechanism to bridge this gap, large-scale projects remain stalled, and clean energy products cannot compete with fossil alternatives.

Page 3

H2Global

The solution — H2Global's double auction mechanism resolves market failures, with the aim to accelerate the emergence of liquid markets

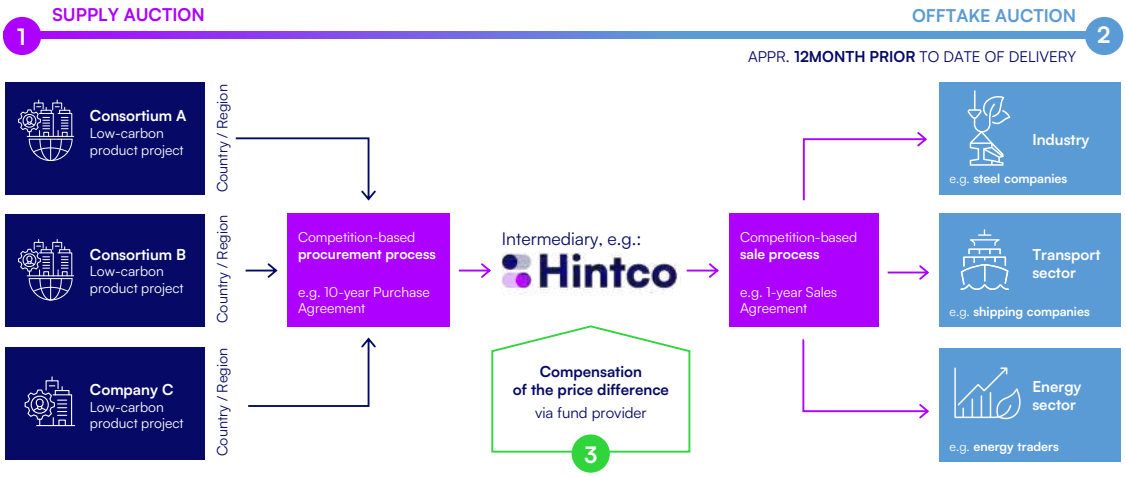


H2Global brings first movers into the market by providing the certainty needed for developers to invest, while ensuring competitively priced, low-carbon products for buyers. This coordinated market-making approach accelerates early deployment and drives long-term cost reductions.

Page 4

H2Global

The solution — H2Global's double auction mechanism in a nutshell — enabling business cases for low-carbon product projects



Page 5

H2Global

The solution — H2Global's double auction mechanism creates value for all key stakeholders

1

For producers,
it provides long-term revenue certainty and gets projects to Final Investment Decision.

2

For fund providers,
it minimizes funding needs and ensures the 'biggest bang for the buck'.

3

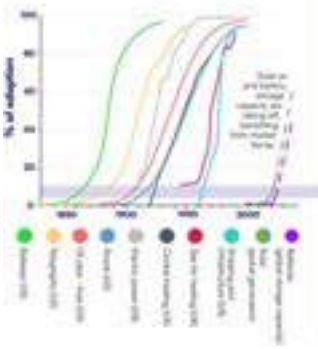
For offtakers,
it manages price risk and aids price discovery towards a liquid market.

Page 6

H2Global

Our role in a global context — H2Global is currently the sole active Green Market Maker in the world

The historical adoption of a sample of infrastructure and energy systems



Stages in market formation and scale-up



KEY TAKEAWAYS

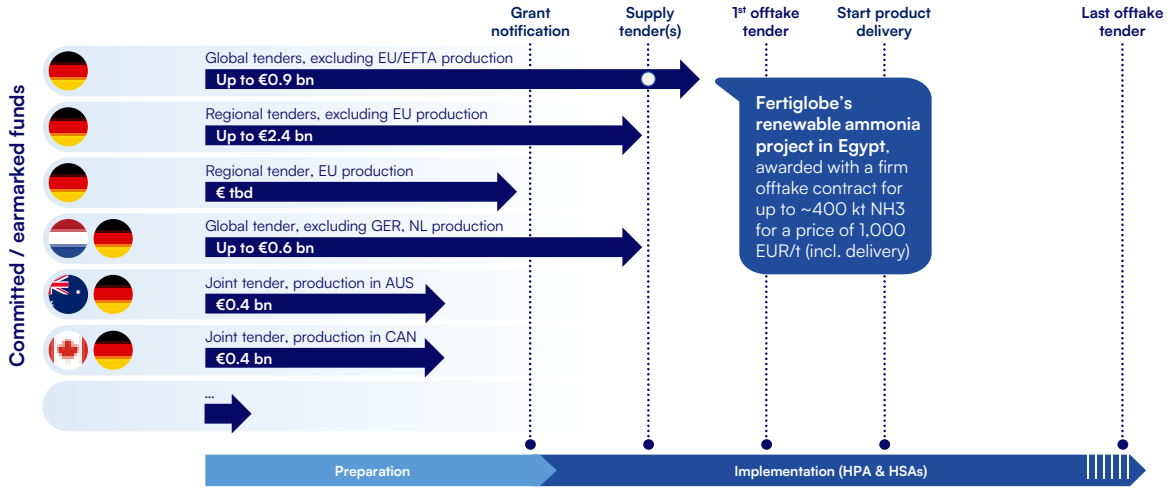
- When markets reach a **tipping point**, market forces lead to **exponential adoption** thereafter.
- **The H2Global mechanism has the power to bring markets to their tipping points** and unlock large-scale GHG emissions reductions.

Page 7

Source: MPP/BEF (2024): Unleashing market forces to scale green industry: The role of Green Market Makers

H2Global

Success to date — USD 6+ billion of public capital for H2Global tenders by Australia, Canada, Germany and the Netherlands



Page 8

H2Global

Currently in implementation — 2nd H2Global supply auction round with a procurement volume of USD 3+ billion

It includes:

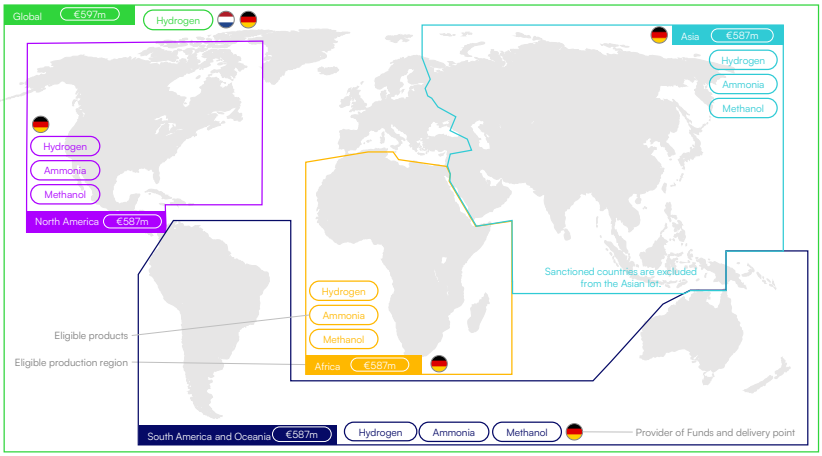
- **four regional lots** for the supply of RFNBO hydrogen, or RFNBO ammonia, or RFNBO methanol,
- along with **one global lot** for the supply of RFNBO hydrogen.

Bidders are free to choose **preferred mode of transport** (e.g., final product, LOHC, LH2, etc.) to the designated delivery point.

Bidders can participate with a single project in both regional and global lots.

These auction lots support policy objectives such as energy import diversification and supply security.

For more details, please visit:
https://hintco.eu/hpa-auctions/



The funding countries, Germany and the Netherlands, as well as sanctioned countries are excluded from the global lot.

Page 9

H2Global

Beyond auctions — The three pillars of the H2Global Foundation

Research



Collaborating with (non-exhaustive): THE WORLD BANK, IRENA, OECD

Support the market creation through targeted research activities, engaging with internationally renowned institutions.

Solutions Lab



Customize H2Global's double auction mechanism to create sector-specific solutions.

Outreach



Raise awareness that H2Global offers a proven, ready-to-use solution for governments and international institutions.

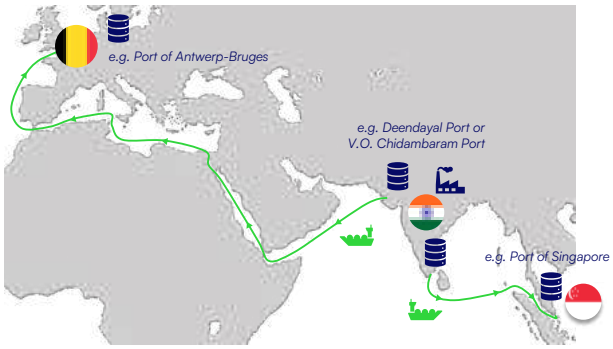
Page 10

H2Global

H2Global Shipping — Our new sectoral initiative, tailoring the mechanism for clean maritime fuels

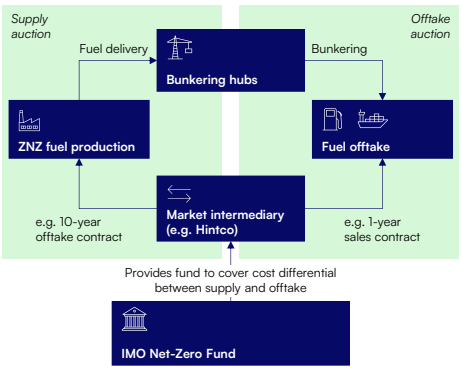
#1 **Shipping tender to be funded by national governments,** enabling the success of a Green Shipping Corridor

Illustrative example



#2 **H2Global mechanism explored as a potential disbursement tool of the IMO Net-Zero Fund**

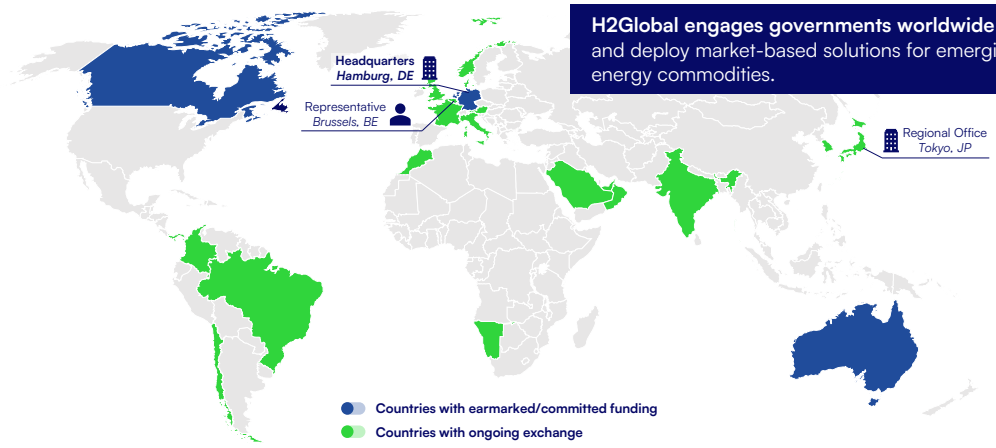
Illustrative example



Page 11

H2Global

Our external reach — The H2Global Foundation's global footprint

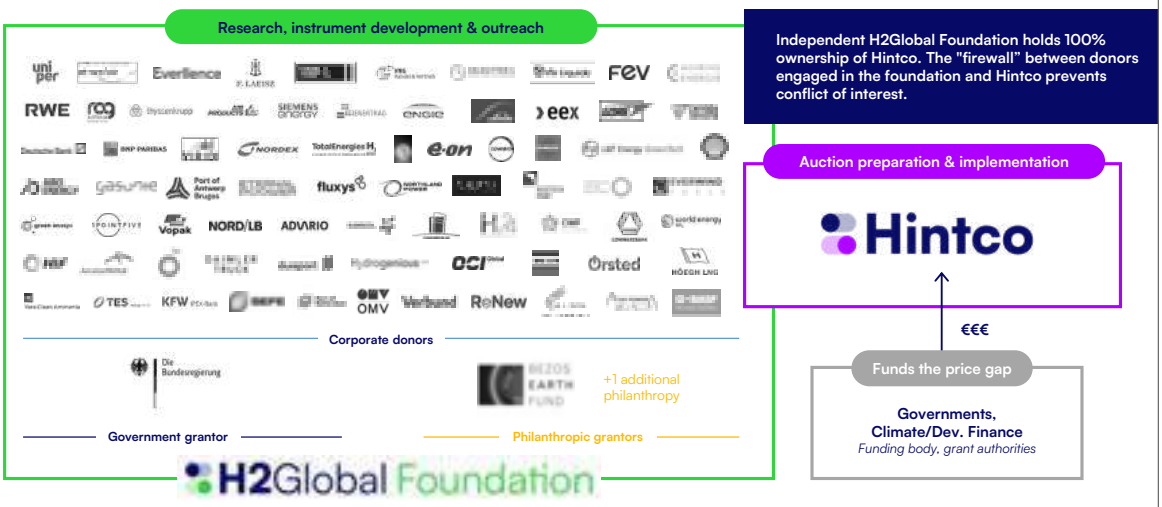


H2Global engages governments worldwide to design and deploy market-based solutions for emerging clean energy commodities.

Page 12

H2Global

Institutional setup — A non-profit foundation with a transitional market intermediary that exits as markets mature



Page 13

H2Global

Partner with us!
Help us shape the ramp-up of the global hydrogen market.
https://h2-global.org/take-action/

Follow us on LinkedIn!
@H2Global Foundation
@HINT.CO GmbH



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Markus Exenberger
H2Global Foundation
Executive Director

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20457 Hamburg, Germany
markus.exenberger@h2-global.org

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H2Global

Panel Discussion

Investment and Market Growth Outlook of Global Clean Hydrogen Projects

Moderator



Neal Won
Principal Analyst, S&P Global

Panelists



Myoe Myint
Senior Energy Specialist, World Bank



Lim Yeon Yi
Senior Manager, KPX



Markus Exenberger
Executive Director, H2Global Foundation

WORLD HYDROGEN EXPO 2025 6th Conference

Global Demand Outlook

Global Demand Outlook 1

LH2-based Global Hydrogen Supply Chain Development and Demand Expansion Strategy



Kenji Yoshimura
Kawasaki Heavy Industries

Education
1990-1992 Master of Engineering, Kyushu University

Professional Career
2025 Oct-Present, Executive, Chief Executive Staff Officer, Think Tank Department, Hydrogen Strategy Division, KHI
2023, Executive, Group Manager, Project Group, Hydrogen Strategy Division, KHI
2020, Senior Manager, Business Development Department, Hydrogen Strategy Division, KHI
2009, Manager, Hydrogen Project Department, Hydrogen Chain Development Center, KHI
1992, Joined in Kawasaki Heavy Industries, Ltd.(KHI)

Research Interest
Energy related equipment
Hydrogen related equipment

Speech Summary
KHI is advancing a global hydrogen strategy for carbon neutrality via large-scale production, transport, and use. Its roadmap spans pilot, commercialization, and full-scale phases, while developing power, mobility, aviation tech, and CO_2 capture to drive decarbonization worldwide.(282 characters)

Company Introduction
KHI leads hydrogen innovation with global supply chains, power systems, and CO_2 solutions.(90 characters)

World Hydrogen Expo 2025 (H2 MEET)

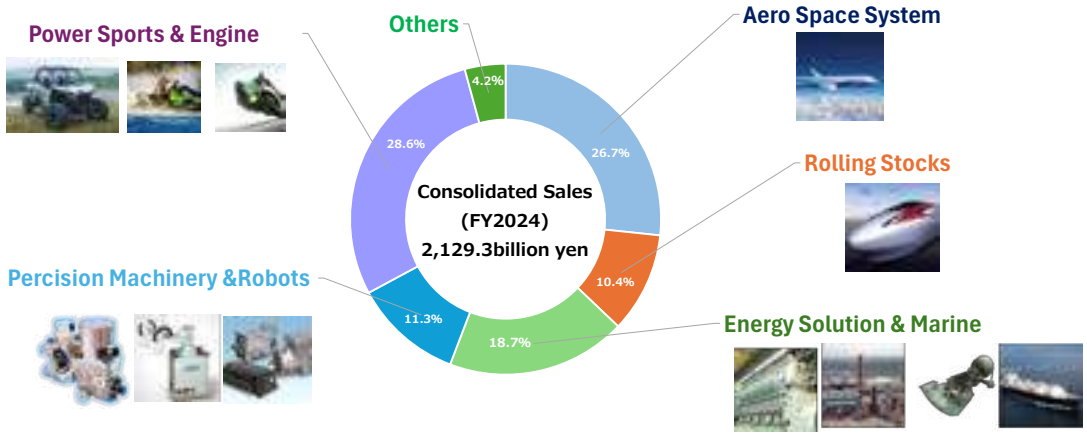
LH2-based Global Hydrogen Supply Chain Development and Demand Expansion Strategy

December 5. 2025
Kenji Yoshimura

Kawasaki Heavy Industries, Ltd
Executive, Chief Executive Staff Officer
Think Tank Department
Hydrogen Strategy Division

Kawasaki
Powering your potential

Kawasaki FY2024



1 USD = 140 JPY,

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KHI Group Hydrogen Products


H_2 Gas Engine


H_2 Gas Turbine


Fertilizer (GH_2 Production)


Electrolysis (Membrane)


Liquefier


LH_2 Loading Arm


H_2 Boiler


HP H_2 Valve

Production

Use

Synergy of Kawasaki Group Technologies

Transport

Storage



LH_2 Carrier


FC Train


H_2 Bikes





LH_2 Tanks




LH_2 Container


H_2 Compressor


HP GH_2 Trailer


H_2 Compressor

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Expected CO2-free H2 Supply chain



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Liquefied Hydrogen

- Liquefaction at a cryogenic temperature of -253℃ ➔ 1/800th the volume of gas
- High-performance insulation technology (double-shelled/vacuum insulated tank)
  ➔ Long-term storage equivalent to LNG
- High purity/No need for refining
  ➔ Suitable for a wide range of applications
  from FCVs to industrial furnaces simply by evaporation


LH2 Storage Tank
at Tanegashima Space Center


Japan's biggest LH2 Tank
at Kobe LH2 Terminal


Large-scale LH2 Carrier
(to be built)


LNG Carrier

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Liquefied Hydrogen Supply Chain

2015 2020 2025 2030 2040~

Pilot Demonstration
- Completed pilot demonstration

Commercialization Demonstration
- Development of commercial-scale equipment

Commercial Chain Operations

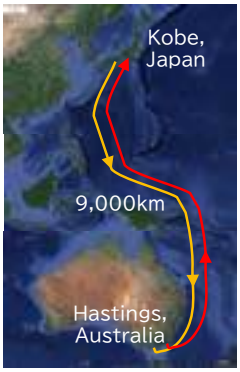
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Pilot Project Demonstration

The first voyage

Departure from Kobe	**24th Dec. 2021**
Arrival at Hastings	**21st Jan. 2022**
Departure from Hastings	**28th Jan. 2022**
Arrival at Kobe	**25th Feb. 2022**









Source：HySTRA

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Liquefied Hydrogen Carrier "Suiso Frontier"





Length	116 m	Speed	13 knot
Width	19 m	Draft	4.5 m
Max crew	25 person	Propulsion	Diesel electric

Vacuum Insulated Double Shell Structure

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Liquefied Hydrogen Supply Chain

2015 2020 2025 2030 2040~

Pilot Demonstration
- Completed pilot demonstration

Commercialization Demonstration
- Development of commercial-scale equipment

Commercial Chain Operations

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Scaling up toward Commercialization

2021 Pilot demonstration	2030 Commercialization Demonstration	Further more
1,250m³ 	40,000~80,000m³ 	160,000m³ 
2,500m³ 	50,000m³ 	200,000m³ 

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Commercialization Demonstration

Green Innovation Fund project

Organization : Japan Suiso Energy (Lead manager),
ENEOS、Iwatani Corporation

Investment : Approx. USD 2.1 Billion
(Government Support Approx. USD 1.4 Billion)

Domestic terminal tests:



Ogijima Island, Kawasaki city





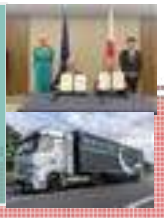
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Worldwide Collaboration for Global Hydrogen Supply Chain

Daimler Truck
Daimler Truck and Kawasaki Heavy Industries signed MoU

Jointly study the optimization of liquid hydrogen supply chains

Target: Early 2030s establish LH2 supply chain



ADNOC
Strategic Collaboration Agreement with ADNOC

Signed a strategic collaboration agreement with UAE energy company (ADNOC) to build a liquefied hydrogen supply chain.





Supplier
(Green Hydrogen)

Supplier
(Bule Hydrogen)

Off taker

Japan-Australia Pilot Demonstration Project

Supported by the government of Japan and Australia

Supported by NEDO from FY2015 to 2022.

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Other application developments for Demand Expansion



FC Train



H_2 Compressor for Refueling station



H_2 Gas Engine



H_2 Gas Turbine



H_2 Aircraft



LH_2 Container for Train



H_2 Compressor for Pipeline





MHFS（Marine LH_2 Fuel System）



H_2 Bikes

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Hydrogen Gas Turbine

	Diffusion / Micro-Mix	Diffusion Combustor	Micro-Mix Combustor
Type H_2 Firing	PUC17（1.8MW） 0~100% H_2/NG Firing (2018)	PUC300（34MW） 0~50% H_2 Co-firing (2021)	GPB300 (34MW) 0~100% H_2 Co-firing (2026)
Project Overview	✓Co-generation system (CGS) with 1 MW class ✓World's first 100% H_2 firing ✓Heat and power were delivered to neighborhood building  @H2CGS Demonstration Facility, Port Island, Kobe	✓Co-firing by-product hydrogen and natural gas. ✓Kerosene can also be used as a backup.  @Seibu Oil	✓Aim at Operation with flexible ratio between 100% hydrogen and 100% natural gas  @RWE Generation SE

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Large scale Hydrogen Gas Engine

For power generation

H_2 Co-Firing Engine (5~8 MWe)





・Actual demonstration test in FY2024
・30 vol.% H_2 co-firing
・Market in 2025

For marine proparsion

H_2 Dual Fuel Engine (2~3 Mwe)





・Op. Mode :H_2 Mode and Diesel Mode
・ Green Innovation Fund Project
「Next Generation Ship Development」
・Actual demonstration test by 2030

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Hydrogen Compressors

For large scale H_2 stations





・Flow rate : 300Nm³/h
・Discharge pressure: 87.5MPa
・Market in 2025





・Flow rate : 2100Nm³/h
・Discharge pressure: 87.5MPa
・Demonstration in 2027

For H_2 pipeline



Flow rate 500,000 Nm3/hr
Inlet Pressure : 30 barA
Outlet Pressure: 60 barA
Pressure ratio: 2.0+(Plus)
Market in : 2026

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Small scale Hydrogen Engine

Consortium「HySE」 established in May 2023



Kawasaki Heavy Industries, Ltd.,
Kawasaki Motors, Ltd.,
Suzuki Motor Corporation,
Toyota Motor Corporation,
Honda Motor Co., Ltd.,
Yamaha Motor Co., Ltd.,
DENSO CORPORATION

2024 Dakar Rally Saudi Arabia in Jan. 2024



HySE-X1 with a hydrogen-fueled engine showed its potential in Dakar 2024 "Mission1000"

Suzuka Circuit in July 2024



World's First Public Demonstration Run of a Hydrogen Engine Motorcycle

HySE: Hydrogen Small mobility & Engine Technology Association

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Kawasaki
Powering your potential

Global Demand Outlook 2

Hydrogen sector in Spain



Javier Brey
President, Spanish Hydrogen Association (AeH2)

Education

2009 - 2015, Ph.D., Hydrogen Economy, Pablo de Olavide University, Sevilla, Spain
1999 - 2001, Postgraduate Diploma of Advanced Studies (DEA) in Electronic Communications, University of Seville, Sevilla, Spain
1992 - 1999, MSc in Telecommunications Engineering, University of Seville, Sevilla, Spain

Professional Career

2009 – Present, President, Asociación Española del Hidrógeno- Spanish National Hydrogen Association (AeH2), President
2016 - Present, Associate Professor, Loyola University, Sevilla, Spain
2016 - Present, CTO and Founder, H2B2 Electrolysis Technologies, Sevilla, Spain
2013 - 2016, General Manager, Abengoa Hydrogen, Sevilla, Spain
2003 - 2013, General Manager, Hynergreen Technologies, Sevilla, Spain

Research Interest

My research focuses broadly on the development and implementation of the hydrogen economy. I am particularly interested in the production of renewable hydrogen, as well as its transport, distribution, and end-use applications across different sectors. A significant part of my work has been dedicated to hydrogen generation technologies, including renewable electrolysis, together with the integration of fuel cell systems as a viable utilization pathway.
In addition, I am strongly engaged in understanding how hydrogen can be deployed at national and regional scales through public policy, regulatory frameworks, market design, and governmental incentive schemes. I am especially motivated by how these elements can accelerate the transition towards a decarbonized energy system and enable hydrogen to become a central vector in sustainable global energy markets.

Speech Summary

This presentation outlines the current status of the hydrogen economy in Spain, including national strategy, deployment progress, public funding, infrastructure plans such as H2Med, and updated data from the AeH2 2025 Project Census. acters

Company Introduction

Founded in 2002, the Spanish Hydrogen Association has 400 members across the value chain.

Hydrogen sector in Spain

Prof. Dr. Javier Brey

WORLD HYDROGEN EXPO 2025
December 4-7, 2025, KINTEX, KOREA

AeH2 SPANISH HYDROGEN ASSOCIATION

The Voice of the Hydrogen sector in Spain since 2002

AeH2 ASOCIACIÓN ESPAÑOLA DEL HIDRÓGENO

400+ members
+ 37% growth since 2021
+ 20 years supporting the sector
+ 15 years of international collaborations

MISSION

Promote and encourage the development and growth of hydrogen technologies in Spain, with the aim of strengthening and enhancing the national industrial fabric.

VISION

Hydrogen is a key energy vector in the decarbonization of the Spanish economy to achieve climate neutrality in 2050. Hydrogen allows for reactivating, redefining and transforming the national economy, through the creation of a technological and productive industrial fabric, and the generation of highly qualified employment.

Board of Directors



President
D. Javier Brey Sánchez



Vice-president
D. Antonio González Garcia- Conde



Secretary
D. Miguel A. Peña Jiménez

Sectoral vocals

- Industrial Gases Sector.
- Renewable Gases Sector.
- Fuel Gas Sector.
- Energy Sector.
- Engineering and Construction Sector.
- Electrolyzers Sector.
- Technology Centers Sector.
- Testing, Inspection and Certification Sector.
- Public Research Organizations Sector.
- Scientific Facilities and Singular Technologies Sector.
- Industrial Development Sector.
- Demand Integration and Renewable Sector.

Our promoting members

bp edp enagas endesa

EY HYUNDAI Iberdrola moeve

Naturgy repsol VINCI ENERGIES

Members



Objectives

CLUSTER

Be the key gathering place for the sector, bringing together companies, institutions, technology and research centers, and universities active in hydrogen technologies.

R&D&i

Promote research and innovation in hydrogen technologies, as well as the promotion of startups and technological knowledge.

DEVELOPMENT

Support the growth of hydrogen technologies by promoting its production, storage, distribution, and end-use applications.

EDUCATION

Provide professional education through established courses in collaboration with various universities and training centers.

LEGISLATION

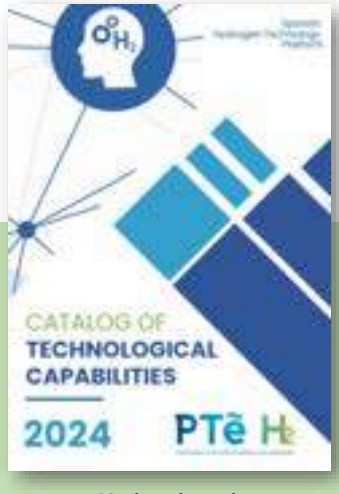
Advocate for the establishment of laws and regulations governing hydrogen as an energy vector.

DISSEMINATION

Establish hydrogen as a recognized energy vector within our society



Updated monthly
www.aeh2.org



Updated yearly
www.pteh2.org

National Collaboration

- Entities

bankinter · Sabadell · ceeer · CEOE Empresas Españolas · fegeca · AEDyR · gasnam · Redexis · sedigas · TECNIBERIA · TOYOTA

- Public Administration

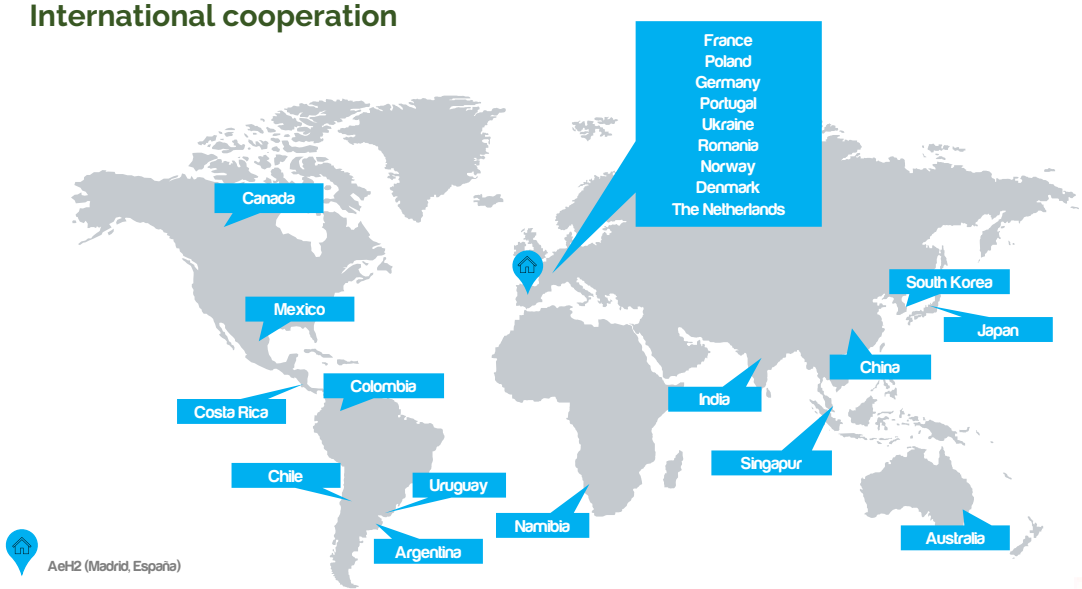
IDAE · CDTI · ICEX · oecc · ICO

- Ministeries

International cooperation

→ International cooperation efforts are translated into the organization of workshops, trade missions, and other activities that promote the presentation and contact between national and international entities (and initiatives).

International cooperation



Projects and Initiatives

PTE H2

UNE Normalización Española

EHEC EUROPEAN HYDROGEN ENERGY CONFERENCE



Working Groups



Census of Projects



AeH2

HYDROGEN POTENTIAL IN SPAIN

- Allows greater penetration of renewable energies in the mix
- Transversality: transport, industry, electricity production and buildings decarbonization
- Key to the "coupling sector" and the circular economy
- Huge potential for renewable hydrogen production. Strategic geographical position.
- Self-sufficiency and potential to become a reference hydrogen exporter

Great opportunity for economic and technology development

The Spanish Hydrogen Roadmap (2020)



"**Hydrogen Roadmap: a commitment to renewable hydrogen"**

6th October 2020 - Approved by the Council of Ministers

Includes **60 actions** to promote the development of hydrogen in Spain, divided in 4 blocks

1. Regulatory instruments
2. Sectoral instruments
3. Cross-cutting instruments
4. Boosting R&D

2030 GOALS



Spain has growing ambitions for renewables and hydrogen

Under the Regulation on the governance of the energy union and climate action (EU)2018/1999, all Member States must have a 10-year plan addressing decarbonization, energy efficiency, energy security, international energy market, and research, innovation and competitiveness, known as NECP (National Energy and Climate Plan, PNIEC in Spanish).



	First PNIEC (published 2020)	Updated PNIEC (September 2024)
GHG emissions reduction by 2030	23%	32%
RE in total energy consumption by 2030	42%	48%
RE in electricity generation by 2030	74%	81%
RE in the transport sector by 2030	15%	28%
Advanced biofuels + RFNBO in transport by 2030	2,1%	**17,26%**
RFNBO in industrial hydrogen consumption by 2030	*25 % (set in the Roadmap, not PNIEC)*	**74%**
Electrolysis capacity installed	4GW	**12 GW**

Funding channeled to commercial projects in Spain

Plan de Recuperación Transformación y Resiliencia (PRTR) Componente 9. Hidrógeno Renovable
1555M€

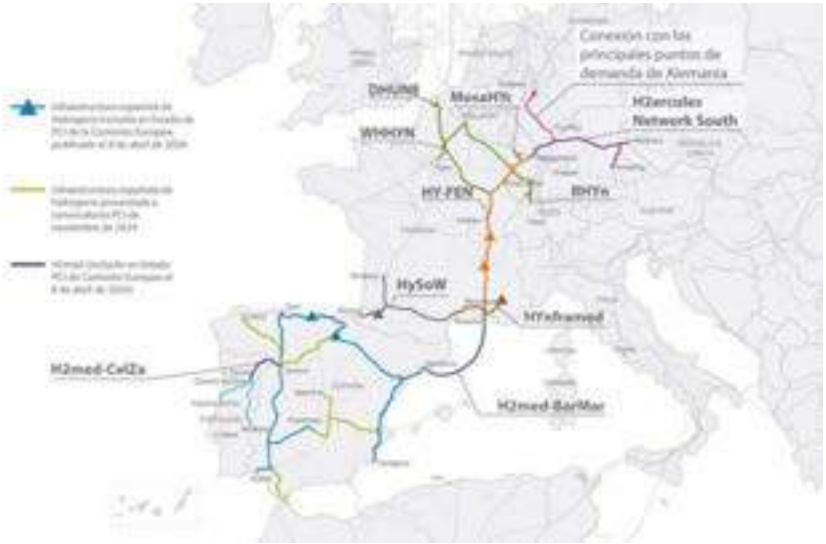


+ IDAE's Hydrogen Valleys Call
7 projects
2,28 GW electrolysis
1214M€

+ European Hydrogen Bank
Auction as a Service – 2nd round
377M€

TOTAL >3100 M€

H2Med and Spanish hydrogen backbone (+ > 6000 M€)



Projects and Initiatives

PTE H2

UNE Normalización Española

EHEC EUROPEAN HYDROGEN ENERGY CONFERENCE

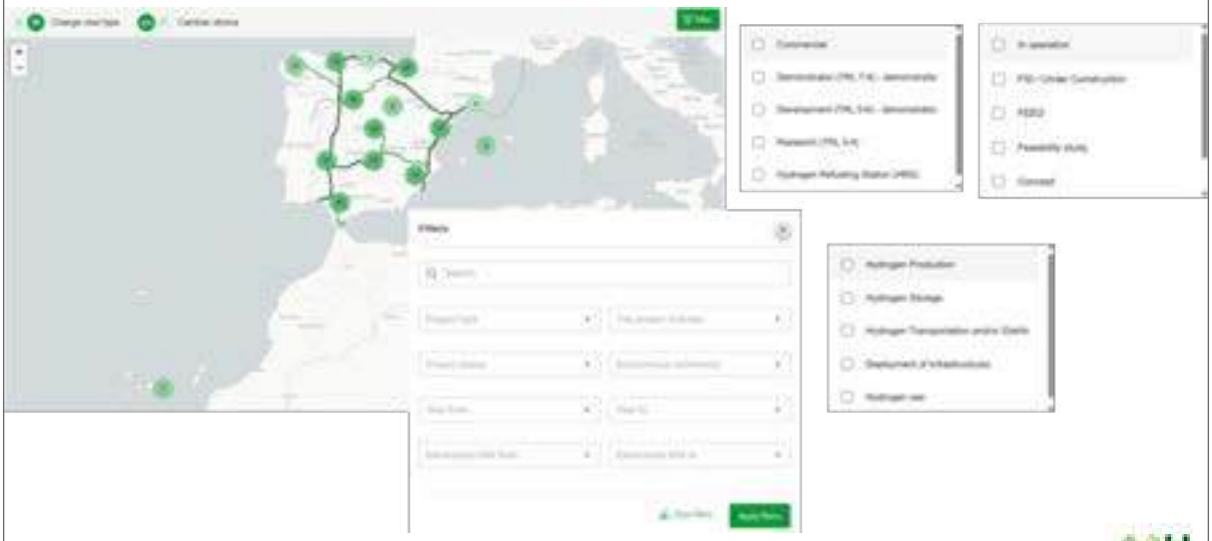
Working Groups

Census of Projects

GREEN HYSLAND

AeH2

AeH2 Census of Projects 2024 – Interactive map and table



AeH2

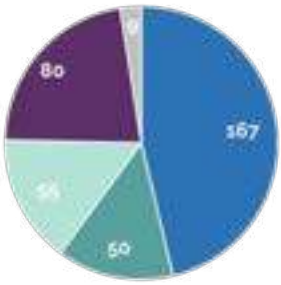
AeH2 Census of Projects 2024 – Overview

361 projects

83 AeH2 Members participated

> 36 000 M€ of total investment

≈2650 M€ public financing







AeH2 Census of Projects 2024 – Commercial projects

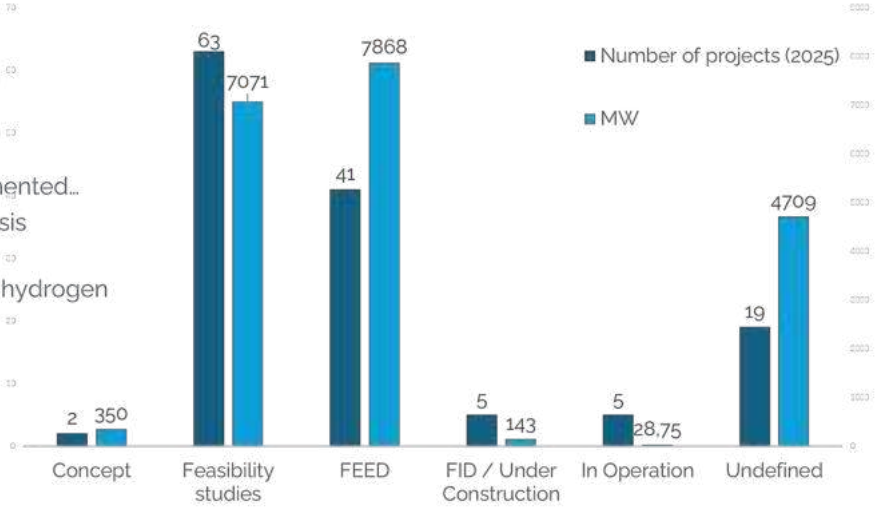
145 commercial projects

41 AeH2 members

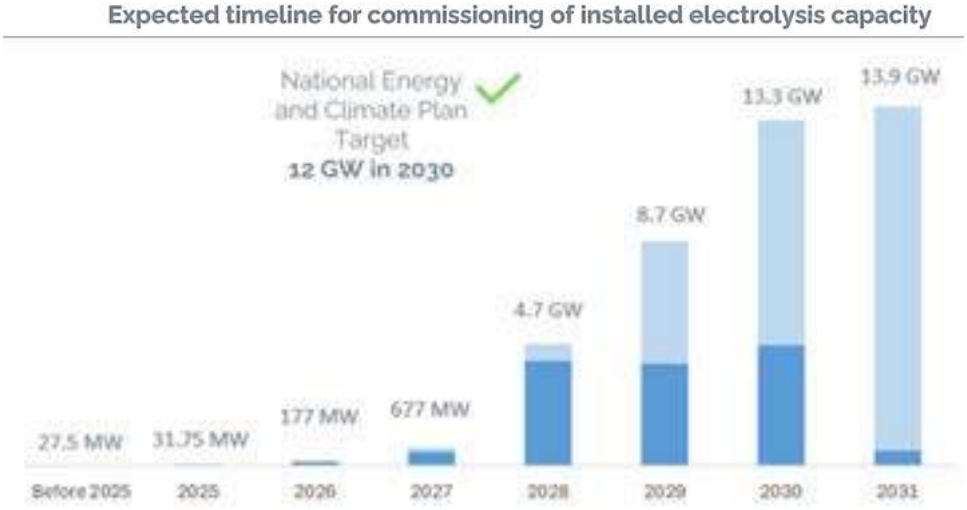
If all of them were implemented...

20 GW, installed electrolysis capacity

2.65 million tons/year of hydrogen produced

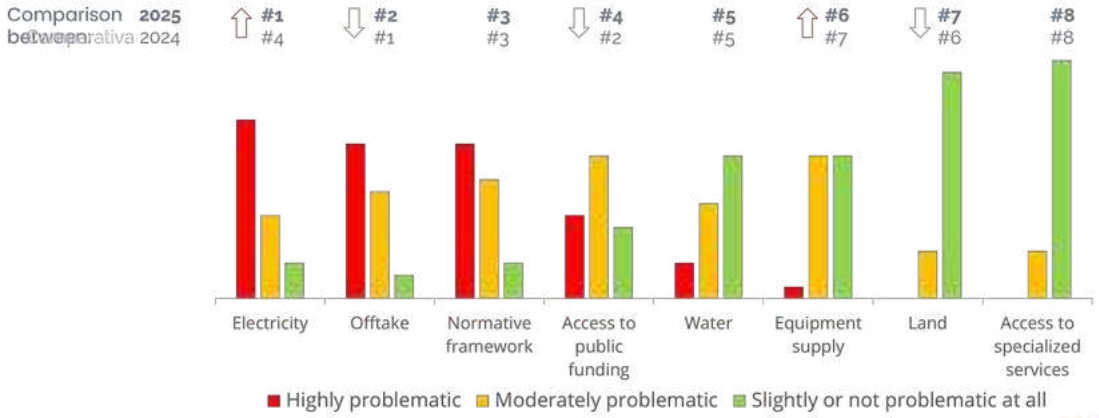


AeH2 Census of Projects 2024 – Commercial projects



AeH2 Census of Projects 2024 – Main barriers

What barriers are commercial project developers currently facing, and how have they rated the severity of these challenges—**"Very problematic," "Moderately problematic," or "Slightly or not problematic"**?



European Hydrogen Energy Conference

EHEC 2026

EHEC is the European conference of reference in the hydrogen sector. Held every two years, it is **organized by the Spanish Hydrogen Association (AeH2)** and brings together experts, researchers and industry leaders in the field of hydrogen, providing a platform to share the latest advances, innovations and developments in technologies based on this energy vector.

- It is the perfect setting to showcase **advances in R&D projects and products.**
- It brings together the latest advances in research and business to a **worldwide audience** of interested parties.
- It facilitates the presentation of technologies for **strategic business collaborations** to emerge.



Following the great success of EHEC 2024, which had **+1300 attendees and +300 speakers** from across the hydrogen value chain, we are proud to announce the next edition of EHEC, to be held in Seville (Spain) in 2026.

Next edition 11-13th Seville March 2026





AeH2

Hydrogen sector in Spain

Prof. Dr. Javier Brey

WORLD HYDROGEN EXPO 2025
December 4-7, 2025, KINTEX, KOREA

AeH2 SPANISH HYDROGEN ASSOCIATION

Global Demand Outlook 3

POSCO HyREX Development Status



Jang Hoi Choi
General Manager, Posco Holdings

Education
1994-2001, B.S., Metallurgical Engineering, Jeonbuk National University, Korea

Professional Career
2001, Joining POSCO (FINEX Department)
2013, Plant leader (FINEX Department)
2016, Leader (Technology Strategy Department, POSCO)
2024-Present, General Manger (Carbon Neutral Strategy Office, POSCO Holdings Inc.)

Speech Summary
POSCO Holdings aims for net-zero by 2050 via HyREX hydrogen reduction steelmaking, leveraging FINEX and ESF tech. Plans include a 2028 demo plant, but challenges remain in clean hydrogen cost, supply, and infrastructure, requiring public-private cooperation and policy support.

Company Introduction
POSCO Holdings is a global industrial group leading steel, battery materials, and various businesses.

WORLD HYDROGEN EXPO 2025

POSCO HOLDINGS



POSCO HyREX Development Status

POSCO Holdings Inc.

Spacewalk, Pohang

1. Intro

POSCO, Growing into the World's Most Competitive Steelmaker



2024 'World's Most Competitive Steelmaker' ranking

Ranking	Company (Country)	Ranking	Company (Country)
1	POSCO (Republic of Korea)	6	SDI (USA)
2	Nucor (USA)	7	Tata Steel (Europe)
3	Nippon Steel (Japan)	8	JSW (India)
4	ArcelorMittal (Multinational)	9	CSC (Taiwan)
5	BaoWu Steel (China)	10	Ternium (Mexico)

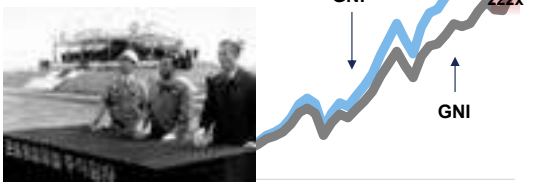
1. Intro

Steel – Huge Contribution to Economic Growth

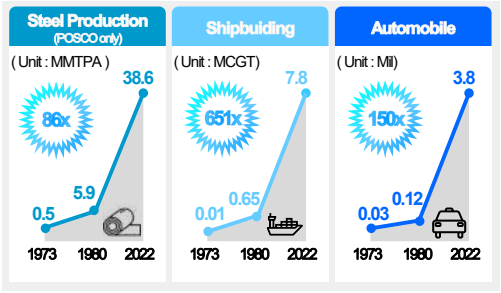
Steel is the irreplaceable core of daily life and the backbone of national manufacturing

World's 8th Largest Trading Nation

GNP Growth $ 4 billion('60)➔$ 1.8 trillion('21)
GNI per capita $ 158('60)➔$ 35,000('21)



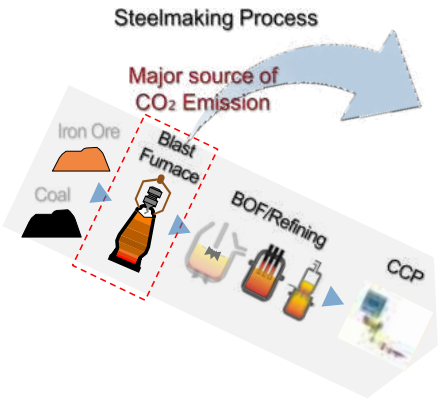
POSCO, the Driving Force of Korea's Industry

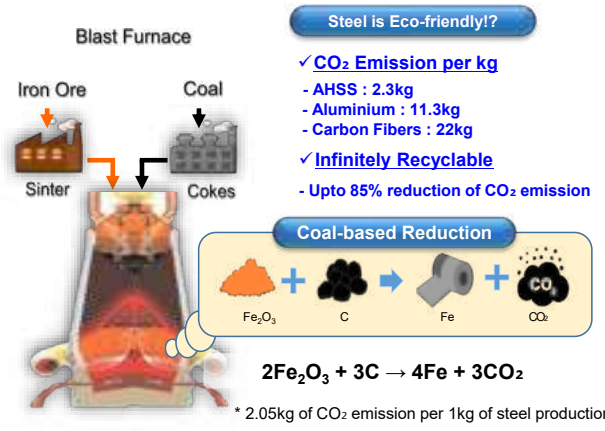


1. Intro

But Big Challenge due to High Emission through Mass Production

Coal used in traditional steelmaking inevitalbly generates substantial CO_2





$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

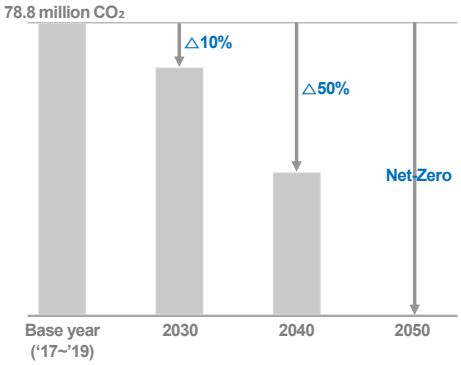
* 2.05kg of CO_2 emission per 1kg of steel production('22)

2. Decarbonization Approach

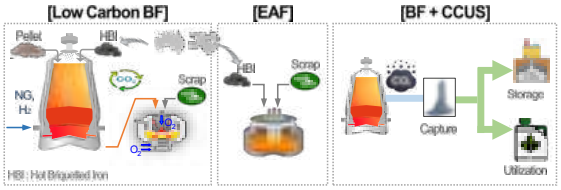
POSCO Declared to Achieve Net-zero in 2050

Through real option – based carbon reduction strategies and breakthrough decarbonization technologies

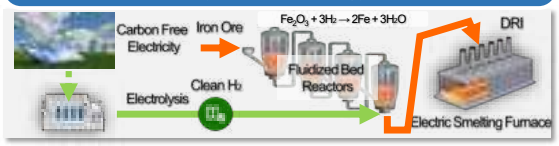
Decarbonization Approach



Carbon Reduction Bridge Technology



HyREX* Technology



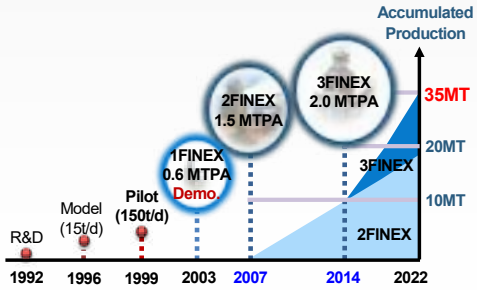
* Hydrogen Reduction

3. Technologies

POSCO already possessed the core technology for HyREX

Technology development can be accelerated by operational and equipment technology and skilled personnel

☑ **Core Tech #1 : FINEX** (fine iron ore reduction)
- 3.5 mil. tons production capacity with 15 yrs of operation
- Above 96% plant factor



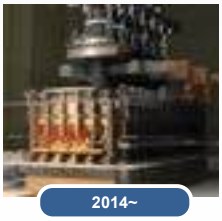
☑ **Core Tech #2 : ESF** (Electric Smelting Furnace)
- Own and operate the world's largest facilities
- 280,000 tons of annual production(Fe-17%Ni)

No.1 ESF (Circle) 120MVA, 22mΦ



2008~

No.2 ESF (Rectangle) 135MVA,40mX14m

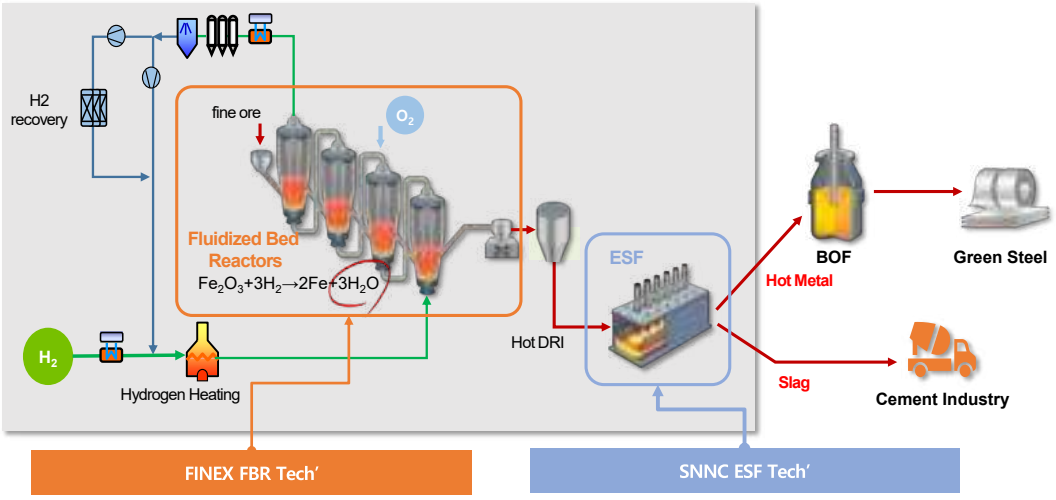


2014~

3. Technologies

Korean-style hydrogen reduction steelmaking technology, HyREX

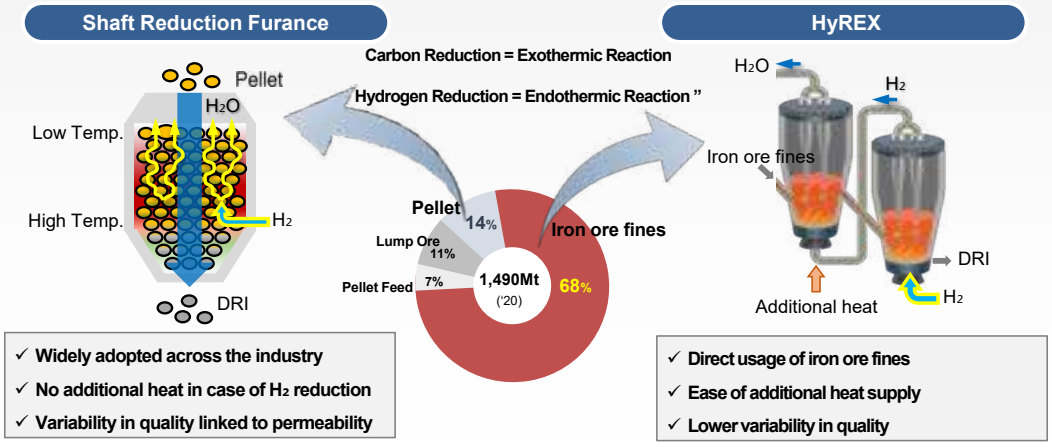
POSCO is developing the Korean-style hydrogen reduction steelmaking technology, HyREX, by leveraging its existing proprietary technologies — the FBR(Fluidized Bed Reactor) and the ESF(Electric Smelting Furnace).



3. Technologies

HyREX, Competitive Solution in terms of Costs and Quality

Flexible in raw material usage, higher quality, and cost savings compared to shaft reduction technology



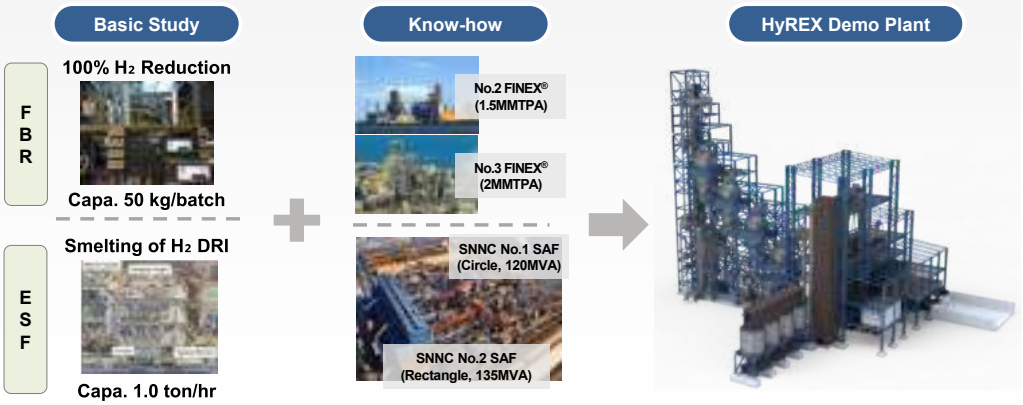
- ✓ Widely adopted across the industry
- ✓ No additional heat in case of H_2 reduction
- ✓ Variability in quality linked to permeability

- ✓ Direct usage of iron ore fines
- ✓ Ease of additional heat supply
- ✓ Lower variability in quality

3. Technologies

Building HyREX Demo Plant prior to Commercialization Phase

By collaborating with leading companies, universities, and research institutes both in Korea and abroad



Scheduled to begin operation in 2028, The plant is capable of producing 300,000 tons per year.

4. Challenges

Clean Hydrogen is Still Very Expensive……

Across the steel industry, many pioneers are struggling due to infrastructure gaps and economic constraints.

Economic Hurdles

- High costs due to limited potential for renewables in Korea - Insufficient resources and high EPC costs
- Massive investment required for infrastructures such as storage tanks and pipelines
- Stranded asset risk in transition to HyREX
- Additional power costs by decreasing by-product power generation

Market Trend

- Global steelmakers are currently facing project delays and cancellations due to uncertainties in supply and economic conditions

Players	Status
ArcelorMittal (EU)	Cancellation of Hydrogen Steelmaking PJTs in Bremen and Eisenhüttenstadt, Germany (June 2025) due to limited hydrogen supply and lack of infrastructure
thyssenkrupp (EU)	Uncertainty in transition from NG-based DRI to Hydrogen-based DRI due to supply and cost competitive issues
CLIFFS (US)	Withdrawal of transition plan for EAF and hydrogen reduction facilities in Ohio state due to policy risks and market uncertainties(June 25)

4. Challenges

Low-cost Clean Hydrogen Essential for HyREX Realization

In Korea, pink hydrogen could be an answer. But several issues shall be addressed.

	Gray	Blue	Turquoise	Green	Pink
Raw Material	Natural Gas & Steam		Natural Gas	Water	Water
Energy	Thermal			Renewable	Nuclear Power
Required Technology	Steam Methane Reforming(SMR) & Autothermal Reforming(ATR)	SMR & ATR with CCS	SMR & ATR with CCUS	Electrolysis	Electrolysis
Production Cost	Low	Mid	Mid	High	Low
CO_2 Emission	High	Mid	Mid	Low	Low

- **Given Korea's renewable limitations, nuclear hydrogen is the most cost-effective option.** In parallel, policy measures such as virtual PPAs should be considered.
- **As Pink Hydrogen alone may not be sufficient to meet HyREX's full demand,** It would be beneficial for the government to explore pathways to facilitate large-scale clean hydrogen imports.

5. Conclusion

Competitive Decarbonization Calls for Strong Public-Private-Market Synergy

Achieving meaningful progress requires the participation of all members of society across every sector, and strong government support is essential to this effort.

- Providing full-cycle support for carbon reduction innovation (R&D → Demonstration → Commercialization → Construction → Operation)
- Building cost-effective, reliable power and energy infrastructure and securing large-scale clean hydrogen supply
- Driving the growth of green steel markets and promoting green premium adoption
- Implementing full value chain benefit-cost sharing for carbon reduction

POSCO HOLDINGS

Thank you



Global Demand Outlook 3

Power Transition in Data Centers



Inki Choi
Senior Manager of Strategy and Marketing,
Bloom Energy Korea

Education
M.S., California Institute of Technology, Aerospace Engineering, CA, USA
B.S., Seoul National University, Mechanical Engineering, Korea

Professional Career
2025-Present, Senior Manager, Strategy & Marketing, Bloom Energy (Korea)
2016-2024, Business Strategy/Sales/Project Management Manager, KC Cottrell (Korea)
2011-2015, Strategic Planning Analyst/Engineer, DB Group (Formerly Dongbu Group) (Korea)

Speech Summary
According to multiple reports from leading energy organizations, the rapid surge in demand for artificial intelligence (AI) has driven data center power requirements far beyond current electricity supply capacities. This session explores the critical choices the data center industry is making to secure urgently needed power amid soaring demand.

Company Introduction
Bloom Energy is a global leader in clean hydrogen energy solutions, headquartered in Silicon Valley, USA. Leveraging high-efficiency fuel technology, the company delivers clean, reliable, and resilient power. Since its listing on the New York Stock Exchange (NYSE: BE) in 2018, Bloom Energy's market capitalization has exceeded USD 33.8billion as of November 2025.
Bloom Energy develops and manufactures solid oxide fuel cells (SOFCs), which generate on-site power through an electrochemical process rather than combustion. This proprietary SOFC technology delivers optimized distributed power solutions for various sectors, including data centers, manufacturers, healthcare facilities, and power utilities.
Collaborating with leading global enterprises and public institutions, Bloom Energy is driving the development of sustainable power infrastructure. Today, the company has deployed approximately 1.5 GW of low-carbon electricity across more than 1,200 sites worldwide, driving the global transition toward cleaner energy.

More information can be found at https://www.bloomenergy.com and https://bloomenergykorea.com.

Global Demand Outlook 4

Green Hydrogen and Regional Decarbonisation: Helios Project at Port Augusta to Support Local Superpower Industries



Jong Hwa Lee

Head of Ammonia Hydrogen Business and Executive Vice President, Hanwha Impact

Education

1989-1982, B.S., Chemical Engineering, Sungkyunkwan University, Seoul, Korea

Professional Career

2012. team leader, Planning Division, SamsungTotal
2014-2015 Managing Director(상무), Business Planning Division, SamsungTotal
2015. Managing Director(상무), Business Planning Division, HanwhaTotal
2015-2016 Managing Director(상무), Energy & Aromatic Production Division, HanwhaTotal
2017-2020. Managing Director(상무), Energy Sales Division, HanwhaTotal
2021-2022. Managing Director(상무), Safety & Environment Division, HanwhaTotal
2022. Executive Vice President(전무), HSE Safety & Environment, HanwhaTotal
2023-Pesent Executive Vice President(전무), Ammonia/Hydrogen TF Leader, Hanwha Impact

Research Interest

Ammonia Cracking and Clean Power Generation: Industrial Demand Strategies

Speech Summary

This presentation outlines the clean hydrogen value chain and the role of ammonia cracking for power generation. It highlights efficiency gains through integrated cracking–CCPP systems, hydrogen turbine demonstrations, and pathways to scalable, low-carbon energy solutions.

Company Introduction

Hanwha Impact is an investment company dedicated to creating a sustainable planet through eco-friendly energy solutions and future-driven innovative technologies, including energy transition, life sciences, and digital/data tech. In addition to our high-purity terephthalic acid (PTA) manufacturing business, we actively pursue M&A and strategic investments.More information can be found at https://www.bloomenergy.com and https://bloomenergykorea.com.

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Clean Energy Value Chain

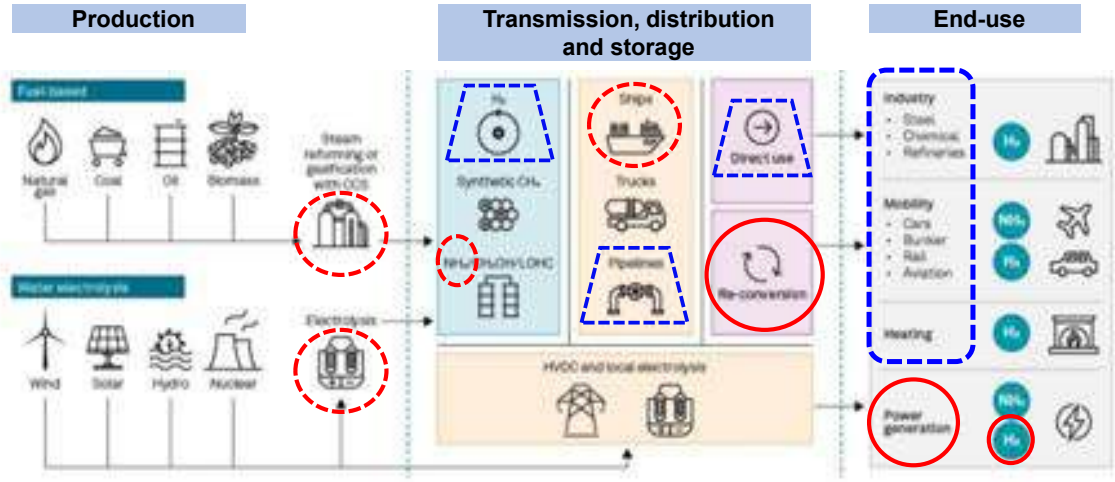
- Hydrogen Power Generation

2025. 12.

Hanwha Impact

Low-Carbon Hydrogen Value Chain

Hydrogen Value Chain



✓ Hydrogen Energy Equivalencies

1 Mt = 33 MWh of energy (LHV) = 130 MMBtu of natural gas = 1,020 gallons of gasoline = 6.434 Mt of ammonia equivalent energy

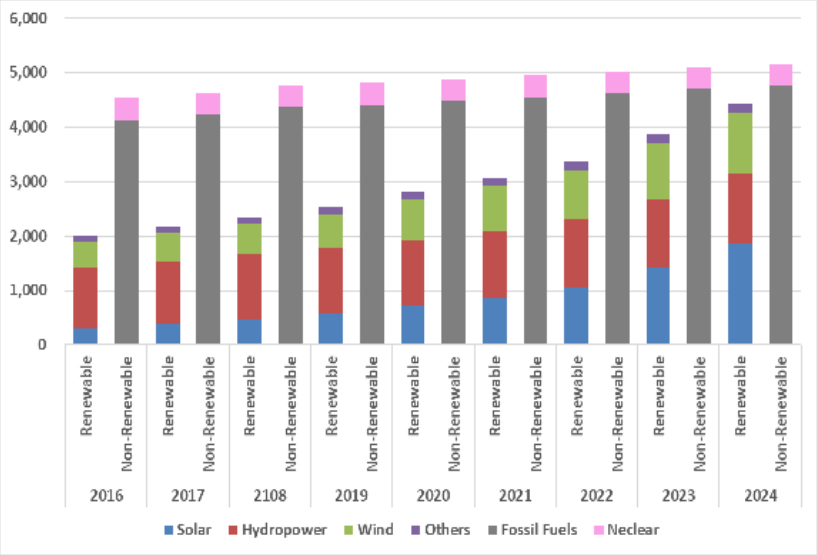
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2

Global Electricity Capacity

Global Electricity Capacity: About 9.6TW in 2024

- Renewable Electricity: 3,073 GW(38.3%) in 2021 → 40.2% in 2022 → 43.0% in 2023 → 4,443 GW(46.2%) in 2024
- Capacity @2024: Solar 1,866 GW, Wind 1,133 GW, Hydropower 1,277 GW, Others 167 GW



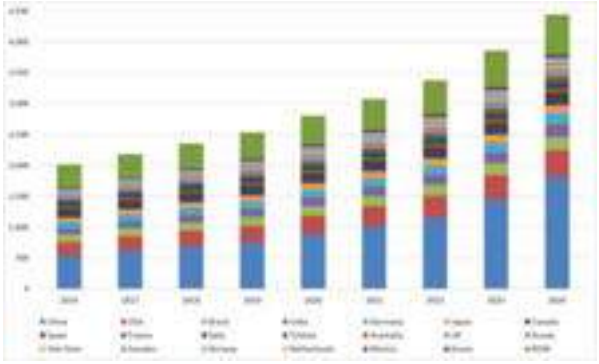
(GW)	Electricity Capacity 2024		
	Total	Non-Ren.	Renewable
China	3,350	1,532	1,818
USA	1,278	851	428
India	534	329	204
Japan	367	237	130
Germany	276	97	179
Russia	251	194	57
Brazil	246	32	214
Korea	158	124	34
France	157	82	74
Canada	155	45	110
Italy	138	65	72
Spain	136	47	88
Mexico	120	86	34
Australia	115	54	60
Türkiye	116	47	69
UK	107	47	60
Indonesia	101	87	14
Iran	96	83	13
Saudi Arabia	94	90	5
Viet Nam	85	36	49
Others	1,730	1,000	730
World	9,610	5,167	4,443

Source: IRENA, Renewable Energy Statistics 2025

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Global Renewable Electricity Capacity

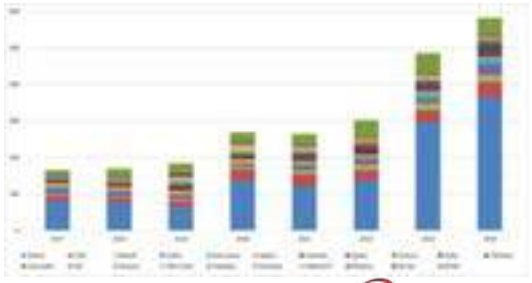
Renewable Power Capacity (GW)



	Renewable(2024)		Solar PV	Wind		Renewable Hydro.	Others	Pumped Storage
	Capa.(GW)	Ratio		Onshore	Offshore			
China	1,818	54.3%	26.5%	14.3%	1.2%	11.3%	1.0%	1.8%
USA	428	33.5%	13.8%	11.9%	0.0%	6.6%	1.2%	1.5%
Brazil	214	86.9%	21.6%	13.4%	0.0%	44.7%	7.2%	0.0%
India	204	38.3%	18.2%	9.0%	0.0%	8.9%	2.2%	0.9%
Germany	179	64.8%	32.6%	23.1%	3.3%	2.1%	3.6%	1.9%
Japan	130	35.5%	24.4%	1.5%	0.1%	7.7%	1.8%	6.0%
Canada	110	70.8%	3.7%	11.3%	0.0%	53.9%	1.8%	0.0%
Spain	88	65.2%	26.7%	23.4%	0.0%	12.4%	2.6%	2.5%
France	74	47.4%	13.7%	14.7%	0.9%	15.7%	2.3%	1.4%
Italy	72	52.4%	26.2%	9.4%	0.0%	13.8%	3.0%	2.9%
Türkiye	69	59.3%	17.1%	11.2%	0.0%	27.9%	3.2%	0.0%
Australia	60	52.5%	31.3%	13.3%	0.0%	7.0%	0.8%	0.7%
UK	60	56.0%	16.7%	15.1%	14.8%	2.0%	7.3%	2.4%
Korea	34	21.4%	16.9%	1.3%	0.2%	1.1%	1.9%	3.0%

	Renewable(2023)		Solar PV		Wind		Hydropower		PSH	
	Capa.(GW)	Gen.(TWh)	Cap	Utilization	Cap	Utilization	Cap	Utilization	Cap	Utilization
China	1,454	2,843	609.4	10.9%	441.9	22.9%	370.6	38.0%	50.9	12.0%
USA	385	962	138.4	17.7%	147.5	33.0%	84.3	33.4%	18.9	13.4%
Brazil	194	630	37.9	15.2%	29.1	37.6%	109.9	44.2%	0.0	0.0%
India	176	370	72.7	17.0%	44.7	19.1%	47.3	38.9%	4.8	11.8%
Germany	160	270	74.9	9.7%	69.5	23.1%	5.6	40.5%	5.3	11.6%
Japan	127	227	87.1	12.6%	5.4	22.3%	28.2	30.5%	21.9	5.1%
Canada	108	419	5.3	15.1%	16.1	28.7%	83.5	49.3%	0.2	7.3%
Spain	81	144	29.6	16.8%	30.9	23.8%	16.8	17.0%	3.3	20.9%
France	67	140	17.4	14.5%	23.1	24.9%	24.6	26.3%	1.7	27.7%
Italy	65	117	29.4	11.9%	12.3	21.9%	18.9	24.4%	4.0	4.5%
Türkiye	59	140	11.3	22.3%	11.8	33.0%	32.0	22.9%	0.0	0.0%
UK	56	136	16.3	9.7%	30.2	31.2%	2.2	28.9%	2.6	8.0%
Australia	52	92	30.7	15.6%	12.9	27.8%	7.7	23.3%	0.8	12.6%
Korea	31	47	23.5	14.5%	2.2	17.9%	1.8	23.3%	4.7	9.2%

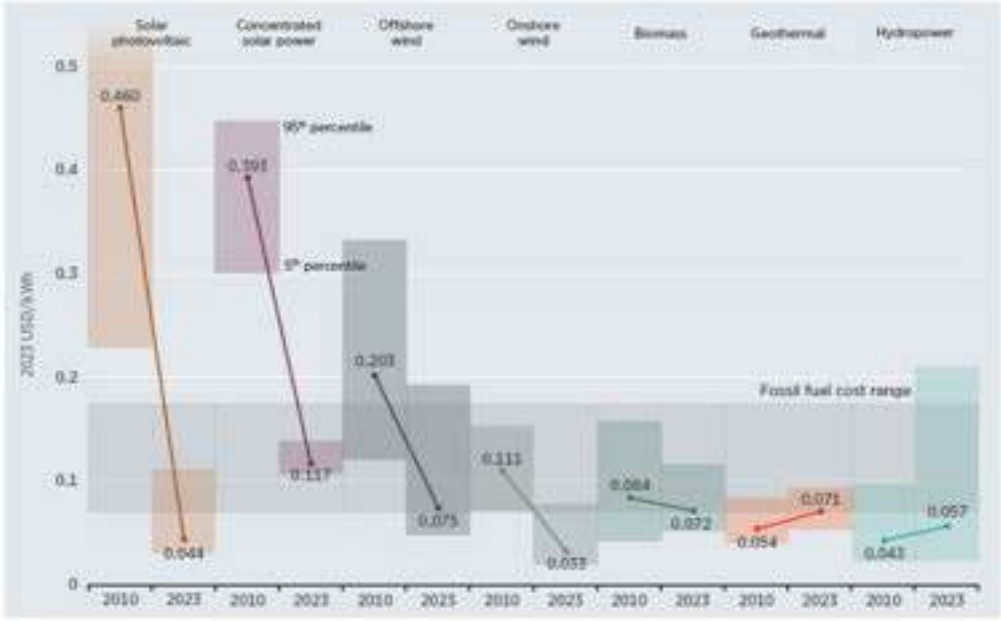
❖ Capacity Addition by Country (GW)



Source: IRENA, Renewable Energy Statistics 2025

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Renewable Power Generation Costs - LCOE

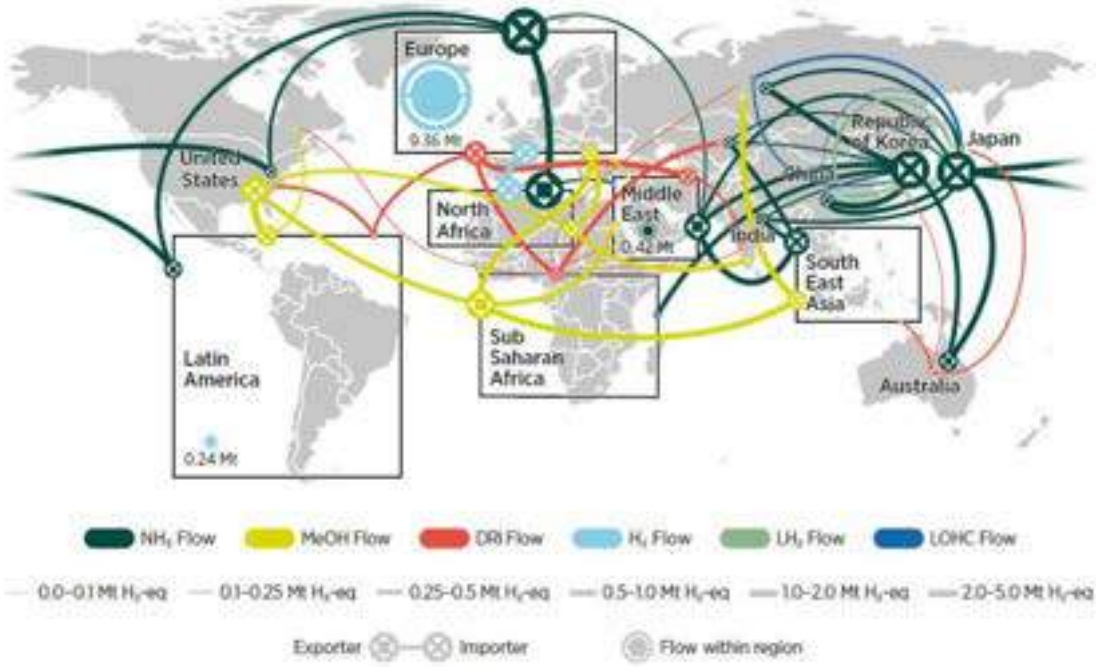


Note: These data are for the year of commissioning. The thick lines are the global weighted average LCOE value derived from the individual plants commissioned in each year. The LCOE is calculated with project-specific installed costs and capacity factors, while the other assumptions, including weighted average cost of capital (WACC), are detailed in Annex I. The grey band represents the fossil fuel-fired power generation cost in 2023, while the bands for each technology and year represent the 5th and 95th percentile bands for renewable projects.

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5

Global Trade Flows in 2050

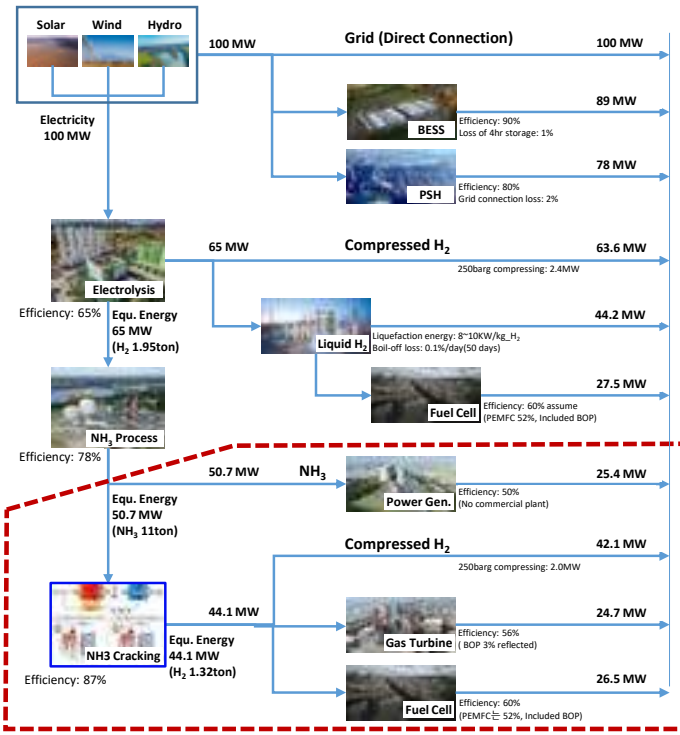


Source: IRENA, THE POTENTIAL FOR GREEN HYDROGEN AND RELATED COMMODITIES TRADE, July 2025

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6

Clean Hydrogen Value Chain – NH_3



- VRE Share in Generation
- Required ESS Capacity
- Electrolysis and H_2-derived commodities

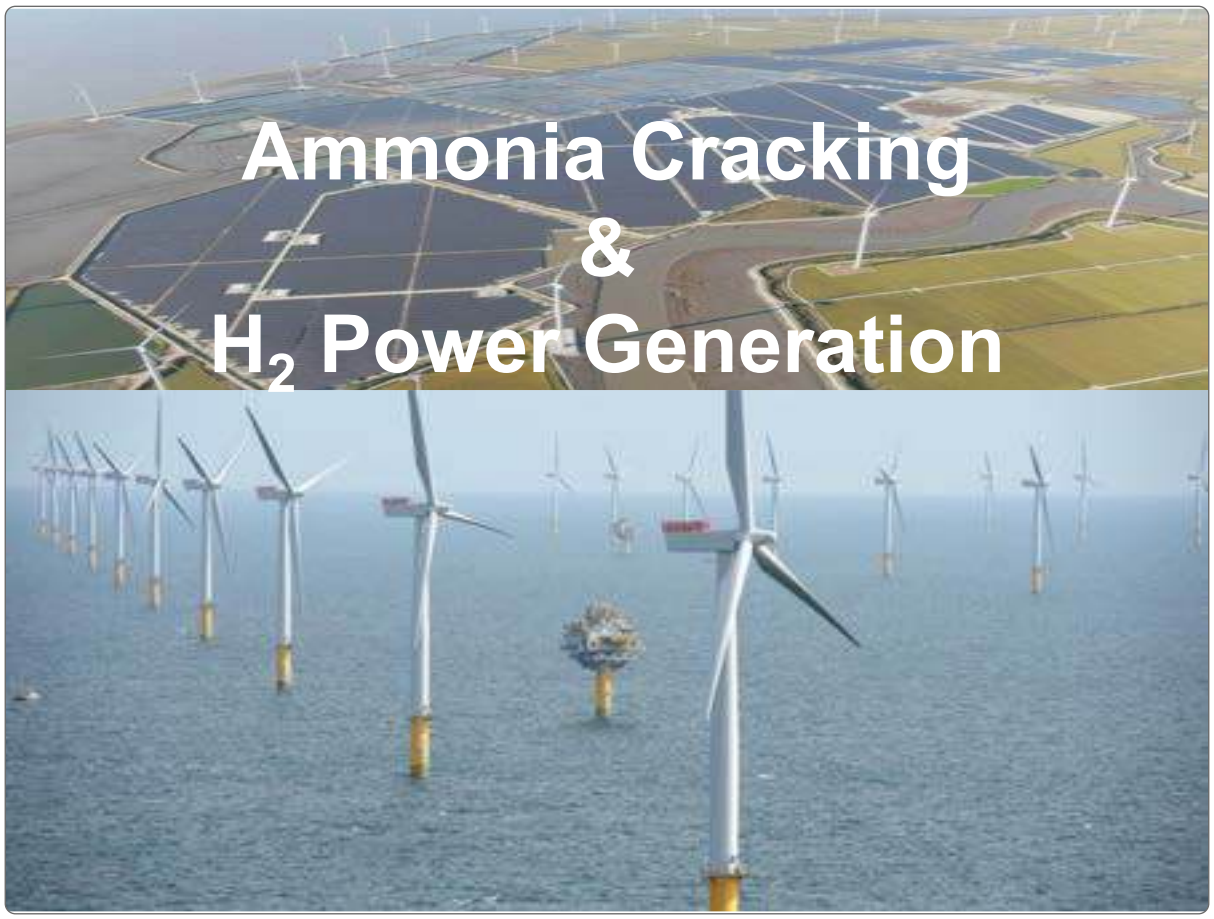
	Generation(TWh)				VRE(TWh)				
	Total	Non-Ren	Renewable		Solar		Wind		Total
France	525	385	140	27%	22	4%	50	10%	14%
Germany	512	242	270	53%	64	12%	141	27%	40%
Spain	286	142	144	50%	43	15%	64	22%	38%
UK	293	158	136	46%	14	5%	82	28%	33%

- Industry: Steel, Chemicals, Refineries, etc
- Mobility: Drones, Cars, Rail, etc
- Heating
- Low round-trip efficiency (RTE)
  Liquid H_2 < 44.2%, Fuel Cell < 27.5%
- High logistics cost for H_2 transport

- Constraints from NH_3 combustion characteristics
- H_2 for industry and mobility
- Economics challenge: very low RTE
  H_2 Gas Turbine < 24.7%, Fuel Cell < 26.5%
- **Exploring alternatives and solutions**

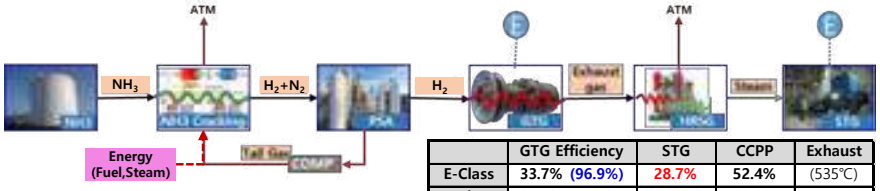
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7



Ammonia Cracking & CCPP

"Stand-Alone Ammonia Cracking" Basic Design by KBR



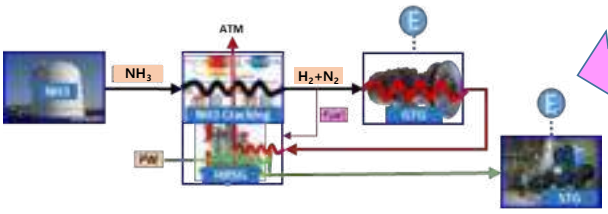
	GTG Efficiency	STG	CCPP	Exhaust
E-Class	33.7% (96.9%)	28.7%	52.4%	(535℃)
F-Class	38.5% (97.5%)	35.9%	60.2%	(593℃)
H-Class	43.3% (97.7%)	37.0%	63.9%	(600℃)

√ **Limited synergy between "Stand-Alone Ammonia Cracking" and "CCPP"**
- Mostly shared utilities only (steam, water, etc.); little heat/power-integration benefit

√ **No clear pathway to materially improve the low "RTE**Round Trip Efficiency**"**

"Integrated Ammonia Cracking" Basic Design by KBR

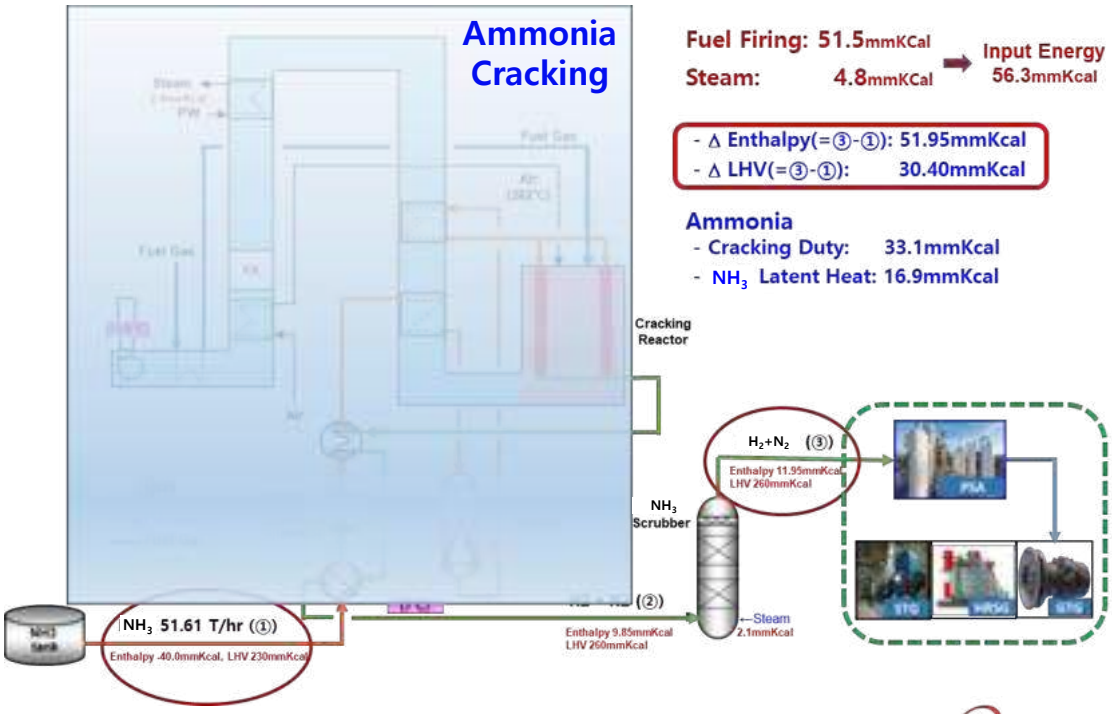
√ **We can now see:**
- **strong synergies**
- **clear answers**
- **viable alternatives**



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9

Ammonia Cracking – Stand-Alone(by KBR)



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10

Ammonia Cracking - Gas Turbine Demonstration

Demonstrating 100% full combustion of 7E-Class with Hydrogen & Mixed Gas

Aug. '21 — Demonstration Project Agreement (Hanwha Impact-Korea Western Power)



Jun. '23 — H_2 59.5 vol% Demo. test



Nov. '23 — H_2 100 vol% Demo(FSNL)



Apr. '24 — Co-firing combustion test



Hydrogen turbine demonstration results

- Model: 7E-Class Gas Turbine Retrofit (80MW)
- Applied Hanwha's Independently Developed Combustor "Flamesheet™" (w/ PSM)

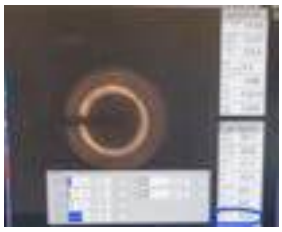
Category	Assessment Items	Target	Value	Result
50% co-firing (June. 2023)	Hydrogen co-firing ratio	50±5 vol%	59.5%	Success
	CO2 reduction ratio	20±2 vol%	22%	Success
	NOx emission	< 10 ppm	6 ppm	Success
100% hydrogen (Nov. 2023)	Hydrogen co-firing ratio	100%	100%	Success
	CO2 emission	-	0.05%	Success
	NOx emission	< 10 ppm	7.6 ppm	Success

Cracking Mixed Gas Combustion Test

- Cracking gas mixture: 75% hydrogen + 25% nitrogen (Vol.%)
- 10-day rig test at the German Aerospace Center (DLR)

"Successful Combustor Operation with New Configuration"

Results	- Good NOx control - Flashback margin secured - Good temperature control

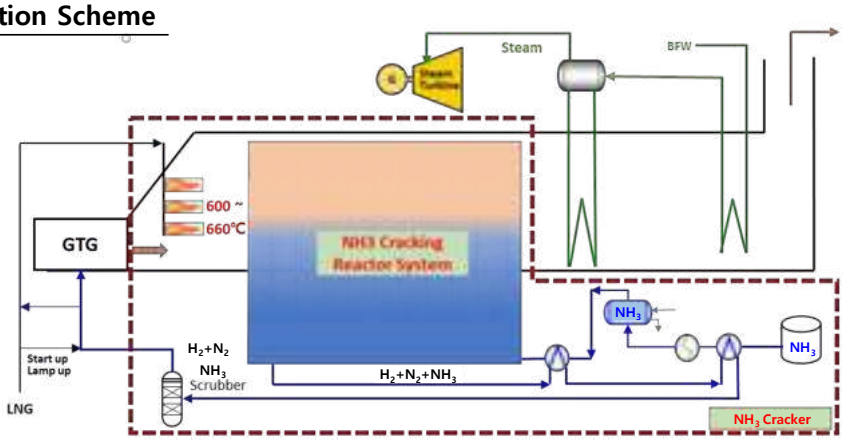


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Integrated Ammonia Cracking & CCPP

Integration Scheme



◆ Key Points

- **Maximize use of GTG exhaust heat for Ammonia Cracking**
- **Minimize HRSG duct firing for Ammonia Cracking**
  - Optimize reactor configuration, GHSV, pressure, temperature profile
- **Prioritize GTG electric generation; minimize STG electric generation**
  - Divert steam/enthalpy to cracking duty.
  - GTG power attribution(energy-accounting basis): 96.9~97.7% of net electric output
  - STG electrical efficiency: 28.7~37%
- **High vaporization latent heat and endothermic reaction of Ammonia**

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Estimated Performance Comparison

The 7E-Class CCPP with Integrated NH_3 Cracking is conservatively designed and can be further optimized – e.g., reactor configuration, GHSV

- The optimized cracking design will be validated at the Daesan Hydrogen Power Plant and then deployed across advanced-class gas turbine
- Increase net CCPP efficiency with Integrated NH_3 Cracking beyond the standalone CCPP baseline

(RE100 Electricity)		E Class		F Class		H Class	
		Standalone (H_2 100%)	Integraion (H_2 + N_2)	Standalone (H_2 100%)	Integraion (H_2 + N_2)	Standalone (H_2 100%)	Integraion (H_2 + N_2)
NH_3 Feed (Cracker)	Ton/hr	53.0	50.4	109.7	89.5	149.1	114.7
	Gcal/hr ①	235	223	486	397	661	508
Fuel (Cracked Gas)		53.2	49.3	110.1	26.0	149.7	0.0
GTG Input (Gcal/H) ②		211.9	206.3	445.1	427.1	605.0	580.5
Generation (MWh)	GTG ③	81.4	81.4	201.0	201.0	290.0	290.0
	STG ④	41.90	44.0	104.3	80.8	142.5	95.3
	PSA	(3.6)	0.0	(7.5)	0.0	(10.1)	0.0
	Operation	(4.6)	(4.6)	(9.6)	(6.9)	(13.0)	(8.8)
	Net Power ⑤	115.1	120.8	288.2	274.9	409.4	376.5
	(Gcal/H) ⑤	99.0	103.8	247.9	236.4	352.1	323.8
CCPP Efficiency (③+④)*0.86/②		50.0%	52.3%	59.0%	56.7%	61.5%	57.1%
Total Efficiency (⑤/①)		42.2%	46.5%	51.0%	59.6%	53.3%	63.7%
NH_3 Unit (kg_NH3/MW)		460	418	381	326	364	305

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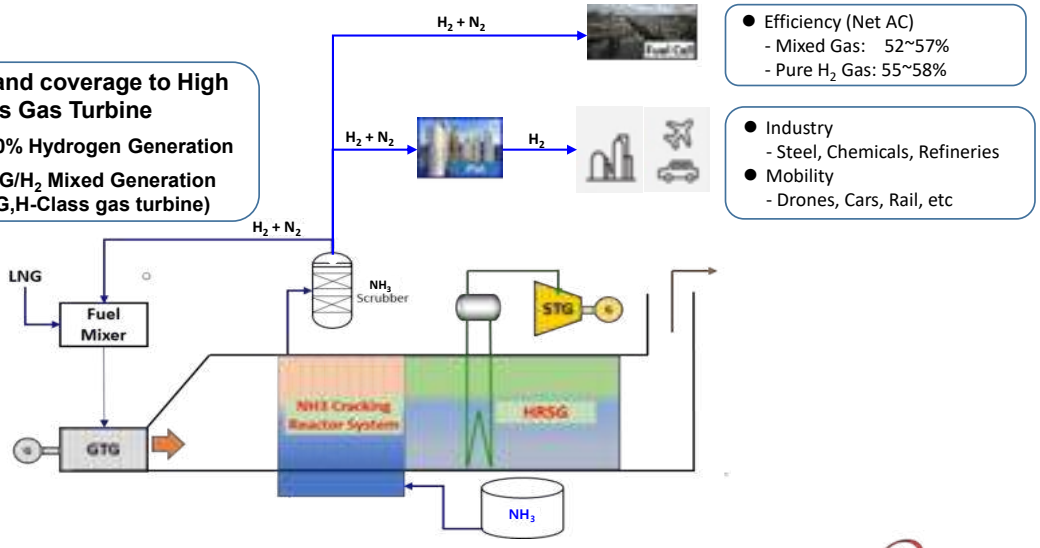
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Integrated NH_3 Cracking Applications

Maximize Hydrogen Production via HRSG Heat Integration

STG Power(eff. 29~37%) ➡ GTG(eff. 97%), Fuel Cell(eff. 52~57%)

Expand coverage to High Class Gas Turbine
- **100% Hydrogen Generation**
- **LNG/H_2 Mixed Generation (F,G,H-Class gas turbine)**



- Efficiency (Net AC)
  - Mixed Gas: 52~57%
  - Pure H_2 Gas: 55~58%
- Industry
  - Steel, Chemicals, Refineries
- Mobility
  - Drones, Cars, Rail, etc

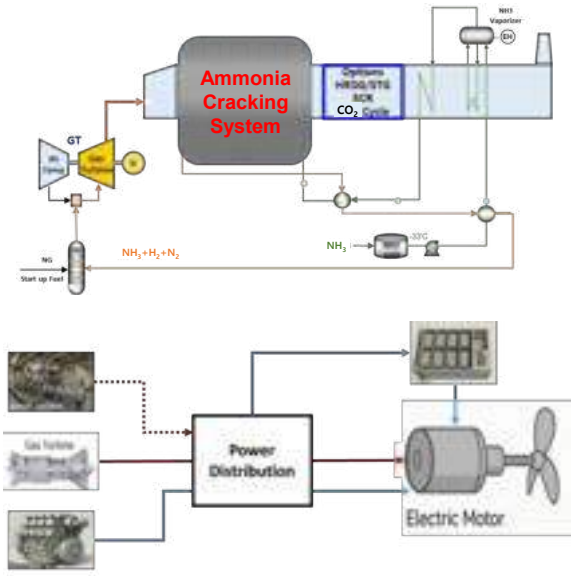
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Integrated NH_3 Cracking Applications

Small Shipboard Gas-turbine Generators

- It is necessary to develop gas turbines capable of firing $NH_3/H_2/N_2$ fuel mixtures
- Estimated NH_3 cracking rate: 50~80wt%(H_2 67 vol%, NH_3 11 vol%, N_2 22 vol%)



GTG-Diesel Hybrid Applications

- **Battleship: Simple Cycle Gas Turbine**
  - Mobility, space/weight constraints
  - Efficiency 25-35%
- **Cruise ship: CCGT**
  - High efficiency, high power, maximum energy
  - Efficiency 45%-55%
- **LNG/Container Ships: CCGT/Diesel Engine**
  - IMO regulations, fuel diversification

√ Combined-cycle gas turbines are well-suited for large, lower-emission vessels and can be installed as modular units

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Efficiency Estimates for Small Marine GTGs

✔ **Assume simple-cycle(SCGT) due to space constraints**
- Higher overall efficiency is achievable with a combined-cycle(CCGT) configuration

✔ **Assume the same efficiency for NH_3 and mixed gas($NH_3/H_2/N_2$)**
- Utilize GTG exhaust heat for Ammonia Preheating, Vaporization and Cracking

✔ **Direct combustion of mixed gas ($NH_3/H_2/N_2$) in GT power generation**
- Utilize N_2 pressure energy for additional power generation

Efficiency estimates vs. $NH_3 \rightarrow H_2$ conversion

		700(Exhaust Temp 530℃)			400 (Exhaust Temp 529℃)		
		NH_3 100%	50% Conversion ($H_2+N_2+NH_3$)	80% Conversion ($H_2+N_2+NH_3$)	NH_3 100%	50% Conversion ($H_2+N_2+NH_3$)	80% Conversion ($H_2+N_2+NH_3$)
NH_3 Feed	Ton/hr	17.1	15.7	14.9	7.7	7.1	6.7
	Gcal/hr ①	76	70	66	35	32	30
GTG Input (Gcal/H)		76.1	76.1	76.1	34.5	34.5	34.5
GTG Generation	MWh	32.6	32.6	32.6	14.3	14.3	14.3
	(Gcal/H) ②	28.0	28.0	28.0	12.3	12.3	12.3
Total Efficiency (②/①)		36.8%	40.2%	42.3%	35.6%	38.9%	41.0%
NH_3 Unit (kg_NH3/MW)		524	480	457	542	496	471

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감 사 합 니 다

Global Demand Outlook 5

Mobility Sector Hydrogen Demand and Market Outlook



Yong Tae Kimm
Vice President, Hyundai Motor

Education
2001, B.S, Chemical Engineering, Seoul National University

Professional Career
2025-Present, Vice President, Energy&Hydrogen Policy Group, Hyundai Motor Company
2023-2025, Vice President, Strategic Policy Division, Hyundai Motor Company
2021-2023, Director, Renewable Energy Industry Division, Ministry of Trade, Industry and Energy*, Korea
*Currently referred to as Ministry of Trade, Industry and Resources
2018-2021, Counselor, Permanent Mission of the Republic of Korea to the OECD

Company Introduction
Hyundai aims to be a Global Energy Transition Leader, driving hydrogen mobility via HTWO

Global Demand Outlook 6

India's Industrial Hydrogen Demand and Market Growth Outlook



Nishaanth Balashanmugam
CEO, GH2 India

Education
2013 – 2014 - Msc, International Business Management, Northumbria University, Newcastle, UK
2009- 2011 - Bachelor of Commerce, Loyola College, Chennai, India

Professional Career
2022 – Present, CEO and Founding Director, Green Hydrogen India (GH2 India), Chennai, India
2012 – Present, Dealer Principal, Honda, Tirupur, India
2018 – 2022, Authorized Dealer for Ford India, Tirupur, India
2011 – 2012, Director, KRR Bajaj, Tirupur, India

Research Interest
Industrial Demand & Market Development
Policy, Regulation & Standards
Power System & Infrastructure for Hydrogen
Financing, Risk Sharing & Business Models
Social, Skills & Just Transition Dimensions
International Cooperation & Corridors

Speech Summary
India today is one of the world's largest consumers of industrial hydrogen, with demand concentrated in refineries and fertiliser production. Until now, almost all of this has been "grey" hydrogen, produced from fossil fuels. The shift to green hydrogen is therefore not a luxury—it is central to meeting India's net-zero commitments, reducing import dependence on fossil fuels, and keeping our industrial exports competitive as global markets increasingly favour low-carbon products.
This presentation will first set out why India is pursuing green hydrogen: to decarbonise hard-to-abate sectors such as steel, refineries, fertilisers and chemicals, to create new industries and jobs, and to position India as a global hub for green molecules and derivatives.
I will then outline the policy enablers driving this transition. At the federal level, the National Green Hydrogen Mission provides the overarching framework—creating demand, supporting supply through schemes such as SIGHT, and addressing infrastructure, standards and R&D. Key ministries and agencies are working in tandem to lower the cost of renewable power, facilitate transmission and open access, and enable exports of green hydrogen, ammonia and other derivatives.
A core part of India's advantage lies in its power ecosystem. Rapidly growing renewable capacity, some of the world's most competitive solar and wind tariffs, and emerging storage solutions together create the foundation for large-scale, low-cost green hydrogen production.
The speech will also touch on state-level policies, where leading states such as Gujarat, Odisha, Andhra Pradesh, Tamil Nadu and Rajasthan are offering land, power concessions and project facilitation, creating hydrogen and e-fuel hubs linked to industrial corridors and ports.
Finally, I will provide a short project and offtake snapshot—covering major announced green hydrogen and ammonia projects, early offtake arrangements, and what this means for India's industrial hydrogen demand and market growth over the coming decade.

Company Introduction
GH2 India (Green Hydrogen Association) is a dedicated industry-led platform advancing India's green hydrogen ecosystem. We work at the intersection of policy, markets and projects to accelerate production, use and export of green hydrogen and its derivatives such as green ammonia, methanol and e-fuels. Our focus areas include policy research and consultation, industry coordination, state-level ecosystem development, standards and certification dialogues, and international partnerships. GH2 India convenes government, industry, financiers, and civil society to enable bankable projects, support offtake creation, and promote a just, inclusive transition that positions India as a global leader in green hydrogen.

WORLD HYDROGEN EXPO 2025 6th Conference

Panel Discussion

Hydrogen Price Stability and Its Impact on Global Demand Expansion

Moderator



Nishaanth Balashanmugam
CEO, GH2 India

Panelists



Kenji Yoshimura
Kawasaki Heavy Industries



Jang Hoi Choi
General Manager, Posco Holdings



Inki Choi
Senior Manager of Strategy and Marketing, Bloom Energy Korea



Jong Hwa Lee
Head of Ammonia Hydrogen Business and Executive Vice President, Hanwha Impact



Yong Tae Kimm
Vice President, Hyundai Motor

Ralph Foong
Chief Hgydrogen Officer, City Energy

WORLD HYDROGEN EXPO 2025 6th
Conference

Hydrogen Deep Dive II：
International Hydrogen Technology Standardization

WORLD HYDROGEN EXPO 2025 6th Conference

Global Clean Hydrogen Technology Standardization Strategy

Global Clean Hydrogen Technology Standardization Strategy 1

Proposed US Regulations and Impact on Global Hydrogen Compliance and Certification



Frank Wolak
President, Fuel Cell and Hydrogen Energy Association

Education
Western New England University, Bachelor of Science - BS, Mechanical Engineering
University of Hartford, Master of Business Administration - MBA, Finance, General

Professional Career
Fuel Cell & Hydrogen Energy Association (FCHEA), President and CEO, 2021 – 2025
FuelCell Energy, Senior Vice President, 2021 - 2019
FuelCell Energy, Vice President, 2004 - 2019
DNV KEMA, Senior Consultant, 2002 - 2004
NORESCO, Vice President, 2000 - 2002
ERI Services, Inc., Vice President, 1997 – 2000

Speech Summary
Title: Proposed US Regulations and Impact on Global Hydrogen Compliance and Certification. The session will outline global certifications of importance to hydrogen and derivative fuel production in the United States, the importance of consistent data in certification and standards utilization, the business implications of proposed US regulatory changes in greenhouse gas reporting and the growing factor of Global Warming Potential in certification development.

Company Introduction
The Fuel Cell and Hydrogen Energy Association (FCHEA) is the U.S. industry association with a mission to advance the commercial production, distribution and use of hydrogen in the United States and beyond. Based in Washington, DC, FCHEA has provided a credible, consistent, and unified industry voice for more than 35 years, driving support at federal and state levels through engagement with policymakers, regulators, and stakeholders.



Agenda

FCHEA

- **Certification for the U.S. Hydrogen Industry**
  - *Why Certifications Matter*
  - *Relevant International Certifications*
  - *Importance of Data*
- **U.S. Regulatory Landscape**
  - *Requirements for Measuring Carbon Intensity*
  - *U.S. Architecture for GHG Data*
- **Global Warming Potential (GWP) in Certifications**
  - *Growing Interest in Measuring Hydrogen*
  - *Accuracy is Necessary for True Impact*
  - *Considerations of International Standards Organizations*

Fuel Cell and Hydrogen Industry Association

FCHEA

The Industry Association for Hydrogen in the United States

Based in Washington, DC

- **Advocating** for Hydrogen and Fuel Cell technology for 35 years.
- **Representing** leading companies, organizations, and partners that are advancing the ***production***, ***distribution***, *and* ***use*** of Hydrogen.
- **Providing** a consistent industry voice to regulators and policymakers at both *Federal and State* levels.
- **Educating** about the ***environmental***, ***economic*** *and* ***societal*** benefits of Hydrogen

Fuel Cell & Hydrogen Energy Association Members

FCHEA

Why Certification Matters to US Hydrogen

FCHEA

US Policies and International Demand enable a US Export Opportunity

- US Tax Credits reduce production costs
- Ample resources for Blue and Green hydrogen feedstock
- International demand pull (H2Global, Japan CfD) offer long-term market certainty

- **Hydrogen/ammonia export strategies require:**
  - Traceable carbon intensity (CI) values
  - Auditable MRV systems
  - Compatibility with international certification frameworks
- **CI evidence directly influences**
  - Compliance with national regulations
  - Tariff exposure
  - Bankability of projects

Certification Systems Define Compliance

FCHEA

Market – Specific Transactions Require Products Meet Regulations

- **EU RED II / RFNBO / CBAM**
  - Detailed LCA, strict electricity sourcing
  - Key for ammonia/e-fuel exports to EU
- **ISCC (International Sustainability & Carbon Certification) / CertifHy**
  - Chain of custody + audited CI
  - Common in project finance
- **TÜV SÜD CMS 70: Green Hydrogen/ TÜV Rheinland “Green Hydrogen”**
  - CI thresholds, MRV documentation
  - Basis for tariff treatment & “clean hydrogen” designation

Importance of Data in Certifications

FCHEA

- **Growing demand for "certified green hydrogen" and derivatives (ammonia, e-fuels, steel, etc.).**
- **Offtakers and financiers want:**
  - Recognized certification schemes
  - Auditable GHG data over the full life cycle
- **Without credible data: No Proof → No Premium Contract**
- **Global certification systems are converging around traceable and scientifically defensible CI data**

U.S. Regulatory Landscape: Certification

FCHEA

Key U.S. Policies Incorporating Hydrogen Carbon Intensity (CI)

- **45V Clean Hydrogen Tax Credit**
  - Requires LCA-based CI calculation (kg CO_2e/kg H_2)
  - Uses GREET-based modeling
  - Strongly shapes project design & electricity and hydrogen sourcing
- **DOE / National Lab LCA Methodology Work**
  - GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies) - U.S. life-cycle assessment (LCA) model maintained by US DOE
  - Updates to H2-GREET will influence global comparisons
  - U.S. developers increasingly aligning with ISO/IPHE CI rules
  - DOE supporting development of transparent project-level MRV
- **State-Level Clean Fuel Standards**
  - California LCFS, Washington CFS, Oregon CFP
  - Require verified CI and third-party auditing
  - Commonly used as reference frameworks in early export deals

U.S. Architecture for GHG data (today)

FCHEA

- **US EPA's GHG Reporting Program (GHGRP):**
  - Provides foundational emissions data for life-cycle modeling
  - Supports harmonization with international verification and standardized methodologies
  - Auditable and transparent framework providing confidence for domestic & foreign buyers
- **Proposed changes to GHGRP may influence data granularity, and degree of consistent data**
- **Impacts from Changes to GHG Reporting Structure:**
  - Modified data collection
  - Increased reliance on estimates
  - More importance given to voluntary schemes
  - Loss of consistency: Potential for fragmentation of key data

Interest in Global Warming Potential (GWP)

FCHEA

- **H_2 has known indirect warming effects:**
  - Extends methane lifetime
  - Increases tropospheric ozone
  - Increases stratospheric water vapor
- **Scientific debate on which GWP value (timeframe in years) to use:**
  - GWP_{100} (like other gases) or GWP_{20} of H_2 in LCA models

  Latest research:
  - $GWP_{100} \approx 11 \pm 5$
  - $GWP_{20} \approx 35–40$
- **Consensus:**
  - Leakage could influence CI in the context of green H_2
  - Growing recognition of this effect in LCA and certification systems

Accuracy of GWP Impact is Critical

FCHEA

- **Environmental Defense Fund real-world measurement campaigns:**
  - Real-world hydrogen leakage rates
  - Detection instrumentation
  - Field measurement campaigns with industry partners
- **Focus areas:**
  - Pipeline & equipment leakage
  - Routine releases (venting, boil-off)
  - Improved detection instrumentation
- **Early findings & claims:**
  - Historic leakage assumptions (e.g., 10–20% in some models) appear overstated.
  - Actual pipeline and equipment leaks tend to be much lower but still relevant.
- **Early work will shape:**
  - Regulatory modeling
  - International certification bodies
  - International interest in "hydrogen-specific MRV"

GWP Considerations - ISO

- **While ISO is not a "certification body," many certification programs are built on ISO frameworks, especially:**
  - ISO 14040/44 – LCA principles
  - ISO 14064 – GHG accounting
  - ISO 14687 – Hydrogen purity / quality
  - ISO 19870-series – GHG methodology (new work)
- **New LCA standards under ISO 14040/14067 frameworks increasingly incorporate:**
  - Hydrogen leakage
  - Indirect climate warming factors
  - System boundaries for CI accounting
- **LCA frameworks working groups are increasingly discussing the incorporation of:**
  - Leakage
  - Indirect warming effects
  - Boundary consistency

GWP Considerations - IPHE

FCHEA

- **IPHE is coordinating a global methodology for calculating the carbon footprint of hydrogen.**
- **IPHE's approach aims to:**
  - Harmonize CI accounting
  - Align definitions across major markets
  - Reduce trade friction
- **Early IPHE discussions include:**
  - Whether hydrogen leakage should be mandatory
  - What GWP values should be applied
  - What system boundaries should be consistent globally

Summary

FCHEA

- U.S. Policies have opened opportunities for export projects as strong partners for global importers. Trade must consider compliance with international regulations.
- Global certification systems are converging around robust, traceable, scientifically defensible CI data.
- Proposed US GHGRP changes may influence US data as a factor in verifications for importers.
- Hydrogen's indirect climate impacts are becoming factors in global CI rules. Accuracy is critical.
- International Standards Organizations are shaping the future of how hydrogen GWP and leakage are measured


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Thank You

Global Clean Hydrogen Technology Standardization Strategy 2

Status and Strategy of Korea's Hydrogen Fuel Cell Standardization (IEC/TC 105)



Hong-Ki Lee
Chair, IEC/TC 105
Vice President, Woosuk University

Education
1989-1993, Ph.D., Electrochemistry,Hanyang University, Seoul, Korea
1986-1988, M.S., Industrial Chemistry, Hanyang University, Seoul, Korea
1978-1982, B.S., Industrial Chemistry, Hanyang University, Seoul, Korea

Professional Career
2023-presentL Chairman, The IEC International Fuel Cell Technology Committee
2024-present: President, The Korea Hydrogen and New Energy Society
2018-present: Chairman, Hydrogen Technology Standard Forum
2014-present: Chairman, Overseas Certification Support Committee
2008-present: Chairman, The Hydrogen Fuel Cell Mirror Committee
1994-present: Vice President(2024) , Professor, Woosuk University

Research Interest
AFC, PAFC, FEMFC system R&D
International Standard for Fuel cell
Catalysts and MEA research
Physical mobility for hydrogen fuel cell system

Speech Summary
This session presents various performance indicators to discuss key issues related to Korea's hydrogen economy roadmap established since 2018..
The session discusses the vision, target and structure of the Standards Forum, established to standardize hydrogen technology with its annual performance indicators.
Furthermore, the current status and future direction of IEC/TC 105, which develops international standards for fuel cells, are explained.

Company Introduction
Woosuk University was provate university established since 1979,and Fuel Cell Regional Innovation Center was established since 2008 by government support.
The activity is Research and development of fuel cells, Core technology construction of fuel cells, Providing of research facilities and Technical support for companies



Contents

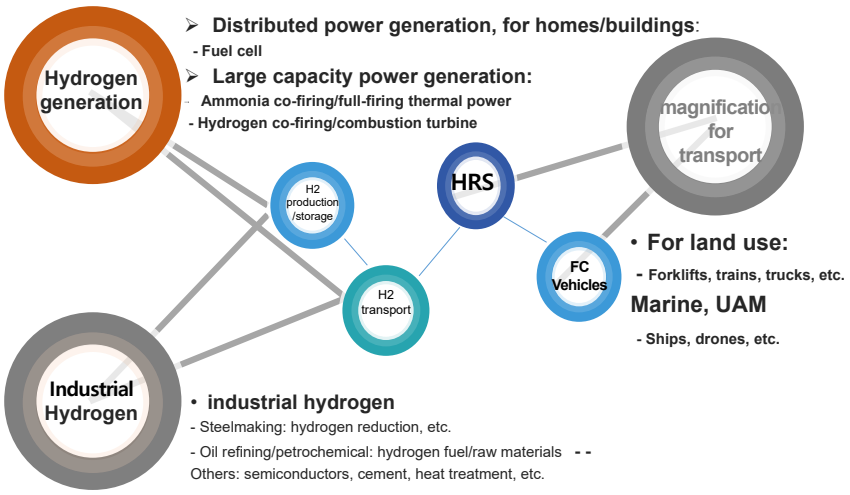
1 Hydrogen Economy Roadmap
2 Hydrogen Technology Standard
3 Status of International Standard

1 Hydrogen Economy Roadmap (2019.01.17)

	Classificaiton	2018		2022	2030	2040
APPLICATION / MOBILITY	FCEV	1,800	100% Domestic	81,000	2023:EV Equiv 2025:Internal E	620 M
	Automobile	1,800		79,000		590 M
	Bus	2		2,000		60 T
	Taxi	-		-	Over 500T km	120 T
	Truck	-	5 ton truck	10 ton	100% Domestic	120 T
	HR Station	14		310	$ 3,000/kg	1,200
	Ships, Train Drone	R & D		Commercialize until 2030		
APPLICATION / ENERGY	Fuel Cell Generation	307MW	$ 3,500/kW	1.5GW	50% Cost down	15 GW
	RPG, Building	7MW	$ 15,000/kW	50MW	$ 5,000/kW	2.1 GW
	H_2 Gas Tubine	R & D		Commercialize until 2030		
H_2 Supply	Amount of supply	130T/y		470T/y		526T/y
	Production Type	Fossile	Large Scale	Electrolyze	Large Storage H_2 Import	Fossile
	Cost of H_2	-		$ 5/kg	$ 3.5/kg	$ 2.5/kg

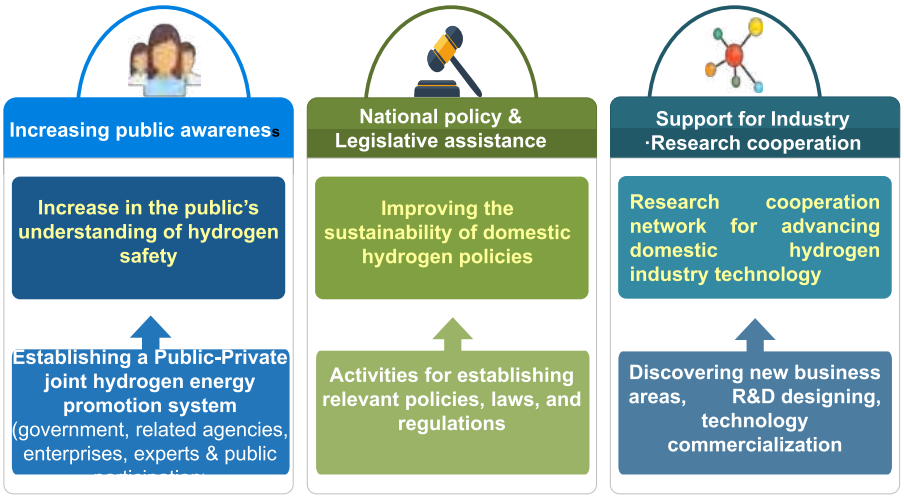
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Hydrogen economy: Based on hydrogen infrastructure, expansion of transportation > power generation > industrial use



1-3. Increase in public acceptance of hydrogen industry

Improvement in public acceptance of hydrogen Industry through customized support activities for the public - policy makers - industrial technical experts



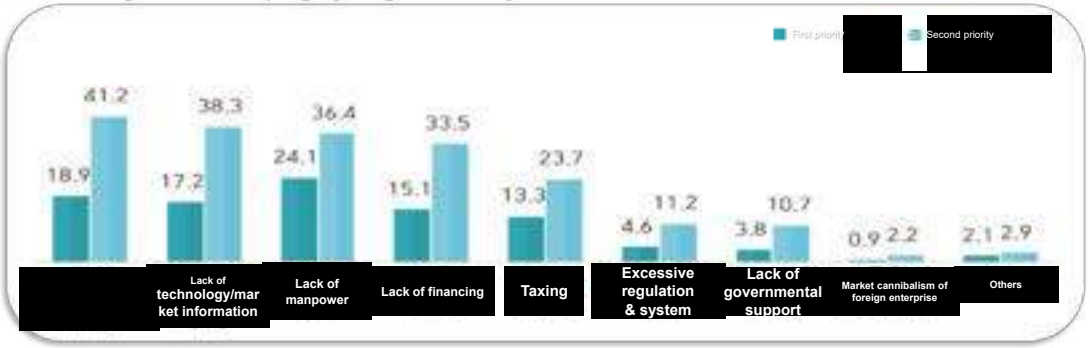
1-4 Survey Results of hydrogen Enterprises in S. Korea

Growth Potential

- **Major obstacles Lack of infrastructure**

➡ Infrastructure, technology & market information, manpower, and finance (left to right)

▶ **Challenges in developing hydrogen industry**



6

2 Hydrogen Technology Standard

Vision

Leading global market share of hydrogen industry by prevailing international standard

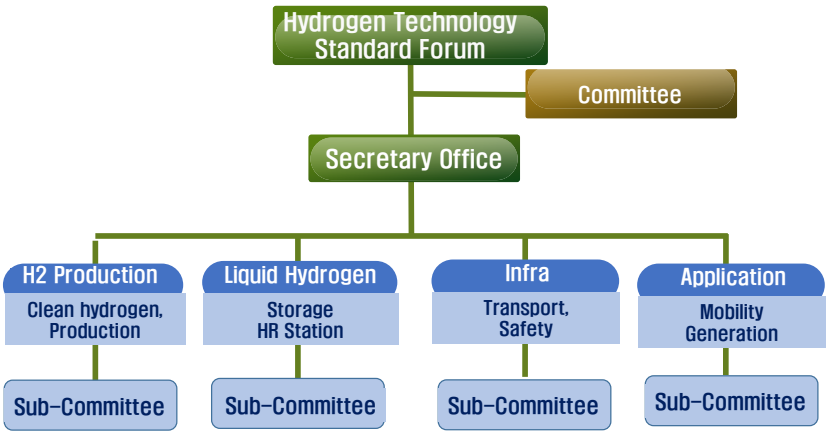
Strategy

1. Achieve the goals of the International Standardization Cooperation Project
2. Serve as a think tank for domestic hydrogen technology standards,
3. Establishing int'l standardization strategies and reviewing int'l joint research.

Action Plan

1. Active participation to present international standards WG
2. Strengthening Korea's new proposal to lead international standards
3. Standardization technology reflected in domestic R & D
4. Occupied hydrogen industry demand with Harmonization of IS
5. Fostering Standards Experts in International Standards Organizations

Structure of Standard Forum



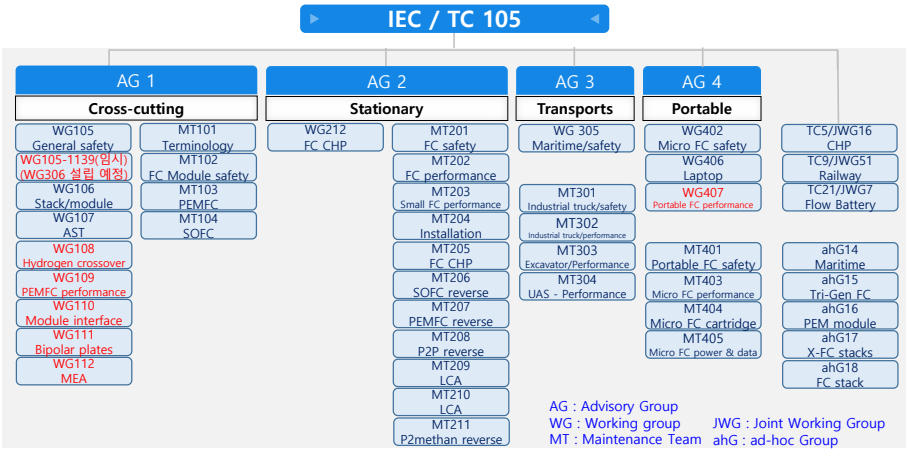
2-2 Items of H_2 Economy Standard

1	Development of integrated standard with R & D	NWIP 25 until 2030
2	Expanded supporting system for international standard	Expanding Expert Support
3	Strengthening cooperation with multilateral IS	NE Asia standard cooperation International forum
4	Expansion of KS standard for H_2 products and services.	100% Harmonization(54)
5	Establishment of KS system for market penetration	Identification of items and KS certification
6	Supply to secure transaction reliability of H_2 charging	Technical development Regulation improvement
7	Support standard activities of small/medium sized companies	Mach-up 30 at 2022
8	**Hydrogen economy standard forum and fostering experts.**	100 Experts at 2020
9	Establishment of hydrogen safety test base	Relevant agency cooperation

3 Status of International Standard

IEC/TC105 Structure

WG(Working Group) 14, MT(Maintenance Teams) 23, ahG(ad hoc Group) 5



* source : IEC/TC105 web('25.10)



❖ TC 105 Liaisons

Committee	Description	Incoming liaison	Outgoing liaison
	Internal IEC Liaison		
TC 8	System aspects of electrical energy supply	Mr Toshiki SHIMIZU	Mr Toshiki SHIMIZU
TC 9	Electrical equipment and systems for railways	Mr Julien D'ARBIGNY	
TC 18	Electrical installations of ships and of mobile and fixed offshore units		Mr Noel Dunlop
TC 21	Secondary cells and batteries		Mr Nobuo SHIGA
TC 108	Safety of electronic equipment within the field of audio/video, information technology and communication technology	Mr Bob Griffin Mr Jos Remy	Mr Toshiki SHIMIZU
TC 120	Electrical Energy Storage (EES) systems	Mr Toshiki SHIMIZU	Mr Toshiki SHIMIZU
SyC LVDC	Low Voltage Direct Current and Low Voltage Direct Current for Electricity Access		
SyC Smart Cities	Electrotechnical aspects of Smart Cities	Mr Kazuo SHIBATA	Mr Kazuo SHIBATA
SyC Smart Energy	Smart Energy		Mr Kazuo SHIBATA
	Liaison ISO		
ISO/TC 22	Road vehicles	Mr Kelvin Hecht	
ISO/TC 110	Industrial trucks	Mr Sylvain Cadou Mr David Goss Mr Andreas Scherb Mr Maxime Vinçonneau	Mr Akio Matsuura
ISO/TC 127	Earth-moving machinery	Mr Chuck Crowell	
ISO/TC 127/SC 3	Earth-moving machinery - Machine characteristics, electrical and electronic systems, operation and maintenance	Mr Minpei SHODA	Mr Hong Ki Lee
ISO/TC 197	Hydrogen technologies	Mr Hidenori Tomioka	
	Liaison A		
EC	European Commission	Mr Thomas Malkow	

IEC/TC105 Projects(14)

Project Reference	Title	Current Stage	WG	Project Leader
PWI 105-1	General safety standard	PWI		
PNW 105-1139 ED1	Fuel cell technologies - Part 4-601: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Safety-Fuel cell/battery hybrid systems for excavators and wheel loaders	PNW	WG 306	Joongpyo Shim
IEC 62282-2-201 ED1	Fuel cell technologies – Part 2-201: Fuel cell modules - Performance test methods for PEM module	ACD	WG 109	Tiancai MA
IEC 62282-2-400 ED1	Fuel cell technologies - Part 2-400: Fuel cell modules - Calculation of Rated Power and Power Density of a PEM stack and PEM module	CDM	WG 106	
IEC TS 62282-2-401 ED1	Fuel cell technologies– Part 2-401: Fuel cell modules – PEM modules Size and interfaces definition (Shape, fluidic, electrical, API interfaces)	ACD	WG 110	Etienne HAVRET
IEC 62282-3-100 ED3	Fuel cell technologies - Part 3-100, Stationary fuel cell power systems - Safety	PCC	MT 201	Stephen Maurer
IEC 62282-4-401 ED1	Fuel cell technologies - Part 4-401: Fuel cell power systems for propulsion and auxiliary power units - Maritime sector - Safety of PEMFC-Systems	ACD	WG 305	Takehiro Maruyama
IEC 62282-5-200 ED1	Fuel cell technologies – Part 5-200: Portable fuel cell power systems - Performance test methods	ACD	WG 407	Toshiki SHIMIZU
IEC 62282-7-4 ED1	Fuel cell technologies - Part 7-4: Test methods - Bipolar plates for PEFC	ACD	WG 111	Zhigang qi
IEC 62282-7-5 ED1	Fuel cell technologies - Part 7-5: Test methods - Membrane electrode assembly for PEFC	ACD	WG 112	Hongmei YU
IEC 62282-8-101 ED2	Fuel cell technologies - Part 8-101: Energy storage systems using fuel cell modules in reverse mode - Test procedures for the performance of solid oxide single cells and stacks, including reversible operation	ACD	MT 206	Stephen Mc Phail
IEC 62282-8-102 ED2	Fuel cell technologies - Part 8-102: Energy storage systems using fuel cell modules in reverse mode - Test procedures for the performance of single cells and stacks with proton exchange membrane, including reversible operation	ACD	MT 207	Hongmei YU
IEC 63341-3 ED1	Railway applications - Hydrogen and Fuel Cell systems for rolling stock - Part 3: Performance test methods for fuel cell power system	BPUB	TC 9/JWG 51	Nan Liu

* source : IEC/TC105 web('25.10)

Thank you.



Regional Innovation Center for the Hydrogen Fuel-Cell Technology

Global Clean Hydrogen Technology Standardization Strategy 3

Global Clean Hydrogen Technology Standardization Strategy



Laurent Antoni
Executive Director, IPHE

Education

1992-1996 PhD at Institut National Polytechnique de Grenoble (INPG), Electrochemistry and Surface Sciences. INPG PhD award 1997
1989-1992 Engineer School INP Grenoble / ENS Electrochemistry and Electrometallurgy of Grenoble

Professional Career

2003 - Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA)
2023- Executive Director of the IPHE
2015-2023 Hydrogen Public Affairs Manager (LITEN)
2013-2014 Electricity and Hydrogen for Transportation Department Manager
2010-2012 Electrochemical Generators Integration Laboratory Manager
2005-2009 Low temperature fuel cell system Laboratory Manager
2003-2005 Team leader in the Fuel Cell Laboratory
1996-2003 UGINE-SAVOIE IMPHY, Mittal Group

Research Interest

Hydrogen technologies

Speech Summary

Low-emission hydrogen is a key lever for decarbonising our economies and achieving global carbon-neutrality targets by 2050. Building trust and securing long-term commitments across the hydrogen value chain, however, requires reducing significant uncertainties—particularly regarding what qualifies as "clean" hydrogen for producers, buyers, investors, and end users. Certification schemes play a central role by verifying that hydrogen meets defined sustainability and emissions-performance criteria, thereby ensuring that emerging low-emission hydrogen markets genuinely contribute to climate-mitigation and broader sustainability goals.
To prevent market fragmentation and enable international trade, there is now an urgent need for mutual recognition of certification schemes for renewable and low-carbon hydrogen and derived products. Establishing a shared understanding of certification mechanisms among governments and stakeholders is essential.
This presentation will examine how standardisation can support this process, fostering interoperability, comparability, and confidence in global hydrogen markets.

Company Introduction

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), established in 2003, is an international Government-to-Government partnership whose objective is to facilitate and accelerate the transition to clean and efficient energy and mobility systems using fuel cells and hydrogen technologies. Each of the IPHE partner countries has committed to accelerate the development of FCH technologies to enhance the security and efficiency of their energy systems, to help address environmental objectives, and to grow the economy.

WORLD HYDROGEN EXPO 2025 | H2MEET 2025 | Hydrogen Frontiers Congress 2025

IPHE
International Partnership for Hydrogen and Fuel Cells in the Economy

The importance of moving toward mutual recognition of hydrogen certification and the role of standardisation

Dr. Laurent ANTONI
Executive Director, IPHE
Senior Fellow, CEA
Chair, ISO TC197/SC1
laurent.antoni@iphe.net

WHE 2025, H2MEET 2025, 5 December 2025, Seoul, South Korea

A Government to Government Partnership to develop a Hydrogen Economy









Chair:
Brazil

Vice-Chairs:
Japan
Netherlands
USA

www.iphe.net

26 Countries & European Commission | Founded in 2003

A Government to Government Partnership to develop a Hydrogen Economy

IPHE's DNA is to monitor information, perform gap analysis and subsequently produce and publish reports, databases, etc.

All documents produced by the task forces and working groups of IPHE stem from government-to-government exchanges and work **exclusively**. They are **publicly available**. They are often presented through dedicated webinars.



Skills *GHG* *Certificatio* *Trade* *Storage*

The IPHE Secretariat maintains database listing **national hydrogen strategies** and technology **deployments** as well.

All resources are available here: https://www.iphe.net/intelligence

Introduction

- Hydrogen's global role in
  - Decarbonization: Hard-to-abate sectors (steel, chemicals, heavy transport, shipping, aviation)
  - Energy Security: Diversification away from fossil fuel dependencies
  - Economic Opportunity: Creation of new export industries and "green" jobs

→ Hydrogen is more than just a new fuel; it is a potential cornerstone of the future energy system.

- Current barriers
  - Cost gap versus fossil fuels, including unabated fossil hydrogen
  - Infrastructure
  - Policy uncertainty

The Need for International Cooperation

- National strategies are necessary but not sufficient. No country can go it alone.
- Without international cooperation and coordination, there is a risk of a fragmented market with incompatible standards, hindering the economies of scale that are crucial for cost reduction.



The Need for International Cooperation

- Four main pillars:

1. **Common Definitions and Standards**: Defining “low-emission/clean/renewable and low-carbon" hydrogen to ensure credibility & trust and to prevent any greenwashing
2. **Global Trade**: Developing trade rules and infrastructures
3. **Financing and Risk Sharing**: Role of public financing (grants, loans, guarantees), blended finance with private capital, carbon pricing mechanisms
4. **R&D Collaboration**: Shared innovation in electrolysis, CCS, storage, and safety to accelerate cost reduction for everyone.

Harmonizing international standards, certification and trade rules is critical to avoid market fragmentation

Global trade in low-emission hydrogen and hydrogen derivatives **helping match supply and demand** at international scale **unlocks decarbonization opportunities** and **cost-efficiency gains**.

Certification of low-emission hydrogen and hydrogen derivatives is a key priority for **multilateral cooperation to unlock this cross-border trade** while enabling **transparency, interoperability** as well as in building **consumer trust**.

At COP28, a Declaration of Intent signed by 39 countries affirmed the importance of a **mutual recognition of certification schemes** based on key principles that recognizes diverse policy choices with regards to strategies, roadmaps, policies and legislation for renewable and low-carbon hydrogen and hydrogen derivatives.

Mutual recognition of certification schemes based on key principles

1 **Political track** — Engage at the political level to obtain continued political endorsement of the implementation of the initiative by signatories

COP

COP28

2 **Technical track** — Develop technical draft and operational program to develop the mutual recognition of certification schemes

Long-term objectives

- Support the development of **harmonized underlying methodologies**
- Develop **mutual recognition framework and mechanism**
- Develop **technical recommendations**

Approach for mutual recognition of certification schemes

Overarching approach

- Use of a **common language**
- Develop **technical recommendations**
- Agree on **harmonized underlying methodologies**
- Establish a **common understanding** between governments on certification mechanisms

Ongoing technical actions and main implementing bodies

- Development of **Hydrogen Certification 101 paper**

WHE 2025, H2MEET 2025, 5 December 2025, Seoul, South Korea

9

Approach for mutual recognition of certification schemes

Overarching approach

- Use of a **common language**
- Develop **technical recommendations**
- Agree on **harmonized underlying methodologies**
- Establish a **common understanding** between governments on certification mechanisms

Ongoing technical actions and main implementing bodies

- Development of Hydrogen Certification 101 paper
- Methodology for **GHG emissions assessment of hydrogen**
- **Conformity assessment**
- **Auditing** management systems

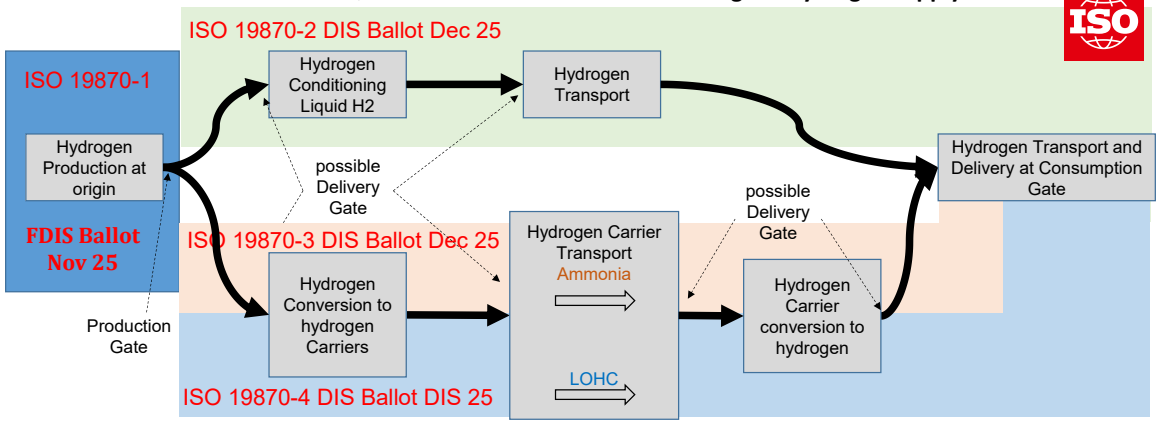
WHE 2025, H2MEET 2025, 5 December 2025, Seoul, South Korea

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Approach for mutual recognition of certification schemes

Agree on harmonized underlying methodologies

ISO 19870-X series – Quantification of GHG Emissions along the hydrogen supply chain



ISO process: CD → DIS (5 months ballot) → FDIS (2 months ballot)→ IS (International Standard)

Approach for mutual recognition of certification schemes

Overarching approach

- Use of a **common language**
- Develop **technical recommendations**
- Agree on **harmonized underlying methodologies**
- Establish a **common understanding** between governments on certification mechanisms

Ongoing technical actions and main implementing bodies

- Development of Hydrogen Certification 101 paper
- Methodology for GHG emissions assessment of hydrogen
- Conformity assessment
- Auditing management systems
- **Coordination** of actions
- **Annual stock take & monitoring** of progress (e.g. in COP Acceleration Plans)

Assessment of the existing landscape

Hydrogen Certification 101

- Reference for broader audience, not a technical guidebook for experts
- Definitions of terminology and concepts
- Information on design of certification schemes and their key elements



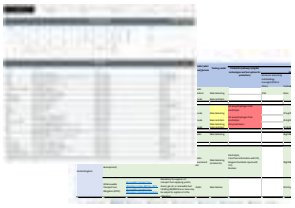
Comparison Report

- Comparison of 21 certification schemes across 11 countries/ regions
- Comparison of:
  1. Product attributes
  2. Chain of custody model
  3. Operational setup & procedures



Inventory

- Systematic collection and mapping of hydrogen certification schemes
- Excel tool with results informing comparison report



Results of comparison and interoperability assessment

1. The **more detailed** the assessment, the **more differences** between schemes can be found
2. **Considerable differences** between certification schemes for hydrogen, many of which are expected to have negative impact on trade of certified hydrogen
3. **Modular approach to address the differences** and improve tradability of certified hydrogen, with common modules and modules specific to individual jurisdictions or certification schemes
4. The **more common modules**, the **higher the benefits** for trade of certified hydrogen
5. Regardless of the level of ambition, modular approach could be implemented in the form of a **hydrogen digital product passport (DPP)**

Results of comparison and interoperability assessment

- 28 hydrogen certification mechanisms included across 13 countries/regions
- 7 of these are pending analysis
- Information up to date as of September 2025
- Information covering 5 different areas
- Online, easily navigable tool

Product Attributes – GHG Emissions

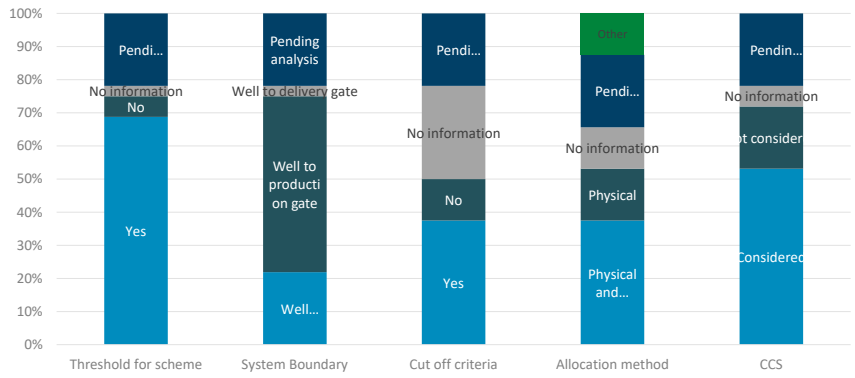
Product Attributes – Electricity Sourcing

Product Attributes – Other Attributes

Chain of Custody Model

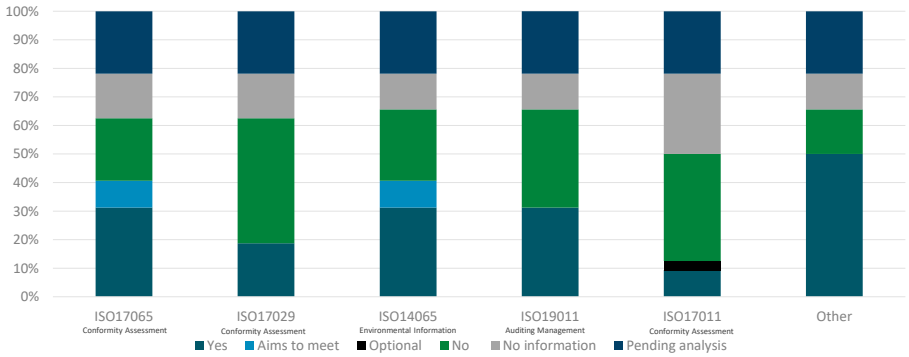
Operational Setup & Procedures

Product Attributes – GHG emissions



Just comparing GHG threshold values makes no sense
Key role of the ISO 19870-x series to allow interoperability and comparison (ISO TC197/SC1)

Operational setup & procedures



Strong need in harmonisation and in promoting whenever possible the usage of the existing ISO standards (ISO/CASCO, ISO/TMBG, ISO TC207/SC7)

Modular approach implemented in the form of a Hydrogen Digital Product Passport (DPP)

Content

- Affiliation, Purpose, Coverage, Data collection and management
- The main data of a hydrogen product (batch)
- Certificates
- Shall be integrated from a project design



Source: IEA Towards H2 definitions based on their emissions intensity (2023)

Almost 10 hydrogen DPPs under development (AUS, DE, FR, UAE, UK, URU)



Conclusions

- Clean hydrogen is on the path to becoming a globally traded commodity
- **International collaboration** and coordination are key
- **International coordination** on standards, certification and trade is as important as national strategies
  - Move toward mutual recognition of certification schemes (e.g H_2 digital product passport)
  - Rely as much as possible on **international technical standards** (ISO TC197, ISO/CASCO, ISO/TMBG, ISO TC207/SC7, IEC TC105)

The coming 2-3 years are critical.
The policies we enact now will determine if low-emission hydrogen remains a niche technology or becomes the backbone of a decarbonized global economy.

Thank you / 감사합니다

International Partnership for Hydrogen and Fuel Cells in the Economy

Global Clean Hydrogen Technology Standardization Strategy 4

Hydrogen Technology Standardization in Europe and Germany：A Catalyst to Drive Green Hydrogen Solutions



Klemens Ilse
Deputy Director, Fraunhofer IWMS

Education
- PhD thesis, written at the Martin-Luther-University Halle-Wittenberg and Fraunhofer CSP. Topic: "Microstructural investigation and simulation of natural soiling processes on PV modules"
- Master of Science in Physics at the Martin-Luther-University Halle-Wittenberg. Thesis: "Fabrication and characterization of silicon nanoparticles embedded in aluminum oxide"
- Abitur (qualification for university entrance)

Professional Career
- Deputy Director of Fraunhofer CSP, a business unit of Fraunhofer IMWS
- Deputy Director of FIP-H2ENERGY@KENTECH
- Group Leader "Materials for H2 Technologies" at the Fraunhofer Institute for Microstructure of Materials and Systems IMWS
- Research associate in business unit "Hydrogen Technologies", Fraunhofer IMWS
- Head of team "Functional and optical surfaces" within the group "Diagnostics and Metrology", Fraunhofer Center for Silicon Photovoltaics CSP

Research Interest
- International cooperation on hydrogen research
- Production of green hydrogen and its derivates from renewable energy, e.g. in desert locations
- Hydrogen logistics
- Standardization and certification of electrolyzers
- New methods for degradation analysis and optimization of electrolyzer components

Speech Summary
Green hydrogen is vital for decarbonization with rapid global growth. This presentation covers evolving standards, certification, regulatory challenges, and success stories. Harmonized approaches ensure safety, trust, and bankability. Collaboration drives scalable, sustainable hydrogen economies.

Company Introduction
Fraunhofer IMWS drives material efficiency and innovation through leading microstructure research.

Fraunhofer IMWS

Fraunhofer Institute for Microstructure of Materials and Systems IMWS

Hydrogen Technology Standardization in Europe and Germany
A Catalyst to drive Green Hydrogen Solutions

Dr. Klemens Ilse - International Hydrogen Technology Standardization Conference, 05.12.2025, Seoul
Head of Group – Materials Diagnostics for H2 Technologies, Fraunhofer IMWS
Deputy Director FIP-H2ENERGY@KENTECH

Fraunhofer Innovation Platform for Hydrogen Energy
KENTECH Korea Institute of Energy Technology
in cooperation with Fraunhofer

The Green Hydrogen Challenge
How is green hydrogen evolving?

Timeline of progress and deployment for different countries in the years 2023-2024



Map overview of H2 strategies and activities

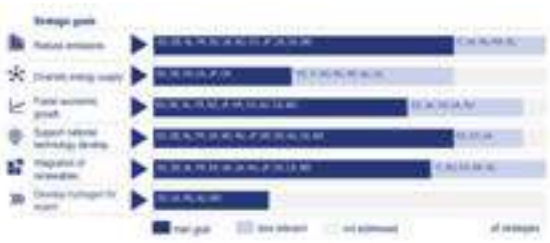


Source: World Energy Council: International Hydrogen Strategies, report Sept.-2020

The Green Hydrogen Challenge

How is green hydrogen evolving?

H2 is clearly recognized as an essential element of a decarbonized energy system



Hydrogen Economy creating international cooperation and partnerships in the energy sector



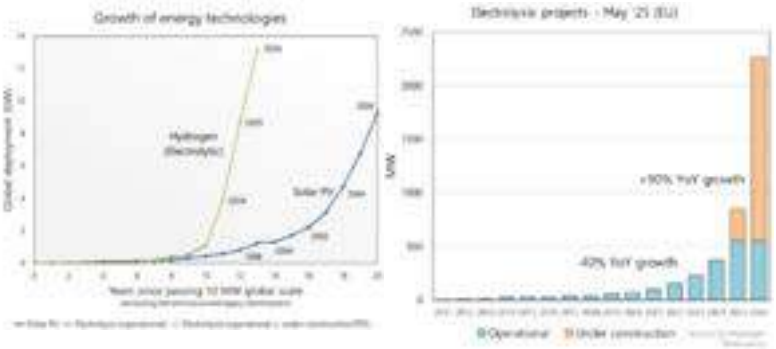
Source: World Energy Council: International Hydrogen Strategies, report Sept.-2020

The Green Hydrogen Challenge

How is green hydrogen evolving?

- Hydrogen is growing faster than solar, fastest-growing energy technology ever
- In the EU, steady historic growth is now accelerating (based on real projects being built)
- Based on projects past FID, global growth exceeds 100%

- Growth is strongly subsidized
- To reach 500GW GH2 capacity by 2030 → annual growth must be 100% over next 5 yrs → it's extremely ambitious
- Even if achieved, 500GW replaces only about 50% of current fossil hydrogen demand → GH2 still in early growth phase.



https://www.linkedin.com/posts/janronge_green-hydrogen-growth-activity-7356560728926965760-DRZF/?utm_source=share&utm_medium=member_android&rcm=ACoAABJf120BoDN93jqcCOviLKTbOpkgUMeXKk8

The Hydrogen Standards Gameboard

Standards Framework and Its Use in Hydrogen

Technical rules & Standards are essential for reliance, bankability, and global trade.

- Standards:
  - Ensure Reliability: Create a baseline for performance, quality, and comparability.
  - Guarantee Safety: Establish uniform rules for components, sensors, and operations.
  - Enable Bankability: Provide a common language to de-risk investments for funders and insurers.
  - Fulfill National Strategy: National Hydrogen Strategies (e.g., Germany) explicitly call for uniform standards.



Hierarchical Model of Legal Frameworks: The Inverse Relationship Between Binding Force and Detail



Sectoral Breakdown of the European and International Hydrogen Standards Ecosystem

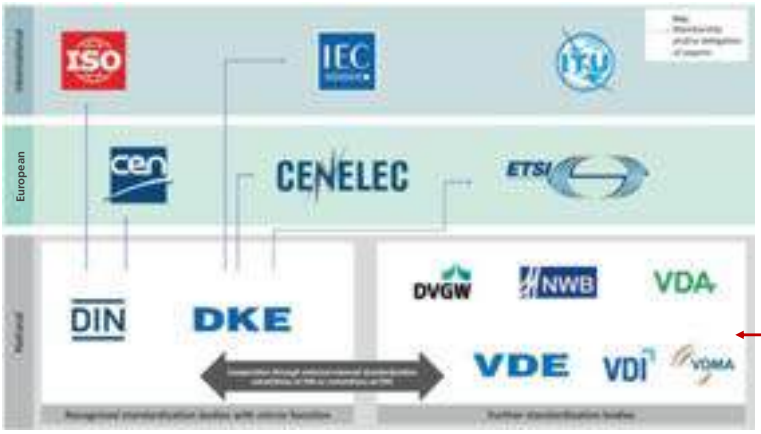
Dr. Klemens Ilse - International Hydrogen Technology Standardization Conference, 05.12.2025, Seoul

- Informationsklassifizierung -

Fraunhofer IMWS

The Standardization Ecosystem

Key players from national to global



Sector-specific organisations

DIN et al.„Standardization Roadmap Hydrogen Technologies 2024" (2024)

Dr. Klemens Ilse - International Hydrogen Technology Standardization Conference, 05.12.2025, Seoul

- Informationsklassifizierung -

Fraunhofer IMWS

The Standardization Ecosystem

German Perspective – Published Standardization Roadmap

Sector specific German certification bodies DKE, DIN, DVGW, VDA, VDI, VDMA and NWB developed the „Standardization Roadmap for Hydrogen Technologies 2024"

- Including recommendations for action for science, technical regulations and monitoring of their editing and implementation

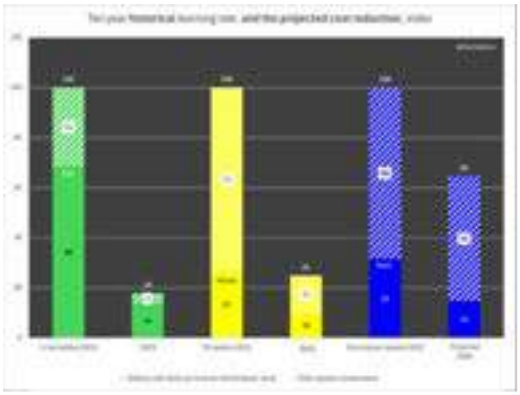


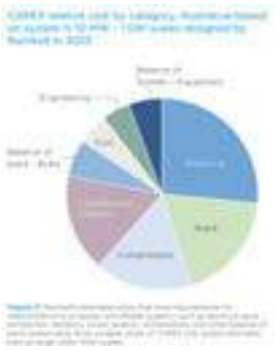


The need for standardization

Standardizing safety and approval of components and systems

- GH2 BOP costs dominate total electrolyzer CAPEX and limits learning-related cost decline.
  - Li-ION batteries & PV much higher in comparison
- Clear standards and benchmarks to reduce cost and enhance deployment
- Standardization directly reduces costs by enabling component compatibility, de-risking design choices, and supporting economies of scale
- Reducing fragmented technical rules to push global value chain integration





https://observatory.clean-hydrogen.europa.eu/hydrogen-landscape/production-trade-and-cost/electrolyser-cost

The need for standardization

Performance metrics of actual devices is barely comparable

- Diversity of new designs and OEMs challenges benchmarking and quality assurance.
- Absence of common definitions for acceptable lifetime performance causes market uncertainty.
- Certification shows that the product has been tested according to comparable standardized specifications
- Certified products are easily comparable, test procedure is transparent for customers

- **Established international cooperation** for joint standards:
  - **PWI proposal** on Water electrolysis technology Performance test at 33rd ISO/TC197 Plenary Meeting Dez. 2024 Seoul
  - Continuation and revision with ISO/TC197 WG4 and further international recognized institutions (**GER, KR, JP, NL**)





Fraunhofer TNO KCL AIST

The need for standardization

Materials threatened by regulation

- Pending regulations (e.g., PFAS ban) threaten the availability of critical components like membranes and seals
- Changing material requirements demand rapid validation and approval protocols.
- Uncertainties in regulatory landscapes risk delaying next-generation technology introduction.

- **International research project** for fundamentals and standardization needs – **EU Horizon project**:
  - Understanding emissions of PFAS from electrolysers and/or fuel cells under product use
    - Successful project application of **European partners**, with Korean participation: **KIST**





Source: slideshare: Overview of pfas activities from the european union, https://www.slideshare.net/slideshow/overview-of-pfas-activities-from-the-european-union-pdf/274783487#6

The need for standardization

Standardizing certification and guarantee of origin

- By use of Certification processes assessing if a specific product meets established characteristics.
- Certifying the sustainability attributes of hydrogen offers trustworthy information regarding its production and delivery methods
  - Demonstrate compliance with regulatory requirements
  - Access to financial incentives
  - Demonstrate voluntary reporting and disclosure requirements
- EU perspective: Delegated Acts: Revised under the "Fit for 55" package, REDIII promotes increased use of renewable energies and RFNBOs across various sectors, particularly for defossilizing areas unsuitable for direct electrification
  - Since Dec 2024 ISCC, CertifHy & TÜV





Source: Hydrogen Certification 101, July 2023



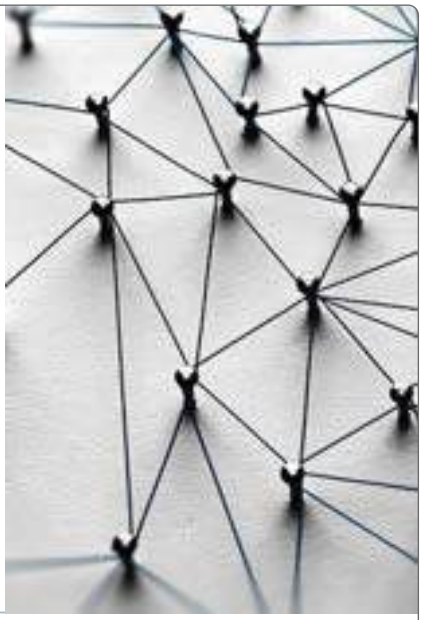
Targets	RED II (2018)	RED III (2023)
Renewable Energy consumed (EU)		
Industry (RFNBOs & H_2)		42% (by 2030) 60% (by 2035)
Renewable energy use in industry (annual increase)		
Renewables energy within final consumption in transport sector	14% (by 2030)	29% (by 2030)
Transport sector (advanced biofuels + RFNBOs)		

Source: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en; https://www.consilium.europa.eu/en/infographics/fit-for-55-how-the-eu-will-turn-climate-goals-into-law/ ; https://www.now-gmbh.de/wp-content/uploads/2024/04/NOW-Factsheet_REDIII.pdf

Conclusions and key takeaways

Green Hydrogen: Success Through Standards and Collaboration

- Green hydrogen is rapidly advancing worldwide, supported by real projects and strong international cooperation, demonstrating the great potential for a sustainable energy future.
- Clear and harmonized standards create trust, ensure safety, and enable investment security, helping green hydrogen projects become bankable and scalable.
- Standardization lowers costs by fostering component compatibility, enabling economies of scale, and reducing risks in design and deployment.
- Certification and guarantees of origin provide transparency and unlock regulatory incentives, further accelerating market acceptance.
- International collaboration and shared technical rules are pivotal for overcoming regulatory uncertainties and speeding up technology adoption.
- Ongoing performance benchmarking and joint qualification processes build confidence in emerging technologies and support innovation.
- Collective action and standardization efforts have already begun to reduce barriers, enhancing the pace of green hydrogen deployment globally.



Contact

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Fraunhofer IMWS

Fraunhofer Innovation Platform for Hydrogen Energy
KENTECH Korea Institute of Energy Technology
in cooperation with Fraunhofer

Global Clean Hydrogen Technology Standardization Strategy 5

Commercial Hydrogen Measurement Standards Development of United States & California



Kevin Schnepp
Director, California Department of Food and Agriculture

Education

1996 B.A. Chemistry - California State University Sacramento
2012 Masters Business Administration with a concentration in Environmental Compliance and Sustainability - Southern New Hampshire University

Professional Career

CHEMIST (5 years) Aerojet Fine Chemicals
ASSOCIATE RESEARCH SCIENTIST II (3.5 years) Exelixis, Inc.
ENVIRONMENTAL SCIENTIST (1.5 years) California Department of Food & Agriculture - Division of Measurement Standards
SENIOR ENVIRONMENTAL SCIENTIST (3.5 years) California Department of Food & Agriculture - Division of Measurement Standards
SENIOR ENVIRONMENTAL SCIENTIST – SUPERVISOR (1.5 years) California Department of Food & Agriculture - Division of Measurement Standards
ENVIRONMENTAL PROGRAM MANAGER I (5.5 years) California Department of Food & Agriculture - Division of Measurement Standards
DIRECTOR (Current) California Department of Food & Agriculture - Division of Measurement Standards

Research Interest

Hydrogen Measuring Systems
Analytical methods for hydrogen analysis (Fuel Cell Applications)
Hydrogen Energy Storage
Hydrogen Production and Generation Life Cycle Analysis

Speech Summary

Discussion on the standards development processes in the United States for hydrogen measuring equipment used in dispensing hydrogen for fuel cell electric vehicles. Presentation will provide an overview of the roles of the National Council on Weights and Measures (NCWM); the National Institute for Standards and Technology (NIST); The National Type Evaluation Program (NTEP); the California Type Evaluation Program (CTEP); and state's authority to adopt and enforce national model regulations. Overview of California specific efforts to support hydrogen fueling infrastructure.

Company Introduction

California Department of Food and Agriculture – Division of Measurement Standards
State program responsible for the development and enforcement of performance specifications for zero-emission and near zero-emission alternative and renewable fuels. Adopts and enforces the specifications, tolerances, and user requirements for commercial weighing and measuring devices used in the dispensing of fuels, lubricants, and automotive products including hydrogen and electricity. Operates the California Type Evaluation Program where new commercial dispensing equipment is evaluated and approved for sale and commercial use in the state.

Commercial Hydrogen Measurement Standards Development

United States & California

cdfa CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

Kevin Schnepp, Director

Serving and Protecting California's consumers, businesses, economy and environment

International, United States, California, and California County Metrology Relationships



International Weights and Measures System - OIML



US Weights & Measures System - NIST
National Institute of Standards and Technology

California Weights and Measures
CDFA-DMS Metrology Program



cacasa
County Sealers

U.S. Weights and Measures Requirements for Commercial Devices

- Unlike many nations, the United States does not have any federal weights and measures laws.
- Weights and measures laws are a state's right to oversee and enforce.
- To ensure an equitable and robust marketplace, the states need to have consistent regulations.
- In the United States, the National Council on Weights and Measures (NCWM) is the consensus standard setting organization that develops the model laws published by NIST in Handbooks 44, 130 and 133.

NCWM

The Consensus Standards Setting Organization for Weights and Measures Jurisdictions in the United States.

- Develops national standards for commercial measurement and method of sale requirements which are published annually by the National Institute of Standards and Technology (NIST) in Handbooks 44, 130 & 133.
- Administers the National Type Evaluation Program (NTEP)
- Collaborates with the four (4) regional weights and measures associations. (Independent and self-governing)
- Maintains a memorandum of understanding (MOU) with NIST who provide technical expertise and advice during the standards development process
- NIST Publishes the Consensus Standards Adopted by NCWM

The National Standards (Model Laws) Published by NIST







5

National Council on Weights and Measures

National Type Evaluation Program (NTEP)

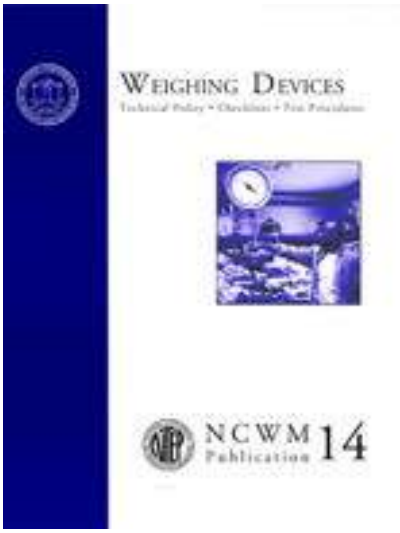
Almost every state requires that commercial weighing and measuring devices be type approved prior to be sold and placed in service.

Type evaluation ensures that a commercial weighing and measuring device meets all the specifications, tolerances, and general code requirements adopted and published in NIST Handbook 44.

Tested and approved devices are issued an NTEP Certificate of Conformance (CC)

6

NCWM Publication 14



Administrative Policy

Content is developed by NTEP Committee and Board of Directors

Technical Policy, Checklists, and Test Procedures

Content developed by NTEP Sectors and approved by NTEP Committee

–Weighing Devices

–Measuring Devices

–Grain Analyzers

California Weights and Measures Requirements

- Prior to installation and use, all commercial weighing and measuring devices must be type approved to assure that the device is accurate; measures repeatably; designed to operate in the conditions it will be exposed to; cannot be easily manipulate to defraud customers; and a fair and accurate accounting of all measurements and fees is communicated to the customer.
- The California Department of Food and Agriculture (CDFA), Division of Measurement Standards (DMS) certifies retail hydrogen dispensers prior to installation for commercial use through the California Type Evaluation Program (CTEP).

California Weights and Measures Requirements

For type evaluation to occur, there must be enforceable standards in the form of tolerances and specifications for the device in question.

CDFA-DMS chaired and sponsored a multitude of U.S. Hydrogen Working Group meetings that led to the adoption of hydrogen vehicle fueling regulations by NCWM. Published in NIST HB 44 Section 3.39 *Hydrogen Gas-Measuring Devices*

Assessment of hydrogen measuring devices required the development of a test standard. CDFA-DMS contracted with U.S. Department of Energy National Renewable Energy Laboratory (NREL) to design and build a hydrogen field standard.

Hydrogen Field Standard (HFS) Hydrogen Dispenser Metrology Testing Device





California Hydrogen Dispenser Requirements



During type evaluation, conformance to CCR Title 4, Division 9 Section 3.39 Hydrogen Gas Measuring Devices as adopted is determined.

Must meet Acceptance Tolerance prior to being placed into commercial service.

Re-tested annually thereafter, Maintenance Tolerances are applied.

Devices are also inspected for conformance during complaint investigations and routine visits.

CA Commercial Hydrogen Dispenser Requirements

Who Enforces?

The State and County Offices of Weights and Measures

State: Establishes specifications, tolerances, user requirements. Establishes method of sale and advertising. Conducts fuel quality sampling and analysis. Takes enforcement action for non-compliant fuel. Conducts type evaluation and certification of approved devices.

Counties: Local weights and measures officials perform field inspections and enforce device compliance requirements.

State and County Officials work together on complaint investigations to ensure continued compliance with established laws and regulations for all commercial weighing and measuring devices.

Method of Sale, Advertising, and Labeling Requirements

- CDFA adopts by reference NIST HB 130 method of sale for hydrogen and codifies legal requirements for retailers.
- All provisions as specified in CCR Title 4, Division 9, Chapter 1, Article 1, Section 3.39 Hydrogen Gas Measuring Devices apply.
- Conformance to requirements is evaluated during initial accuracy assessment of newly installed type-certified dispensers, during annual reinspection, and any routine/complaint testing.

Hydrogen Fuel Quality Sampling and Testing

Chapter 14 of the Business and Professions Code requires the Division of Measurement Standards to establish and enforce quality specifications for transportation fuels in California.

Quality standards for hydrogen fuel were published in 2011 as SAE International's Surface Vehicle Standard J2719 - Hydrogen Fuel Quality for Fuel Cell Vehicles.

SAE J2719 has been adopted by reference by the Department of Food and Agriculture in California Code of Regulations Title 4, Division 9, Chapter 6, Article 8, Section 4181.



Division staff conduct regular routine sampling of hydrogen fuel sold at retail. Additional sampling occurs to address any fuel quality complaints.

Division staff also include particulate sampling to ensure compliance with SAE J-2719 maximum particulate requirements.

Samples are collected in duplicate and evaluated in one of our two hydrogen fuel quality laboratories.

Hydrogen Fuel Quality Sampling and Testing Apparatus



Fuel Quality Sampling Gas Analysis



Fuel Quality Sampling Particulates

Hydrogen Fuel Quality Laboratory



JUNE 3, 2025

Hydrogen Oversight

Ongoing Efforts

Working with particulate sample device manufacturer to develop high-flow sampling device and procedures.

Configuring a test standard for high-flow heavy duty vehicle fueling applications.

Updating fuel sampling SOP to include high-flow dispensers for HD fueling. Current equipment can work for collecting gas samples for analysis.

Developing regulatory language to include an additional user requirement (UR) for dispensing equipment to conform to fueling protocols established by SAE J-2601. Joint effort with CARB to determine implementation requirements



Thank You!

California Department of Food and Agriculture
Division of Measurement Standards
dms@cdfa.ca.gov

Kevin Schnepp, Director
Kevin.schnepp@cdfa.ca.gov

Appendix Slides

The following slide detail the test data acquired during evaluation of each of test methods: Gravimetric, PVT, and Master Meter

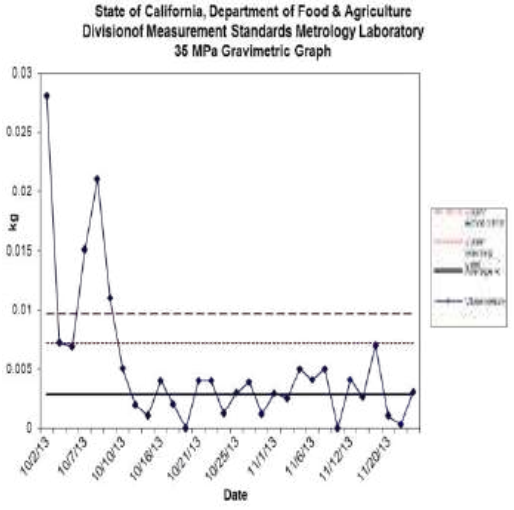
Assessing Control Chart Data

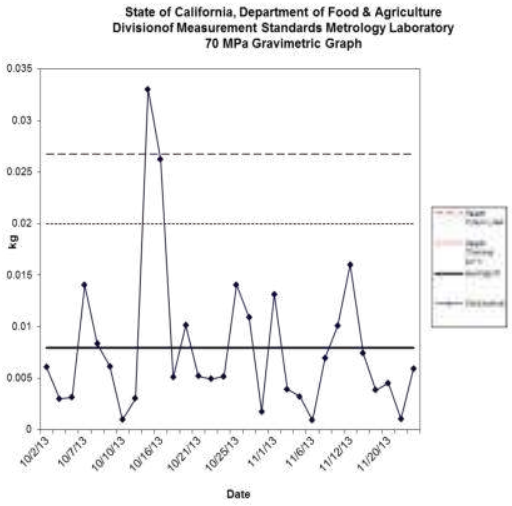
To calculate the expanded uncertainty, the measurement uncertainty was multiplied by a coverage factor, k, based on the degrees of freedom (number of data points, n – 1) to provide a level of confidence of approximately 95%

2kg 35 MPa				
Procedure	**Degrees of Freedom (n-1)**	**Measurement Uncertainty**	**Coverage Factor k**	**Expanded Uncertainty**
Gravimetric	19	2.4 g	2	4.8 g
Volume	29	15.5 g	2	31 g
Master Meter	29	144.4 g	2	288.8 g

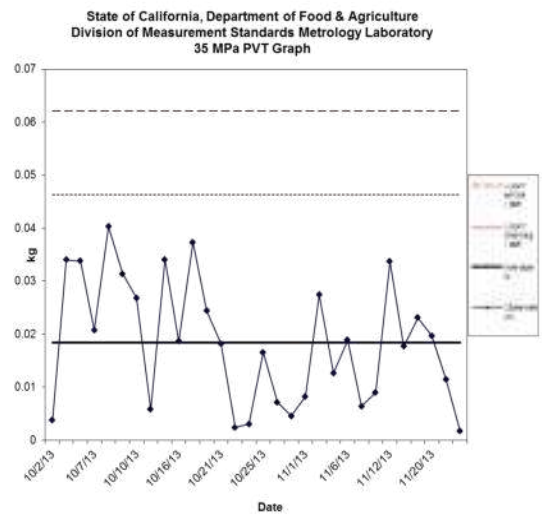
4kg 70 MPa				
Procedure	**Degrees of Freedom (n-1)**	**Measurement Uncertainty**	**Coverage Factor k**	**Expanded Uncertainty**
Gravimetric	29	7.6 g	2	15.2 g
Volume	19	16.8 g	2	33.6 g
Master Meter	29	170.0 g	2	340 g

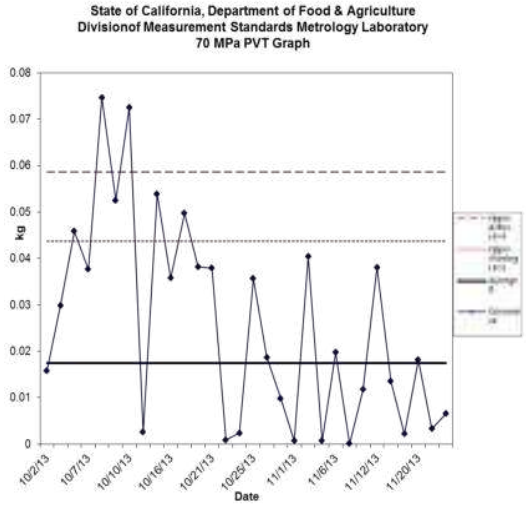
Validation of the Reference Standard Gravimetric Control Charts



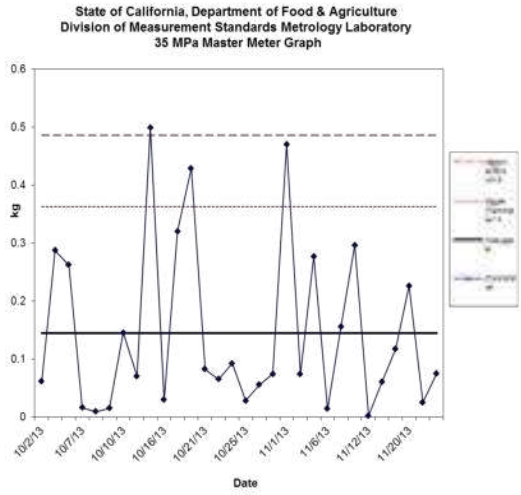


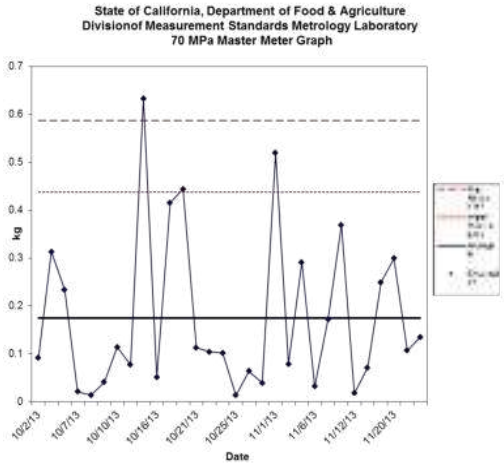
Validation of the Reference Standard PVT Control Charts





Validation of the Reference Standard Master Meter Control Charts





Panel Discussion

Investment and Market Growth Outlook of Global Clean Hydrogen Projects

Moderator



Laurent Antoni
Executive Director, IPHE

Panelists



Hong-Ki Lee
Chair, IEC/TC 105
Vice President, Woosuk University



Klemens Ilse
Deputy Director, Fraunhofer IWMS



Kevin Schnepp
Director, California Department of Food and Agriculture

WORLD HYDROGEN EXPO 2025 6th Conference

Hydrogen Deep Dive III：
Clean Ammonia

WORLD HYDROGEN EXPO 2025 6th Conference

Global Technology and Policy Trends for the Expansion of Clean Ammonia

Global Technology and Policy Trends for the Expansion of Clean Ammonia 1

Global Clean Ammonia Market and Outlook



Alexander Oliver Bower
Global Head of Marketing & Sales,
Gentari Hydrogen Sdn Bhd

Education
1995 – 1999, BA, Business Economics, University of Leicester, United Kingdom
2004 – 2006 MSc Energy, Trade and Finance, Bayes Business School, United Kingdom.
2017 – 2019 Global Executive MBA, INSEAD

Professional Career
1999 – 2001, Finance, Halliburton, Leatherhead, United Kingdom
2001 – 2006, Power Trading, London, United Kingdom
2006 – 2018, Senior Vice President, Head of LNG Trading, Engie, Paris, France
2018 – 2022, Senior Project Director, TotalEnergies, France & Singapore
2022 – 2023, Commercial Director, InterContinental Energy, Singapore
2023 – Present, Global Head, Marketing & Sales, Gentari Hydrogen Sdn Bhd, Singapore

Speech Summary
The speech will begin with a brief introduction to the PETRONAS and Gentari, followed by an overview of Gentari's clean ammonia projects. It will then cover key trends in the global green ammonia market and demand outlook, concluding with key points on future direction.

Company Introduction
Gentari is PETRONAS's clean energy arm, focused on clean hydrogen, renewables, and EV charging

Global Clean Ammonia Market and Outlook

World Hydrogen Expo 2025 - Green Ammonia Session

Alex Bower
Global Head, Marketing & Sales
Gentari Hydrogen Sdn. Bhd.

Friday, 05 December 2025

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PETRONAS

A progressive energy and solutions partner enriching lives for a sustainable future

Open

• [Open]

CORE PORTFOLIO

Exploration & Production

Upstream

Gas & Power

Gas

Chemicals & Products

Retail & Marketing

Downstream

'STEP OUT in 2022'

Clean Energy Solutions

Gentari

A new independent entity focused fully on **clean energy solutions** to capture opportunities in the energy transition space, alongside core portfolio.

Our business

We offer **clean energy solutions** through our **three pillars** to help customers achieve their net zero ambitions – no matter how far along they are in their decarbonisation journey.

Renewable Energy

- To be the leading next-generation Commercial and Industrial (C&I) and utility- scale renewable energy developer, accelerating the adoption of renewable energy

Hydrogen

- To be a large-scale clean hydrogen producer and go-to industry partner in enabling decarbonisation

Green Mobility

- To be Asia Pacific's leading green mobility solutions partner, accelerating every driver's shift to sustainable solutions



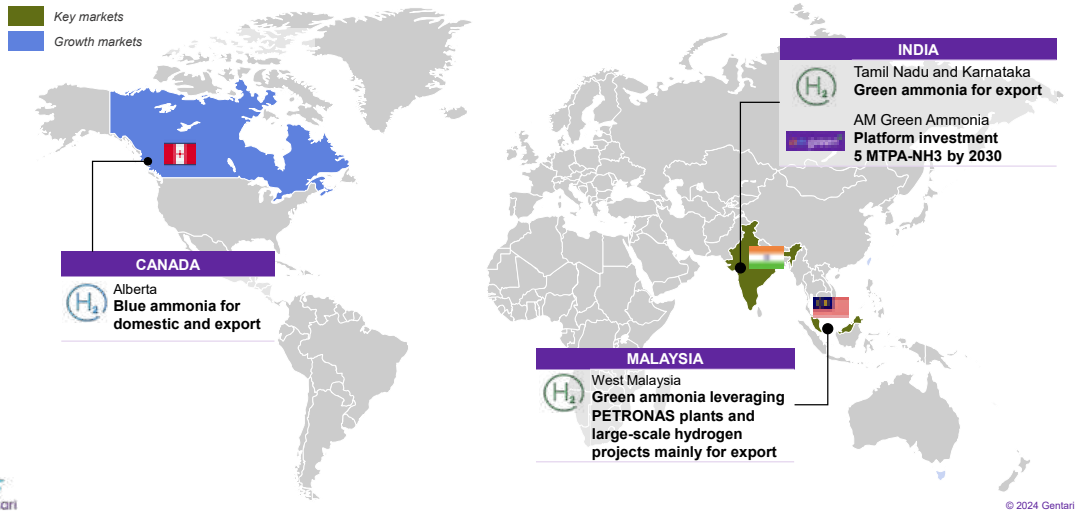
Gentari's Global Low-Carbon Hydrogen/Ammonia Projects

Developing hydrogen and ammonia projects globally, capitalizing on inherent capabilities in project development, molecule production, and sales & trading

Low-carbon hydrogen supply nodes:

Key markets

Growth markets

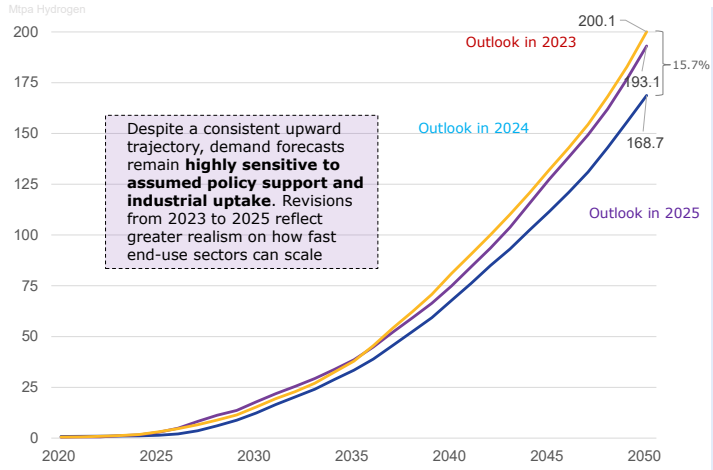


gentari

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Demand: Clean hydrogen demand by 2030 is now projected to be at 12 Mtpa vs last year's forecast of 18 Mtpa

An upward long-term outlook with most of today's demand remains policy-driven as the main enabler, highlighting the need for uptake through cost competitiveness and infrastructure readiness



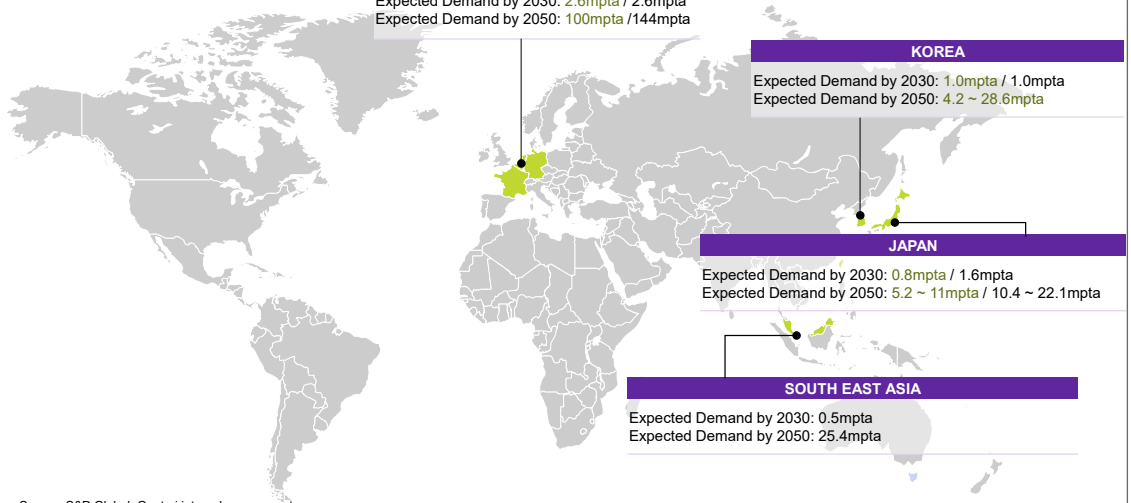
Insights

- **Most of the forecasted demand by 2030 is yet to be supported by binding offtake.** Cumulative demand (2020-Q1 2025) through binding offtake agreements was below 2 Mtpa
- **Inflection point emerges around 2029–2030**, where demand rises to 12 Mtpa, signalling possible sector activation – though this is conditional on policy and buyer readiness
- **Demand-side risks remain underappreciated**, especially if infrastructure readiness, conversion tech. or policy enforcement lag. A demand delay may undermine project bankability and offtake certainty

Source: Wood Mackenzie Lens Hydrogen (May 2025)

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Snapshot of Key Green Ammonia Import Regions (green/blue&green combined, NH3/mpta)

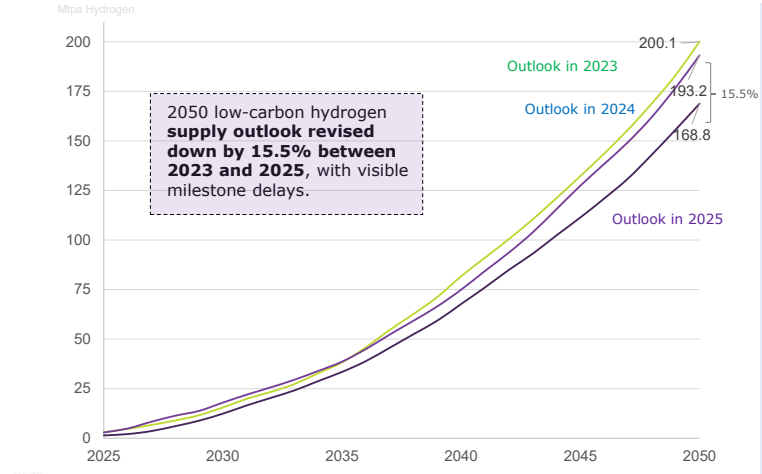


Source: S&P Global, Gentari internal assessment

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Supply: Recent outlook revision signal a two-year shift in supply-side clean hydrogen scale-up

Downward revision of supply forecast was mainly driven by delays in projects due to high costs, market uncertainties in both policies and offtake, and macroeconomic concerns



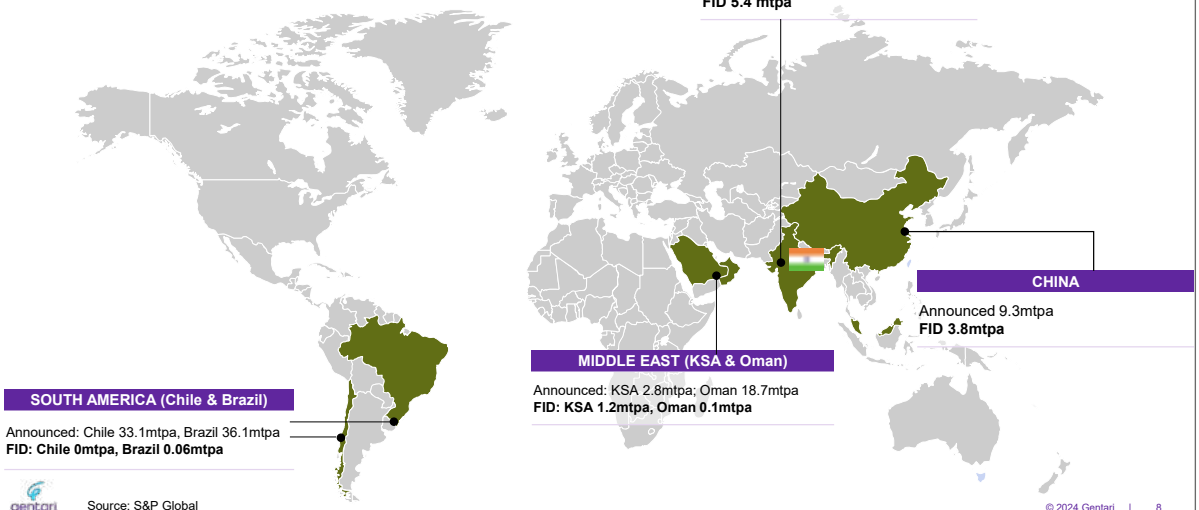
Insights

- The supply forecast for 12 Mtpa has slipped from **2028 to 2029**, and the 169 Mtpa milestone has shifted from **2048 to 2050** — reflecting a **~2-year delay** in key ramp-up points.
- This **structural lag in the projected industry build-out** suggests that early-mover projects may face both first-mover advantages and risks if their internal timelines are not recalibrated accordingly.

Source: Wood Mackenzie Lens Hydrogen

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Snapshot of Key Green Ammonia Export Regions



Source: S&P Global

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Considerations on Green Ammonia Market Outlook

✓Regulatory Measures for Market Formation: Tension with Economic Viability
- Introduction of strong regulations on carbon intensity (e.g., accelerated RFNBO transposition, CBAM, etc)
- Direct carbon regulation and monetization mechanisms (e.g., delayed adoption of IMO carbon tax, ongoing ITMO discussions)

✓Competition with Blue Ammonia: Diverging Responses in Asia and Europe
- Asia: Growing preference for green ammonia in both government policy and market supply, especially in South Korea
- Europe: Adoption of the Low-Carbon Hydrogen Delegated Act, allowing blue ammonia to ease cost pressures and accelerate hydrogen market development

✓Pace of Supply Chain Development: Although dependent on demand growth, some regions show rapid, bold moves
- Subsidies for green ammonia production (e.g., China's NDRC announcing national grants covering 20% of CAPEX for decarbonization projects)
- Maturity of upstream value-chain industries: advancing technologies and economies of scale are enabling cost competitiveness versus fossil fuels

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Global Technology and Policy Trends for the Expansion of Clean Ammonia 2

Ammonia Cracking Technologies: Status and Outlook



SeongHoon Woo
CEO, Amogy

Education
2011-2015, Ph.D., Materials Science and Engineering, MIT, USA
2007-2011, B.S., Materials Science and Engineering, POSTECH, Korea

Professional Career
2021-, CEO/Co-Founder, AMOGY, USA
2018-2020, Research Staff Member, IBM, USA
2015-2018, Staff Scientist, Korea Institute of Science and Technology (KIST), Korea

Research Interest
Ammonia-to-Power

Speech Summary
An overview of ammonia's role as a hydrogen carrier and Amogy's cracking catalyst technology to enable low-cost clean hydrogen. Highlights include catalyst advantages, commercial applications, and key global pilot projects.

Company Introduction
Amogy provides carbon-free ammonia-to-power energy solutions to decarbonize hard-to-abate sectors like power generation, maritime shipping, and heavy industry. Proven in real-world applications, its patented ammonia cracking technology offers a mature, scalable, and highly efficient method for splitting ammonia into hydrogen and nitrogen. The produced hydrogen is directed to integrated fuel cells or hydrogen engines, generating high-performance power with zero carbon emissions.

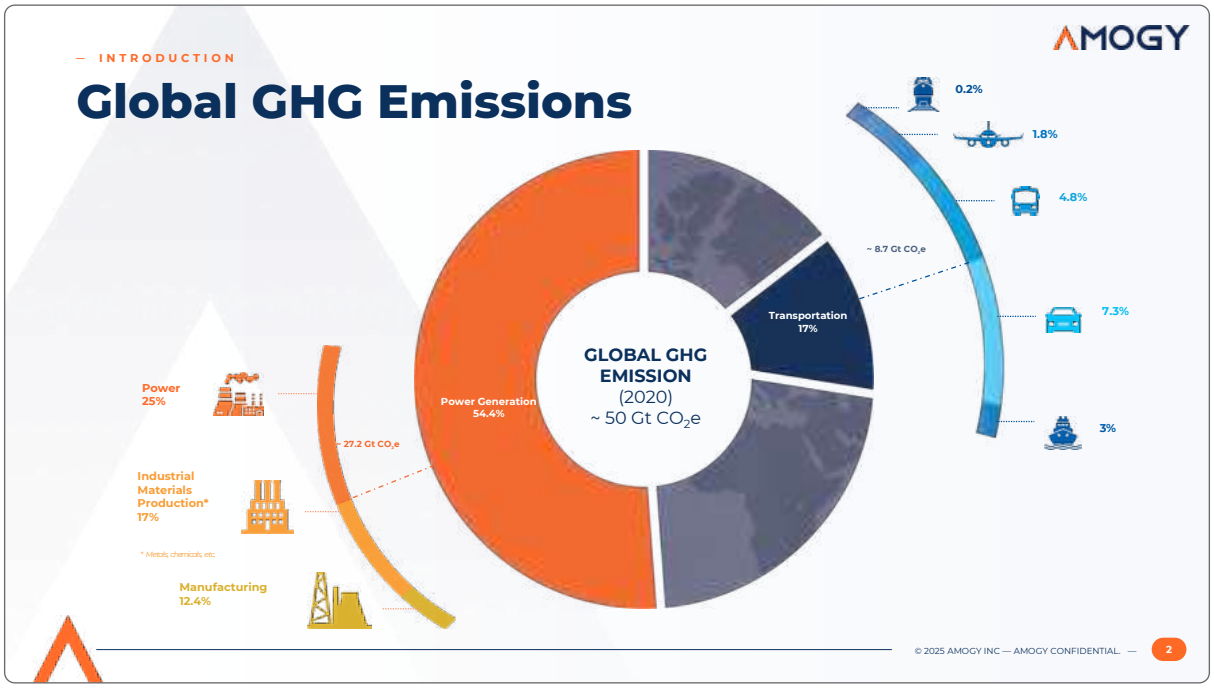
Amogy is headquartered in Brooklyn, New York, with additional locations including Houston, Texas and Seoul, South Korea. Amogy is backed by investors including Amazon, SK Innovation, Aramco, Mitsubishi Corporation, Samsung Heavy Industries, BHP Ventures, AP Ventures and more. For more information, visit www.amogy.co.

AMOGY

Ammonia Cracking Technologies: Status & Outlook

Seonghoon Woo, Co-founder & CEO

December 2025



AMOGY

— HYDROGEN ECONOMY

Hydrogen: the Missing Piece in Energy Transition

Will hydrogen be the best solution to decarbonize heavy industries?

Hydrogen (H_2)
for hard-to-decarbonize industries

- Abundant material
- Technology ready
- Regulation & government support

Trillion $ Market

$830B (2019) $205B (2020) $360B (2020) $240B (2020)

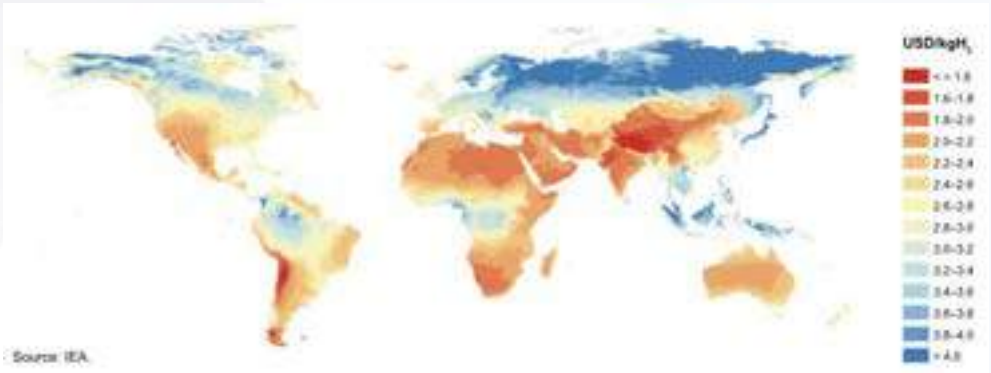


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AMOGY

— HYDROGEN ECONOMY

HYDROGEN PROBLEM
Renewable hydrogen source is far from where it's mostly needed!



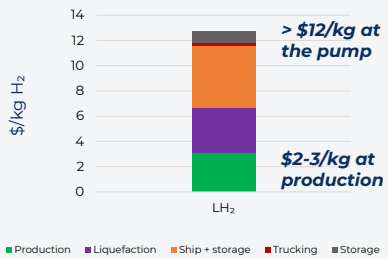
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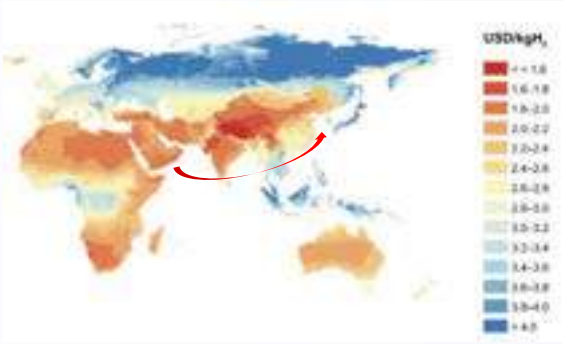
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— HYDROGEN ECONOMY

Hydrogen: High-Cost Transportation/Storage

Cost of H_2
Saudi Arabia to South Korea





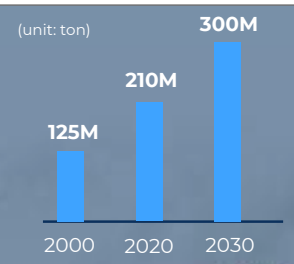
- *Average H_2 cost in California is ~**$15/kg***
- ***4-5x more expensive** than diesel (energy-basis)*

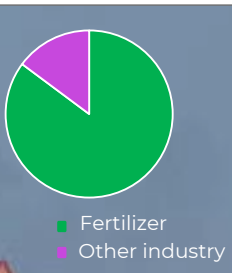
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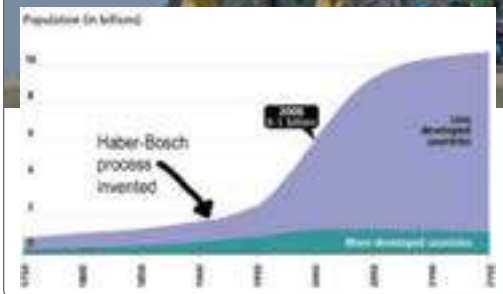
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About Ammonia

AMMONIA – NH_3







The **Haber-Bosch Process** has often been called the most important invention of the 20th century, driving the world's population from 1.6 billion in 1900 to almost 8 billion today.

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— ABOUT AMMONIA

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Ammonia Infrastructure Today



190 MTA of production



200 ports store ammonia



4,000 km+ of pipelines in U.S.



20 MTA of waterborne trading



500 vessels capable of carrying ammonia

- 100+ years of scaled industrial use of ammonia
- No ammonia-to-power technology available to date

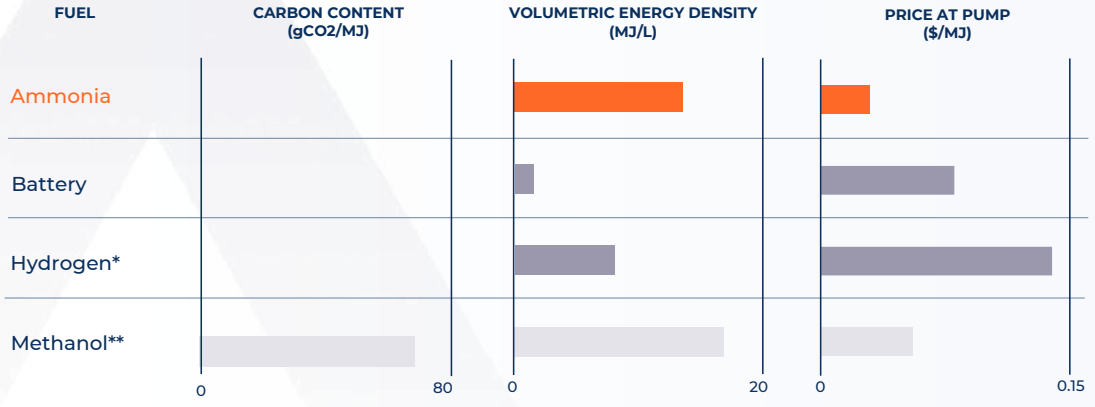
MTA: million metric tons per annum
Sources: DNV, IRENA

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AMOGY

— ABOUT AMMONIA

Ammonia vs. Hydrogen



*Low carbon liquid hydrogen
**Low carbon methanol

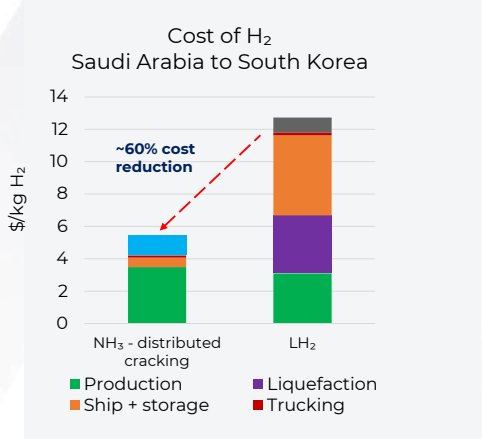
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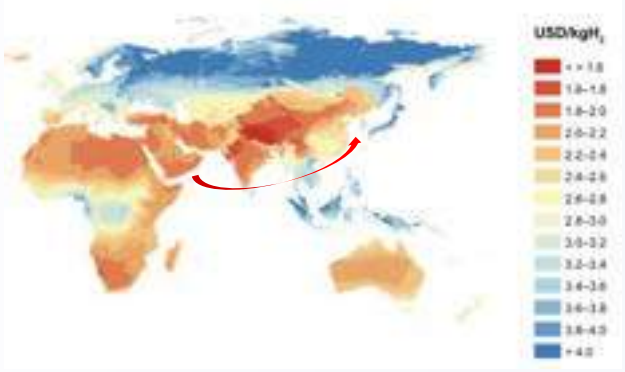
AMOGY

— ABOUT AMMONIA

Ammonia: Most Economic H_2 Carrier

Ammonia is the most mature and lowest-cost H_2 carrier with the lowest infrastructure needs.





Ammonia enables ~60% cost reduction compared to LH_2
- High energy density: 7-8x battery & 3-4x H_2 gas
- Easy to store, deliver, and use

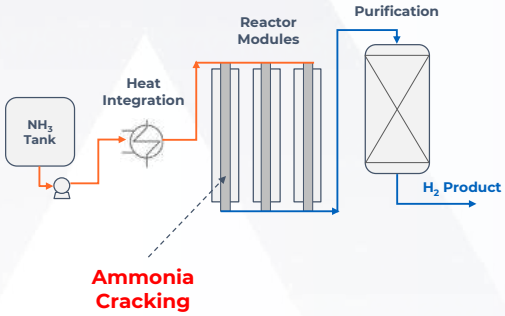
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— ABOUT AMMONIA

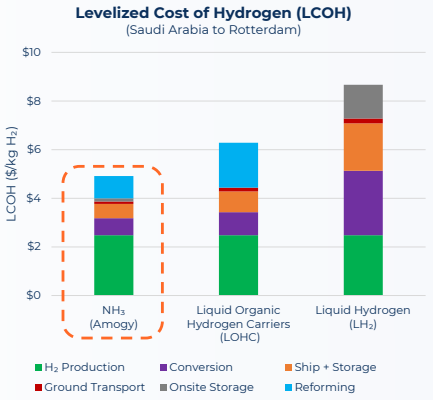
AMOGY

Ammonia as a Hydrogen Carrier

NH_3 Cracking Process Overview



NH_3 vs. Alternative Carriers



H_2 Production: Argus Ammonia Analytics Q2 2024. **Conversion:** IRENA Technology Review of Hydrogen Carriers 2022. **Ship + Storage:** IRENA Technology Review of Hydrogen Carriers 2022, distance of 7,500 km. **Trucking:** Goldman Sachs Carbonomics 2022, distance of 100 km. **Onsite Storage:** IRENA Technology Review of Hydrogen Carriers 2022; LH_2 includes regasification. **Reforming:** IRENA Technology Review of Hydrogen Carriers 2022. NH_3 based on 20-year cracking facility with Amogy's catalyst at 85% utilization and 8% discount rate; LOHC includes dehydrogenation.

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— ABOUT AMMONIA

AMOGY

Large-Scale Cracking Projects

First-mover projects in Europe and East Asia.





Air Liquide ammonia cracker

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— WHY AMOGY

AMOGY

Amogy for Ammonia Cracking

Market Opportunity

Ammonia Cracking Catalyst



Onshore **Offshore**

H_2 Gen. | Turbines | FSRU

Economic Benefits with Amogy



Normalized Reformer Volumes[3]

- Amogy Low Ru
- Competitor Ni

Amogy Low Ruthenium vs. Nickel

- **>90% decrease** in reactor size[1,2] (CAPEX)
- Up to 80% reduction in catalyst tonnage
- Minimized fuel usage (OPEX)

Note: volume comparisons were derived assuming the same feed rate, conversion, and final product quality among all three catalysts; **1)** and **2)** reformer size decreases include both pre-reformer only and full system (pre + main); **3)** Visualization based on full reactor system.

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ABOUT AMOGY

Company Profile

- **100+ Employees**
- **Founded: Nov. 2020**
- **Funding to date: $317M**
- **Headquarters: Brooklyn, NY**
- **Other Locations:** Houston, TX, South Korea

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AMOGY

— ABOUT AMOGY

Company Footprint







Geoje, Korea
SHI Facility – MFG (2026)





Houston, TX
Product Dev, MFG



Brooklyn, NY
Amogy HQ, R&D Lab

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Our Investors



- **Funding raised to date: $317M**
- Seed: $3M | Mar 2021
- Series A: $20M | Nov 2021
- Bridge (uncapped note): $46M | Jun 2022
- Series B: $150M | Mar 2023
- Bridge (convertible note): $56M | Dec 2024
- Series B-2: $42M | Oct 2025

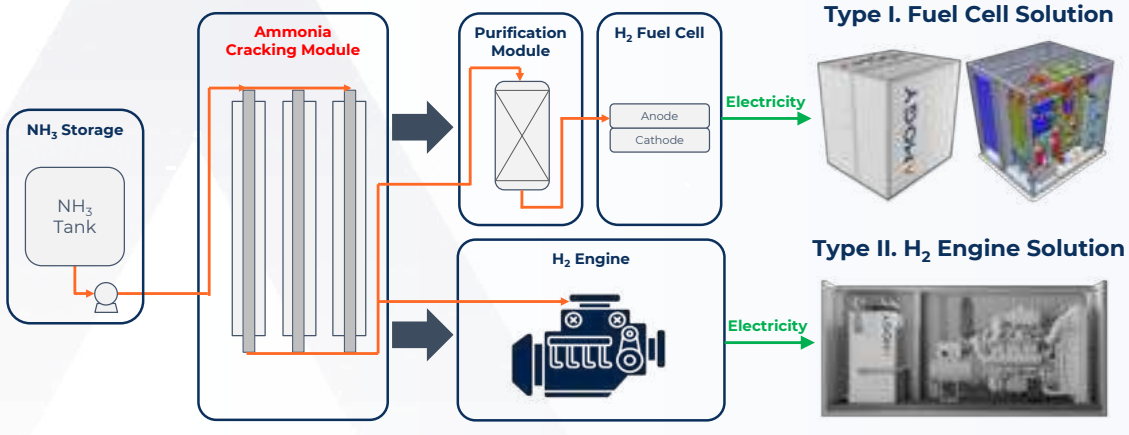
SK · Climate Pledge Fund · amazon · TEMASEK · aramco · KDB Bank · Samsung Heavy Industries · Mitsubishi Heavy Industries · Mitsubishi Corporation · MOL 商船三井 · APVentures · DC Data Collective · GS · Korea Zinc · Hanwha · Bon Angels · Marunouchi Innovation Partners · BHP · YANMAR · ZEON · Pathway Investment · KIBO INVEST · Quantum · SV Investment · Pacific Capital · Seoul IP · KARPOWERSHIP · Collab Fund · Newlab

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AMOGY

— ABOUT AMOGY

Amogy's Technology



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Ammonia Powered Tugboat

World's first carbon-free, ammonia-powered vessel:

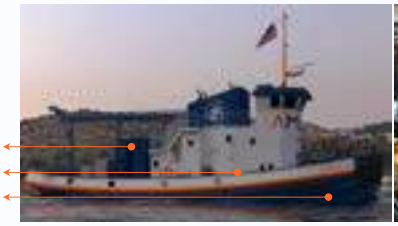
- Stored energy: >5 MWh_e
- Vetted design from regulatory bodies to ensure full safety compliance
- Demo date: September 2024

Watch Demo



Partners:

DNV SEAM





FC Hybrid
Reactor
NH_3 Tank

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AMOGY

— OUR TECHNOLOGY

Amogy Milestones


Drone
2021


Tractor
2022


Class 8 Truck
2023


Tugboat
2024


Houston Facility
2025

2026+

Ammonia-to-power commercial deployments

Power Generation

Maritime

Hydrogen Carrier

$3M | Seed (Feb. '21)
$20M | Series A (Oct. '21)
$46M | Bridge (Jun. '22)
$150M | Series B (Mar. '23)
$56M | Bridge (Dec. '24)
$42M | Series B-2 (Oct. '25)

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— OUR TECHNOLOGY

AMOGY

Markets & Products

Ammonia-to-Power Solutions

Fuel Cell (P1)





Maritime Shipping

Engine (P2)





Distributed Power

Catalyst (P3)





Industrial Cracking

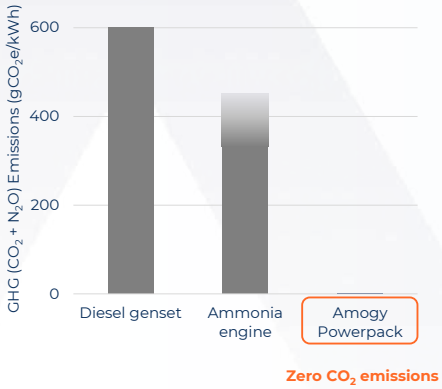
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— OUR TECHNOLOGY

AMOGY

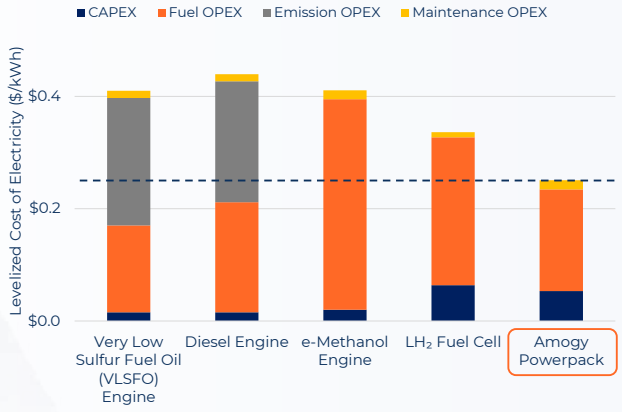
The Cheapest Zero-Carbon Solution

Complete CO_2 reduction



Zero CO_2 emissions

Cheapest carbon-free solution



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CO_2: Carbon dioxide, N_2O: Nitrous oxide. Air pollutants consist of NO_x: Nitrogen oxide. LCOE: levelized cost of electricity. Assumptions: NO_x and GHG emissions: NH_3 engine data from academic sources assuming 40%-70% ammonia as fuel. Diesel generator data taken from auxiliary genset for an offshore vessel. LCOE comparison: maritime feeder vessel application of 3.5 MW, fuel costs sourced from Argus Consulting and IRENA, Emission OPEX includes EU ETS and FuelEU Maritime penalties in 2030.

AMOGY

— OUR APPLICATIONS

Applications

Maritime Power



Samsung Heavy Industries Is Advancing Ships Powered By Ammonia

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Stationary Power



GS E&C, Amogy, and HD Hyundai Infracore Partner with South Korean City Pohang-si to Advance Ammonia-Based Distributed Clean Power Generation

GS · HD HYUNDAI INFRACORE · pohang

Cracking Catalyst



Amogy Accelerates Commercialization of Ammonia Cracking Catalyst in Partnership with JGC

JGC · NEDO

Success Through Partnerships

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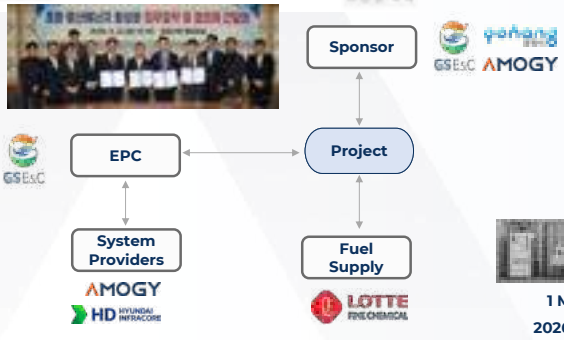
— FOAK PROJECTS

Distributed Power in Pohang

GS건설이 포항에 짓는 특별한 발전소…탄소는 '0', 경쟁력은 '↗'

포항시, 분산에너지 활성화 협약…"무탄소 에너지 공급"





Project Overview

- **Amogy's 1st stationary power deployment under Korea's DEA**
- **Scope:** 1 MW pilot in late 2026-2027. SPC with GS is being established to own the project
- **Path to scale:** scaling to 40 MW in 2028+



1 MW
2026–27



10-40 MW
2028



FOAK: first-of-a-kind

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– FOAK PROJECTS

JGC/NEDO Project in Japan

'SK이노·고려아연 투자' 아모지, 日 JGC와 암모니아 분해 기술 상용화



JGC NEDO

Sponsor

AMOGY Catalyst Provider

Project

idemitsu Demo Site

Technology Provider

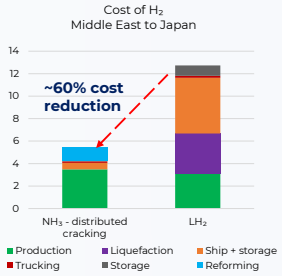
Kubota

TAIYO NIPPON SANSO

Project Overview

- **Amogy catalyst confirmed for Japanese cracker pilot**
- **Scope:** Amogy to provide catalyst for pre-reformer of NEDO-funded demonstration project (1 TPD hydrogen)
- **Path to scale:** Future deployment of commercial-scale plants producing hundreds of TPD of hydrogen





FOAK: first-of-a-kind

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Ammonia Market Outlook

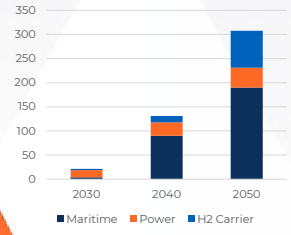
— GLOBAL AMMONIA MARKET

AMOGY

Growing Clean Ammonia Demand

Ammonia Market Growth to 2050E (MTA)





Agricultural/Industrial

- ✓ Continued growing demand
- ✓ Strong demand by industrial producers and "big food" to decarbonize and meet sustainability goals

Shipping Fuel

- ✓ The scalable clean fuel solution
- ✓ Regulations driving fleet conversion and orderbook commitments
- ✓ Insufficient current decarbonization toolbox (e.g. scrubbers) to meet GHG reduction targets

Power Generation / H_2 Carrier

- ✓ Decarbonizing energy source for countries with poor renewable sources
- ✓ Co-firing for coal plants or CCGT power generation
- ✓ Ammonia as a hydrogen carrier

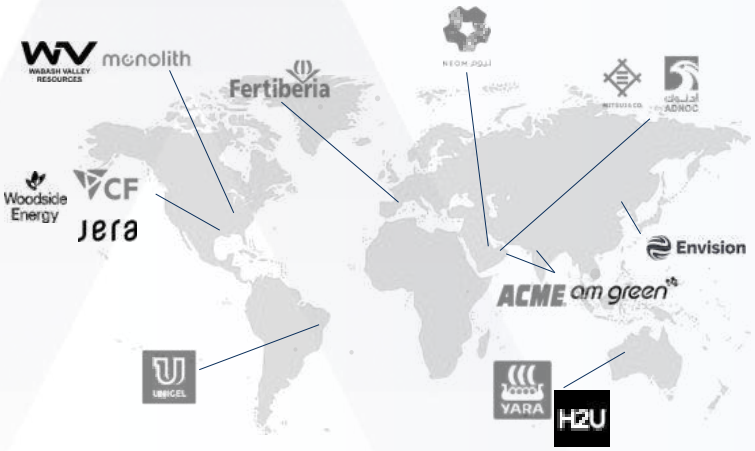
Note: MTA: Million Ton Per Annum
Sources : IRENA Ammonia Innovation Outlook 2022, Argus Ammonia Analytics Long-Term Ammonia Outlook 2023, Yara Clean Ammonia Capital Markets Day 2022.

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— GLOBAL AMMONIA MARKET

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Clean Ammonia Supply is Accelerating



- **300+ MTA** new projects announced
- **8 MTA** of firm projects; **40 MTA** of maturing projects
- **14** new ammonia terminals in Asia

90% of hydrogen export projects will produce ammonia.

Figures represent active project locations as of August 2025 based on data from Ammonia Energy Association. **Firm** refers to projects with FID or under construction; **Mature** refers to projects which meet 5 or more out of the 9 AEA evaluation criteria. **14** terminals with total storage of 1 MT.

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— GLOBAL AMMONIA MARKET

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Zoom In: China & India

Rapid Supply Infrastructure Buildout

- **40+ MTA** projects announced
- **5+ MTA** reached FID (40% of global total)
- Entirely green ammonia
- Projects co-located with solar PV
- Inner Mongolia (China) and Gujarat (India)

Commercial Detail

- Pricing of **$500-600/t from China** and **$600-700/t from India**
  - **~50% cost reduction** vs N. America
- Available for exports for power gen in East Asia



Source: Ammonia Energy Association. Figures represent active project locations as of August 2025.

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— GLOBAL AMMONIA MARKET

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Demand Drivers of Clean Ammonia

Governing Body	National Policy
	CHPS – subsidized 15 yr contracts for power gen from clean NH_3/H_2 (7% of all power by 2035) DEA – incentivizes distributed power <40 MW. Path for Korean companies to become utilities
	Roadmap for ammonia as a fuel: 2030 (3 MTA); 2050 (30 MTA); Power sector decarbonization target of 60% by 2035.
	National H_2 strategy; 50% of power from hydrogen / ammonia by 2050; Green Data Centre Roadmap (300 MW of capacity for green power). Increased focus in Q4 '25
	Net-zero electricity by 2050; 12% of power gen from hydrogen / ammonia; Renewable Portfolio Standard for large power users[1]
	CBAM: requires exports into the EU to pay a GHG tax on embedded emissions; RED III: 42% of industrial energy in EU must be renewable
	IMO GHG Framework: introduces emissions limits for ocean-going vessels and institutes a tax on GHG emissions for non-compliance

CHPS – Clean Hydrogen Production Standard, which subsidizes ammonia for power generation (2% of South Korean power in 2030, 7% in 2036). **DEA –** Distributed Energy Act, promotes the use of distributed power generation for grid stability. 1 – requires a minimum of 10% of power to come from renewable sources. **CBAM:** Carbon border adjustment mechanism; RED III: renewable energy directive

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— GLOBAL AMMONIA MARKET

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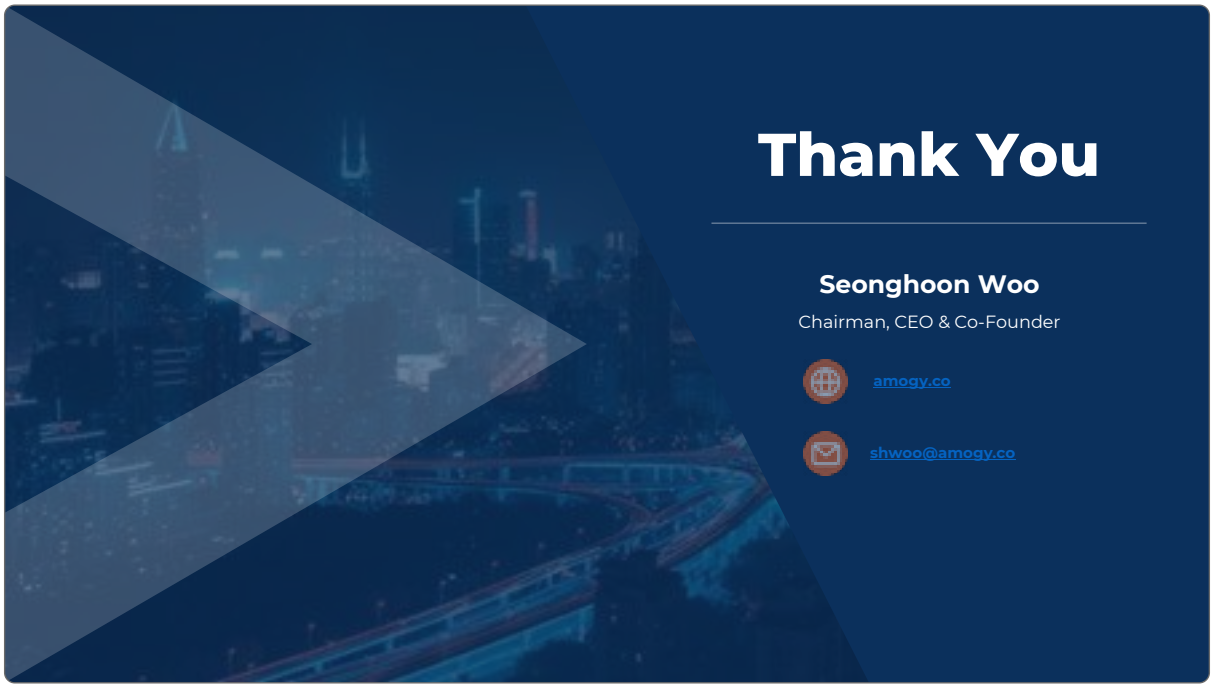
Ammonia Demand Drivers

Strong regulatory demand drivers can enable exponential growth.

Market	Customers	End Use	Regulatory Drivers	Clean NH_3 Type	Timing / Profile
Asian Power	• Power asset operators • Data centers • Behind-the-meter	• Coal replacement • Power gen decarb • FTO – grid access issues	• Japan CfD • Korea CHPS, DEA • Voluntary corporate	**Green** & **Blue**	2026 2030 2035 2050
Shipping Fuel	• Vessel owners & operators • Shipyards	• Shipping fuel decarb	• IMO • FuelEU Maritime • Voluntary corporate	**Green** & **Blue**	2026 2030 2035 2050
Fertilizer	• Fertilizer producers	• Agriculture focused on low-carbon	• RED III for industry • CBAM • Voluntary corp.	**Blue** (EU), **Green** (Asia)	2026 2030 2035 2050
EU Cracking	• NH_3 crackers and refineries	• Refinery decarb to avoid penalties • Heat & power	• RED III for transport • CBAM • Voluntary corp.	**Green**	2026 2030 2035 2050

Source: Yara Clean Ammonia.

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Global Technology and Policy Trends for the Expansion of Clean Ammonia 3

Development of Ammonia Fuel System for Marine Applications



HoKi Lee
Vice President, Samsung Heavy Industries

Education

Ph. D. Mechanical Engineering, Washington State University, USA (2008)
M. Sc. Mechanical Engineering, Washington State University, USA (2005)
B. Sc. Mechanical Engineering, Washington State University, USA (2003)

Professional Career

2022 - Head of Green Energy Technology Center, Samsung Heavy Industries
2009 - 2022 Principal Research Engineer, Samsung Heavy Industries
2008 - 2009 Instructor, Washington State University

Research Interest

LNG handling and fuel supply systems
Reducing carbon emissions from ships
Alternative fuel technologies
Nuclear energy utilization
Greenhouse gas reduction technologies.

Speech Summary

IMO's GHG regulations spotlight ammonia as a vital green marine fuel. Samsung Heavy Industries developed an ammonia fuel system for propulsion ships, showcasing its design, function, and safety approach. This system significantly mitigates environmental impact, facilitating its widespread adoption in the shipping industry.

Company Introduction

Since its foundation in 1974, Samsung Heavy Industries has successfully delivered ships and offshore facilities to global shipping firms and oil companies. Samsung Heavy Industries has attained industry leading competitiveness by striving to realize advanced technology, production efficiency, and high value-added shipbuilding. Samsung Heavy Industries continues to bolster its position by pioneering new markets.

SAMSUNG HEAVY INDUSTRIES

Development of Ammonia Fuel System for Marine Applications

HOKI LEE (Vice President)

Green Energy Technology Center / Samsung Heavy Industries

December 2025

SAMSUNG HEAVY INDUSTRIES

CONTENTS



1 | Overview of Ammonia Technology for Marine Applications

2 | Ammonia Fuel System
- Key Technologies of Ammonia Fuel System
- Ammonia Pilot Test Facility

3 | Ammonia-based Hydrogen Utilization Technology

4 | Concluding Remarks

SAMSUNG HEAVY INDUSTRIES



1 | Overview of Ammonia Tech. for Marine Applications

Environmental Regulations for Shipping

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Continuous Strengthening of Environmental Regulations for Net-zero in International Shipping

- **[IMO] Revised GHG strategy : Net-zero GHG emissions by 2050**
  * Greenhouse Gas
- **[IMO] EEDI/EEXI and CII regulations → Net-zero Framework (Pricing mechanism for GHG emissions)**
  * EEDI: Energy Efficiency Design Index, EEXI : Energy Efficiency eXisting ship Index, CII : Carbon Intensity Indicator
- **[EU] FuelEU Maritime regulation and EU-ETS (Emission Trading System)**





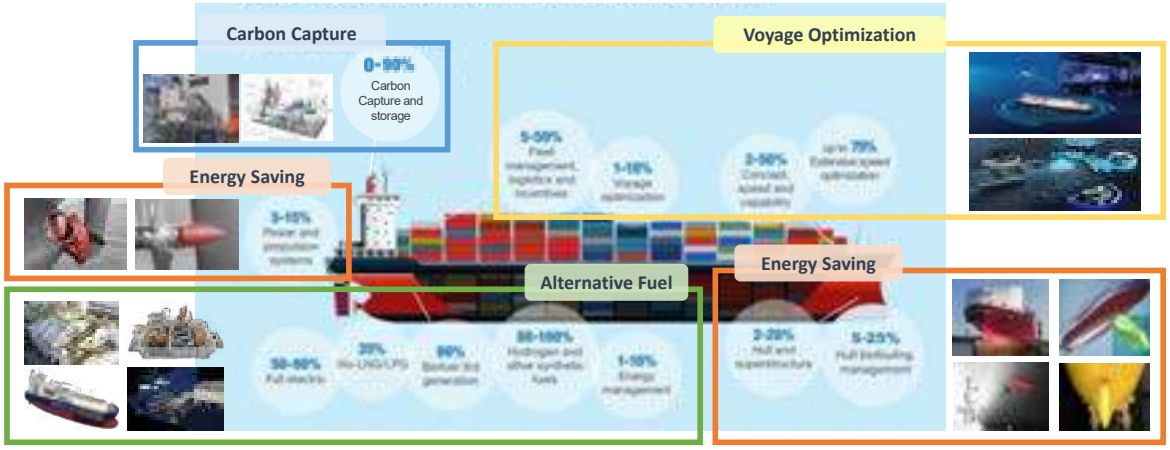
* Source: IMO, DNV, LR

Technical Solutions for GHG Reduction

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A Wide Variety of Solutions and their GHG Reduction Potential

- Achieving net-zero through transition to eco-friendly alternative fuels



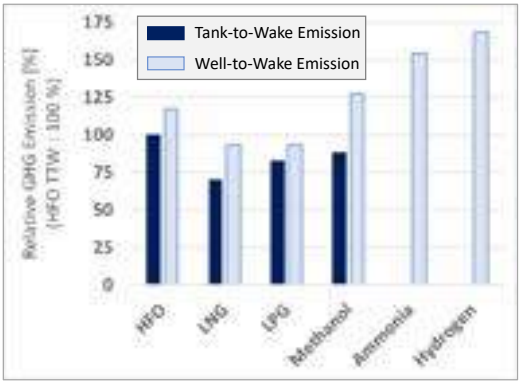
* Source: IMO

Outlook for Alternative Marine Fuels

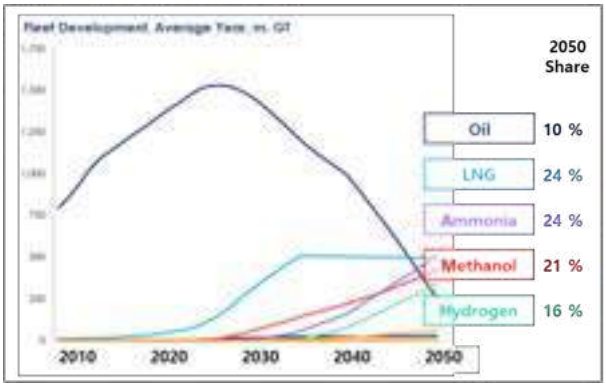
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Transition to Zero-carbon Fuels Driven by Technology and Market Conditions

- [Short Term] Low-carbon fuels (LNG, LPG) & carbon capture technology
- [Long Term] Zero-carbon fuels (ammonia, hydrogen) & carbon-neutral fuels (e-fuels)



GHG Emission of Alternative Marine Fuels



Outlook of Marine Fuels

* Source : Clarksons Research ('23)

Ammonia for Marine Applications

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Ammonia : Representative Zero-carbon Solution Available before Commercialization of Hydrogen

- Reduction of CO2 emission by 90 % compared to heavy fuel oil
- Growing demand for ammonia as power generation and marine fuels and hydrogen carrier
- Needs for safety system and emission management technology due to toxicity

SHI's Technology Development for Entire Ammonia Value Chain



Clean H2/NH3 Production | Transport | Storage & Supply | NH3/H2 Utilization



Blue/Green NH3 FPSO

* Floating Production, Storage and Offloading



VLAC & NH3 FSRU

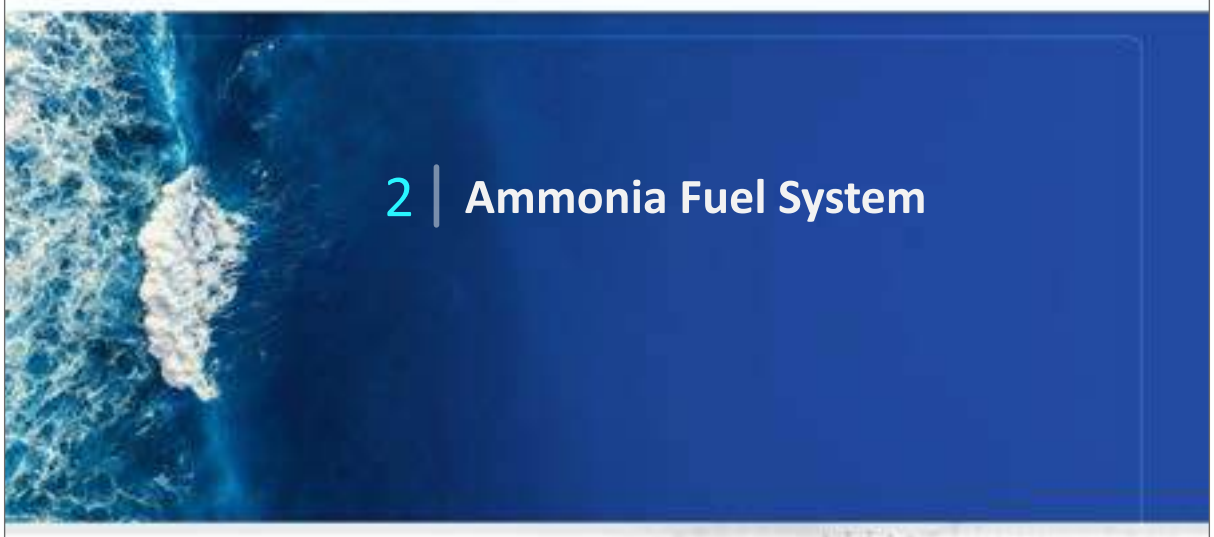
* Very Large Ammonia Carrier * Floating Storage and Regasification Unit



NH3 Fueled Ship

- 7/21 -

SAMSUNG HEAVY INDUSTRIES



2 | Ammonia Fuel System

- 8/21 -

Development Roadmap

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Advancement and Commercialization of Key Technologies for Ammonia Fueled Ship

- R&D in response to ammonia DF engine development status and market demand
  * Dual Fuel
- Development of key technologies → Commercialization of VLAC → Commercialization of ammonia fueled ships
  * Very Large Ammonia Carrier

Development Roadmap for Ammonia Fuel System

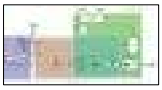
'23	'24	'25	'26
System Design	**Pilot Test**	**System Optimization**	**Commercialization**
• Process development • Basic & detail design	• Facility construction • System verification	• Design for commercialization • System improvement	• VLAC • Ammonia fueled ship







LFSS for ME-LGIA



LFSS for XDF-A



Key Technologies of Ammonia Fuel System

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Core Systems and Specifications for A-max COT

Ammonia Fuel Tank



- Material : Low temp. carbon steel
- Capacity : 3500 m³
- Design : 4 barg, -50 °C
- BOR : 0.05 %/day
  * Boil-off Rate

Fuel Supply System



- Fuel supply to engines
- Capacity : 4.5 ton/h
- Pressure & temp. control
- Fuel circulation/recovery

Re-liquefaction System

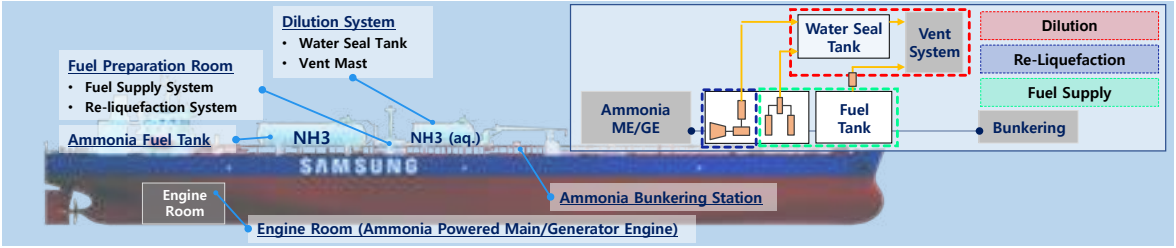


- Re-liquefaction of BOG
  * Boil-off Gas
- Capacity : 150 kg/h
- Prevention of stress corrosion cracking

Dilution System



- Absorption of ammonia into water
- Treatment of effluent
- Reduction of ammonia concentration



Key Technologies of Ammonia Fuel System

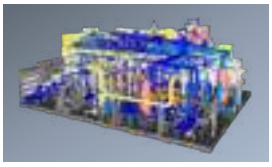
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Fuel Supply System - Basic and Detail Design for Various Ship Specifications

- Development of design package (PFD, H&MB, P&ID, sizing, etc.) for A-max, VLCC, Containership and VLAC
  * Process Flow Diagram, Heat and Material Balance, Piping and Instrumentation Diagram * Very Large Crude Oil Carrier * Very Large Ammonia Carrier
- Design improvement by pilot tests and third party verification

Ammonia Treatment System

- Development of treatment system for safe handling and less emission of ammonia
- Pilot tests and performance verification of treatment systems based on dilution, adsorption and combustion methods



[Fuel Supply System for A-max]



[Fuel Supply System for VLAC]

Fuel Supply System



[Dilution System]



[Adsorption Recovery System]



[Combustion System]

Ammonia Treatment System

Key Technologies of Ammonia Fuel System

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Control System - 'Push and Go' System for Single-Command Operation

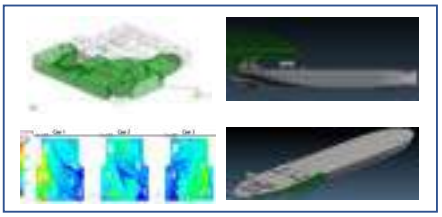
- Automated control system considering optimal operating conditions
- Single-command start-up and automatic LFSS control responding to engine signals
  * Low-flashpoint Fuel Supply System

Safety Study

- CFD simulation on dispersion and ventilation for risk assessment (fuel preparation room, vent mast, bunker station)
  * Computational Fluid Dynamics
- HAZID/HAZOP and design optimization of ventilation system, vent mast and gas detection equipment
  * Hazard Identification / Hazard and Operability



'Push and Go' Control System



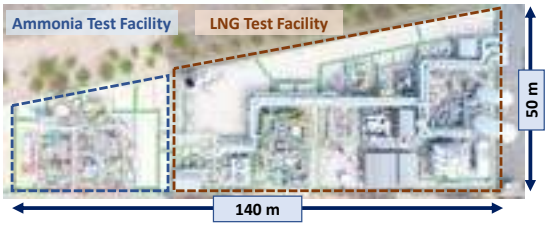
Safety Study

Ammonia Pilot Test Facility - Introduction

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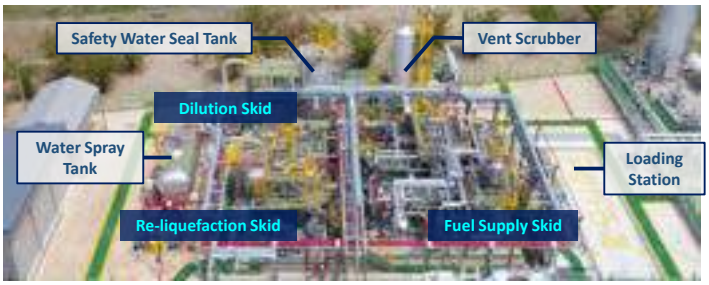
Purpose of Test Facility

- Verification of system performance and safety
- Optimization of system design and control logic
- Expansion into Green Energy Test Hub
  (LNG + ammonia + hydrogen)



Facility Overview

- Location : SHI Geoje shipyard
- Area : 1,260 m^3
- Main system
  - Fuel supply skid
  - Re-liquefaction skid
  - Dilution skid



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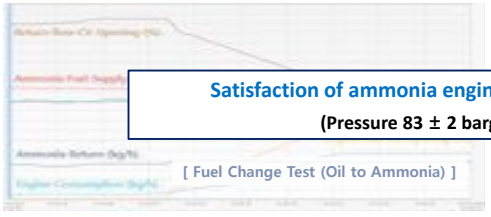
Ammonia Pilot Test Facility - Test Results

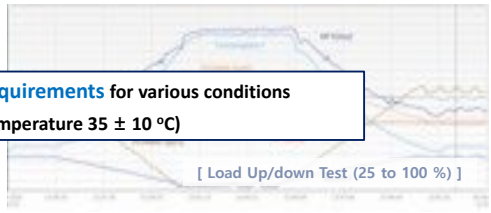
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Verification of System Performance → Certifications from Classification Societies (LR, KR)

* Statement of Fact (SoF)
* Lloyd's Register, Korean Register

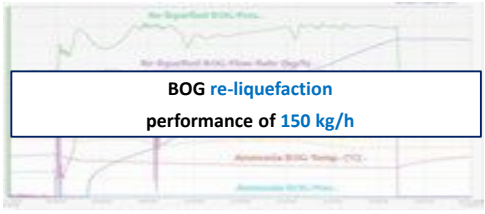
- Fuel supply system


[Fuel Change Test (Oil to Ammonia)]


[Load Up/down Test (25 to 100 %)]

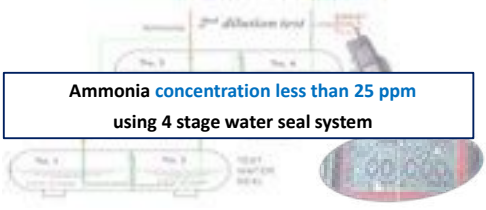
Satisfaction of ammonia engine requirements for various conditions
(Pressure 83 ± 2 barg, Temperature 35 ± 10 °C)

- Re-liquefaction system



BOG re-liquefaction
performance of 150 kg/h

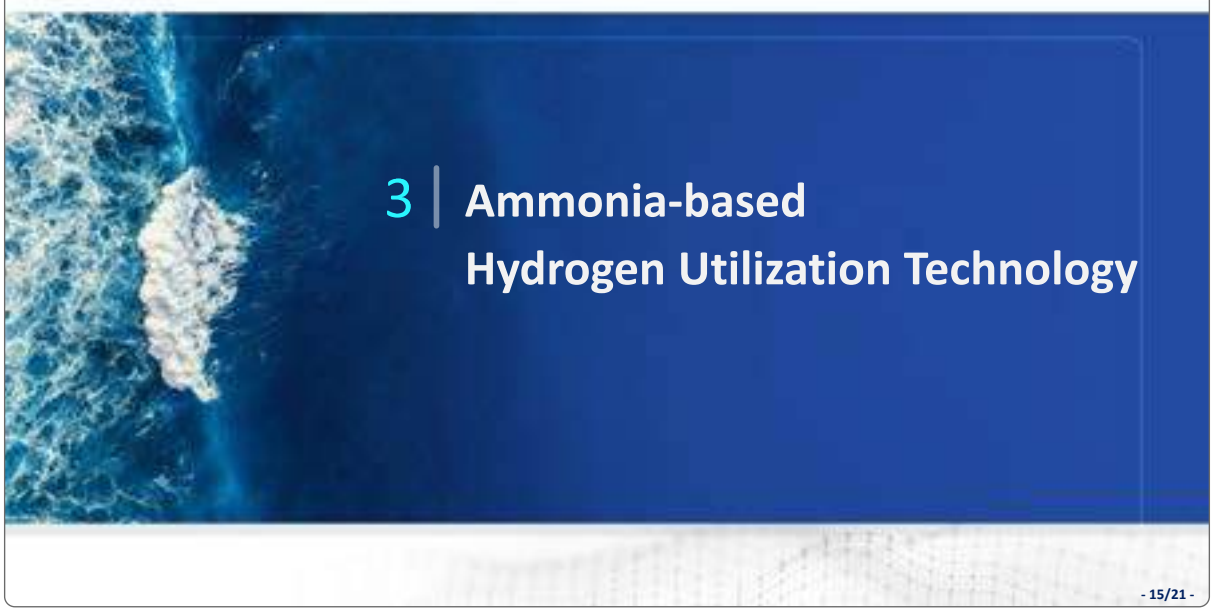
- Dilution system



Ammonia concentration less than 25 ppm
using 4 stage water seal system

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3 | Ammonia-based Hydrogen Utilization Technology

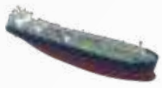
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Technical Trends of Ammonia Carrier

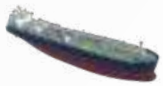
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Future of Ammonia Carrier : More cargo, Net-zero Emission, and Simple System

Cargo Capacity



- LPG/Ammonia Partial Filling for 84k VLGC



- LPG/Ammonia Full Filling for for 88k VLAC



- Ammonia Full Filling for 93k + Size

More Ammonia Cargo & Bigger Size

Fuel & Propulsion Trends



NH3 Fuel Cell
Net-zero Emission



NH3 Burning with Engine
Near-zero Emission

LPG Burning with Engine
Heavy Emission

Oil Burning with Engine
Fossil Fuel → Heavy Emission

Target for Net-zero System

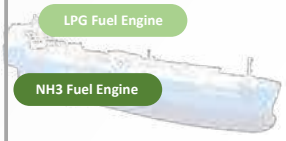
System Complexity

Complex System / Heavy Maintenance — Simple System / Low Maintenance

Past

HFO Fuel Engine

LPG Fuel Engine



NH3 Fuel Engine

Future

NH3 Fuel Cell

Complex & Heavy Maintenance
→ Crew Shortage

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Fuel Cell Powered Ammonia Carrier

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Key Technologies of Fuel Cell Powered VLAC

Optimum Arrangement for F/C System

- Totally changed for fuel cell system
  - FC room / Motor room / SWBD room
  - Other machinery areas



Fuel Cell & Elec. Propulsion System

- AMOGY powerpack system
- Redundancy concept for single fuel
- Dual electric motor with reduction gear





Fuel Gas Supply System

- NH3 fuel gas supply system
- Waste heat utilization
- Segregated fuel gas supply room



Ammonia Cargo Tank

- Type A cargo tank for ammonia cargo



Electrical Essential System

- AMP & BRU and battery system for operation mode
- Optimized elec. grid system (DC to DC / DC to AC mixing)



* AMP : Alternative Maritime Power
* BRU : Breaking Resistor Units

Technology Development for Ammonia Powerpack

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Strategic Collaboration with AMOGY

- AMOGY : U.S. company developing compact and high-efficiency ammonia cracking technology
- Collaboration to develop next generation ammonia-based power generation system for ships



Detailed Development Plans

FAT Facility

- Expansion of pilot test facility for FAT
- Conducting FAT for ammonia-based power generation system

* FAT : Factory Acceptance Test



Manufacturing

- Cooperation on mass production and optimization of AMOGY cracking module
- Management of equipment, process and supply chain



Next Generation Product

- System scale-up for large ships and onshore power generation
- Optimization of reformer container and BOP



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4 | Concluding Remarks

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SHI Vision & Future Plans

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A Leading Provider of Green Energy Solutions for a Net-zero Future

- Timely preparation of ammonia fuel technologies, from engines to fuel cells
- Driving eco-friendly shipbuilding and offshore industries with technological innovation and strategic cooperation



* WHRS : Waste Heat Recovery System
* ORC : Organic Rankine Cycle
* OCCS : Onboard Carbon Capture and Storage System

- 20/21 -


Innovative R&D for the Sustainable Voyage to a Net-zero Future
AMMONIA
SAMSUNG
Thank You

Global Technology and Policy Trends for the Expansion of Clean Ammonia 4

Progress and Outlook of the Green Ammonia Project by Hive Energy



Colin Loubser
CEO, Hive Energy Africa

Colin has more than 25 years of experience in researching, founding and setting up new business enterprises in deregulating, emerging and nascent industries. These include Renewable Energy (Wind & Solar PV), Telecommunications, Payment Systems, Carbon Credits, Biocarbon production, Green Ammonia and Green Hydrogen

2015 – Current: Hive Energy: Africa Initiate, establish and lead the Hive Hydrogen Green Ammonia Project in Coega and new Renewable Energy Projects in Mozambique and South Africa.

PROGRESS AND OUTLOOK OF THE COEGA GREEN AMMONIA PROJECT BY HIVE HYDROGEN

HIVE HYDROGEN
WORLD HYDROGEN EXPO 2025



Artist's impression - to scale - impression of the Coega Green Ammonia Plant

COEGA GREEN AMMONIA PROJECT - HIGHLIGHTS

HIVE

~$5.3bn
Project Capex

~1 million tons
Annual Green Ammonia Produced/year

3,309 MW
Renewable Energy Capacity

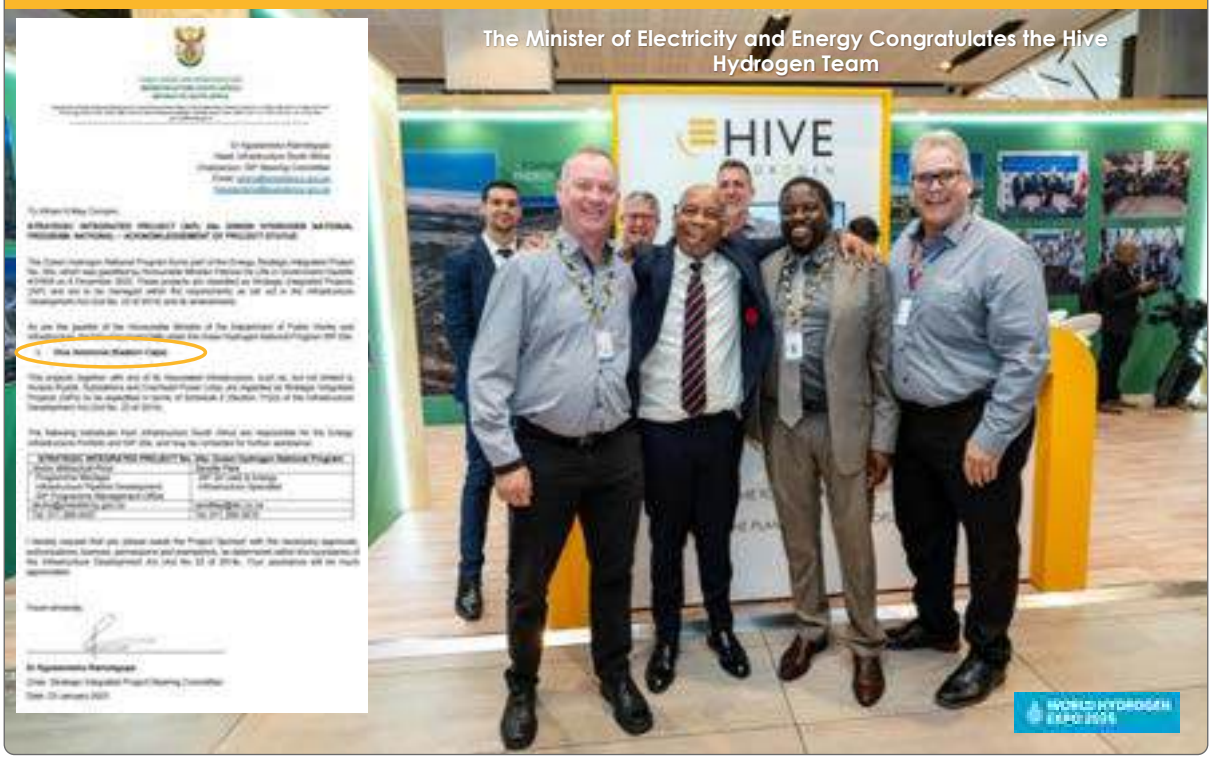
Q4 2029
COD





- **World leading**, fit for purpose, modern embedded infrastructure built in 2009.
- Port with **18m Draft**, 3.4km Breakwater for year round operation of 250m Berth - Suitable for Very Large Ammonia Carriers.
- Available **Skilled Labour, Electrical Grid built, modern road and rail fully operational**

STRATEGIC INTEGRATED PROJECT – DECEMBER 2022



JAPAN - MEMORANDUM OF COOPERATION DECEMBER 2023



OFFICIALLY S.AFRICA'S LIGHTHOUSE GREEN HYDROGEN PROJECT



12 June 2025: The Honourable Cyril Ramaphosa President of South Africa, congratulating the Chairman of Hive Hydrogen - Thulani Gcabashe and the Head of New Ventures for Climate Fund Managers - Sebastiaan Surie on the signing of the final development stage $20m / R360m Development Funding Agreement for Hive Hydrogen to take the Coega Green Ammonia project to Final Investment Decision.

COEGA GREEN AMMONIA IS EU FLAGSHIP PROJECT FOR GLOBAL GATEWAY



A PARTNERSHIP WITH KOREA IN 2026 WILL COMPLETE THE PICTURE

Hive Hydrogen has been building strong relationships with S. Korea and are actively looking for Green Ammonia off-takers, equity investors, Engineering, solar panel manufacturers and development partners from South Korea



President Lee Jae-myung at the G20 summit in November 2025 met with South African President Cyril Ramaphosa, the chair of the summit.





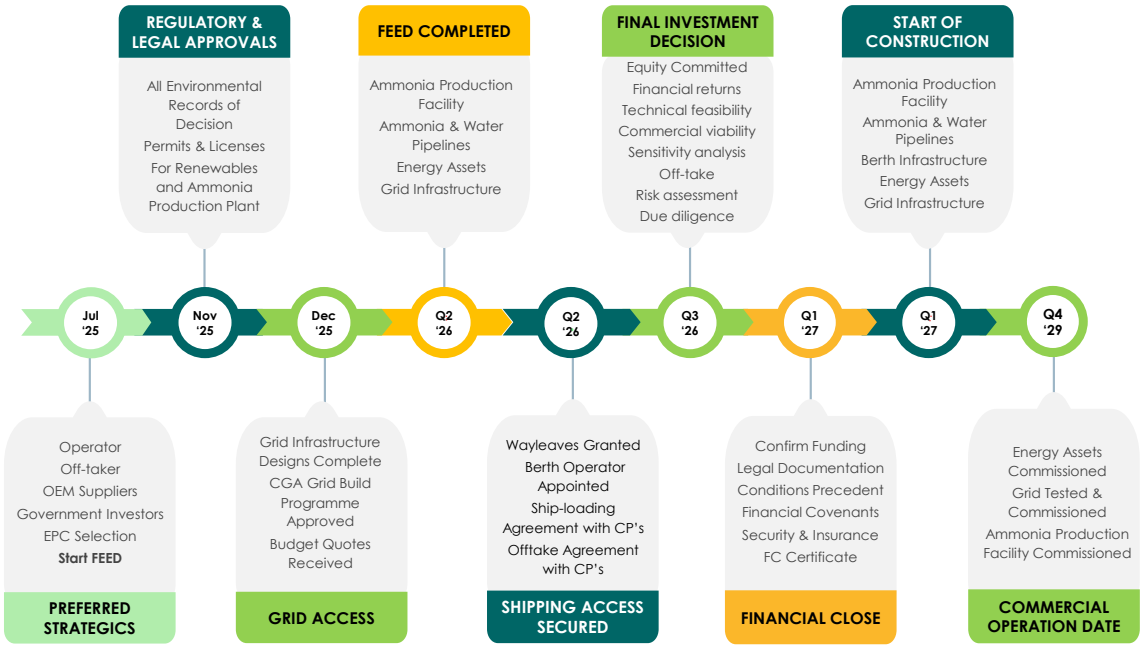
MAJOR PROGRESS IN PAST 12 MONTHS

DEVEX FUNDING	• **$20m** (FEED & BFS) Development Funding terms agreed with Climate Fund Managers - 12 June 2025 • **$5m** Pre-FID funding - board approved - Development Bank of SA (08 May 2025)
3 309MW RENEWABLEs INVESTMENT OPPORTUNITY	• Funders/Investors have a **unique opportunity to invest** in Ready to build Wind and Solar Assets. The liberalized Electricity Regulations and S. African Government Support for Green Hydrogen makes it **one of worlds best locations** to invest in
NEW ENABLING LEGISLATION ENACTED	The Electricity Regulation Amendment Act 38 of 2024, effective January 1, 2025, to **modernize** South Africa's electricity sector established a new Transmission System Operator (01 July 2024) , to oversee the national grid, promote competition, and renewable energy. The Act also introduced the **open market** platform for electricity trading.
GRID ACCESS ON TRACK	• **Full Ministerial support** ensuring requirements are in plan for government and NTC • Bi-lateral confirmations given to S. Korea, Japan, EU, Malaysia, Germany and others
MORE EFFICIENT ELECTROLYSER	• **Game changing Solid Oxide Electrolyser Cells** with 20-30% better efficiency vs Alkaline launched 30 October 2025
LESS RENEWABLES LOWER AMMONIA PRICE	• **FOB Price < $650/ton** when SOEC is utilized as higher efficiency requires lower Capex on renewables v Alkaline (2,777MW v 3,309MW) and consequent lower wheeling costs reduce OPEX as a result too
EPC RFP (FEED) PROCESS COMPLETE	• RFI Stage completed with 17 EPC's shortlisted • **FEED RFP** responses receive and selection process underway

INVEST IN HIVE ENERGY

© Private and Confidential

KEY PROJECT MILESTONES



THANK YOU



Colin Loubser
CEO Hive Africa

colin.loubser@hive-energy.com

SCAN HERE

https://www.hiveenergy.co.uk/clean-futures/green-hydrogen/coega-green-ammonia-project/

SUPPLEMENTARY INFORMATION TO FOLLOW

Global Technology and Policy Trends for the Expansion of Clean Ammonia 5

Investment Strategy for Green Ammonia Infrastructure in Korea



KwangJun Kim
Senior Executive Director, Saman Corporation

Education

1988 Bachelor of Science in Chemical Engineering, Inha University
2014 Completion of the Chief Energy Officer Course, Korea Energy Economics Institute

Professional Career

2024 ∽ Senior Executive Director of SAMAN Corporation
2018 ∽ 2024 Managing Director of Byuksan Corporation
2004 ∽ 2017 New Business Group Manager of POSCO
1996 ∽ 2004 Section Chief of POSCOE&C
1989 ∽ 1996 Assistant Manager of Hyundai Engineering
1987 ∽ 1989 Process Operation Engineer of KUMHO Petrochemical Corporation

Research Interest

2011 ∽ 2023 Gas Wholesale Business Division Member of the Gas Technology Standards Committee
2014 ∽ 2016 Executive Committee Member, LNG Equipment Technology (ISO/TC67/WG10)
2011 ∽ 2014 Director of the Synthetic Natural Gas Technology Research Project

Speech Summary

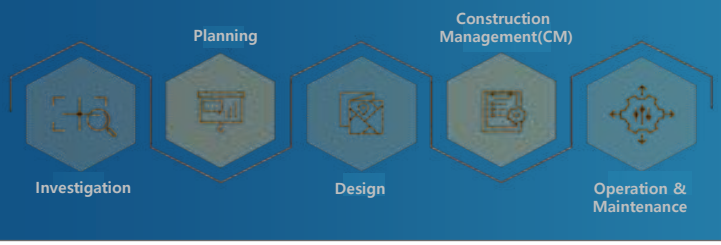
At the present time, interest in green hydrogen and ammonia is growing globally to address climate change. In Korea, the CHPS market is scheduled to begin operations in 2024, and various companies are participating through various clean hydrogen power generation methods. However, at present, infrastructure for unloading, storing, and supplying clean ammonia imported from overseas is a key requirement.
This article will introduce the legal standards and capacity calculations for this ammonia infrastructure.

Company Introduction

SAMAN is a No. 1 multidisciplinary engineering firm in Korea.
SAMAN's excellence has been proven by many major domestic and international Construction and development projects.
Under the management philosophy of "With Technology let's make Human & Nature come together.", we have more than 1,600 professional technical personnel, including over 360 specialized technicians and Ph.Ds with the best technical skills.

Investment Strategy for Green Ammonia Infrastructure in Korea

2025.12.05



Kim Kwangjun (김광준)
Senior Executive Director
kjkim2@samaneng.com

Saman is taking the lead with its mission to create environment-friendly social infrastructure that facilitates harmony between human and nature.

saman Saman Corp.

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1. Saman Corporation
2. Clean Hydrogen Portfolio Standard(CHPS) Value Chain
3. Korean Hydrogen Lows
4. Process Flow
5. Ammonia Import & Send-out Conditions
6. Ammonia Storage Capacity
7. System Configuration of Ammonia Process

1. Saman Corporation

SAMAN in Numerical View



1. Saman Corporation

【 LNG Terminal 】

- **Project** Dangjin Terminal Storage Tanks #5–7(Engineering Services)
- **Client** Korea Gas Corporation(KOGAS)
- **Location** Seokmun National Industrial Park, Dangjin-si
- **Schedule** Feb. 2023 – Feb. 2030
- **Facilities** Three 270,000kl storage tanks(above ground), Utilities and Facilities
- **Scope of Work** LNG storage tanks, including tank structures and surrounding piping(Engineering services)



- **Project** Dangjin LNG Terminal (Phase 1) (Engineering and Construction Management Services)
- **Client** Korea Gas Corporation(KOGAS)
- **Location** Seokmun National Industrial Park, Dangjin-si
- **Schedule** Jul. 2020 – Jul. 2027
- **Facilities** 1,560 t/h vaporization sending-out facilities, loading/unloading facilities, LNG bunkering facilities, Buildings, utilities and facilities
- **Scope of Work** Design and engineering of a production terminal handling 1,560 t/h of LNG(Engineering services)



1. Saman Corporation

【 Green Ammonia Infra. 】

- **Project** Samcheonpo Green Ammonia Infra pre-feasibility study (Engineering Services)
- **Client** Korea South-East Power Corporation(KOEN)
- **Location** Gyeingsangnam-do Geseong-gun Hai-myeon Deoho-ri
- **Schedule** May. 2025 – Nov. 2025
- **Facilities** Two 50,000ton storage tanks(aboveground), 200 t/h vaporization sending-out facilities, unloading facilities, Buildings, utilities
- **Scope of Work** Ammonia storage tanks and Infra Facilities including boiler renovation (Engineering services)



- **Project** Boryeong Green Ammonia Infra Basic Design (Engineering Services)
- **Client** Korea Midland Power Corporation(KOMIPO)
- **Location** Chungcheongnam-do Boryeong-si Ocheon-myeon
- **Schedule** Nov. 2025 – Oct. 2026
- **Facilities** Two 40,000ton storage tanks(aboveground), 200 t/h vaporization sending-out facilities, unloading facilities, Buildings, utilities
- **Scope of Work** Ammonia storage tanks and Infra Facilities including dock renovation (Engineering services)



1. Saman Corporation

【 Green Hydrogen 】

- **Project** Chungju Dam Hydropower-Based Green Hydrogen Infrastructure Pilot Project(Engineering Services)
- **Client** Korea Water Resources Corporation(K-water)
- **Location** Dream Park Industrial Complex, Chungju-si
- **Schedule** Sep. 2024 – Dec. 2025
- **Power Source** Chungju Dam Unit 2 Hydropower
- **Production** 1.5 MW PEM Electrolyzer
- **Scope of Work** 1.5 MW green hydrogen production facility(Engineering)

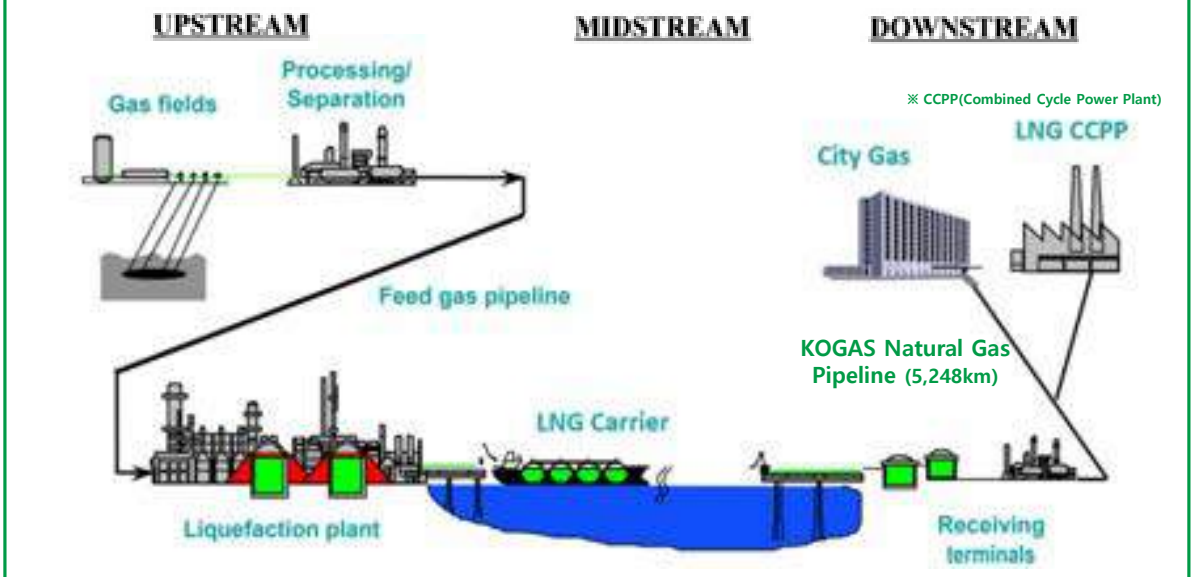


- **Project** Seongnam(Water Treatment Plant) Green Hydrogen Infrastructure Project(Engineering Services)
- **Client** Korea Water Resources Corporation(K-water)
- **Location** Seongnam Water Treatment Plant, Seongnam-si
- **Schedule** May 2024 – Sep. 2024
- **Power Source** Small hydropower generation at the water treatment plant
- **Production** 0.6 MW ALK Electrolyzer
- **Scope of Work** Supply facilities for a mobile hydrogen refueling station(Engineering)



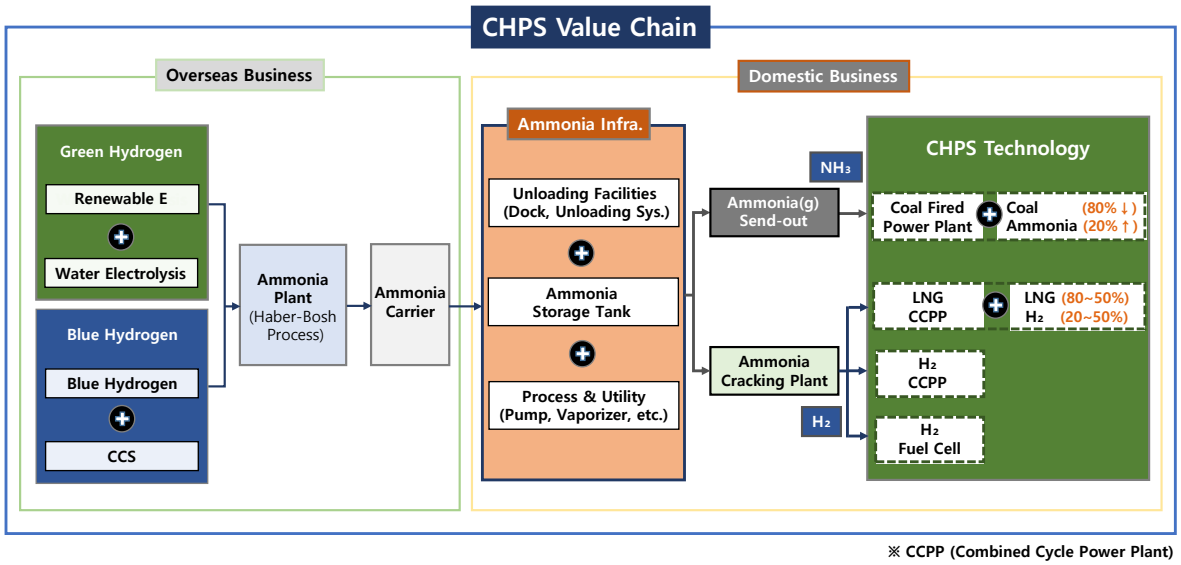
2. Clean Hydrogen Portfolio Standard(CHPS)

【 LNG Chain 】



2. Clean Hydrogen Portfolio Standard(CHPS)

CHPS can be participated by various clean power plants, but ammonia infrastructure, which is the unloading, storage, and supply facilities for clean ammonia imported from overseas, is an essential facility.



※ CCPP (Combined Cycle Power Plant)

3. Korean Hydrogen Lows

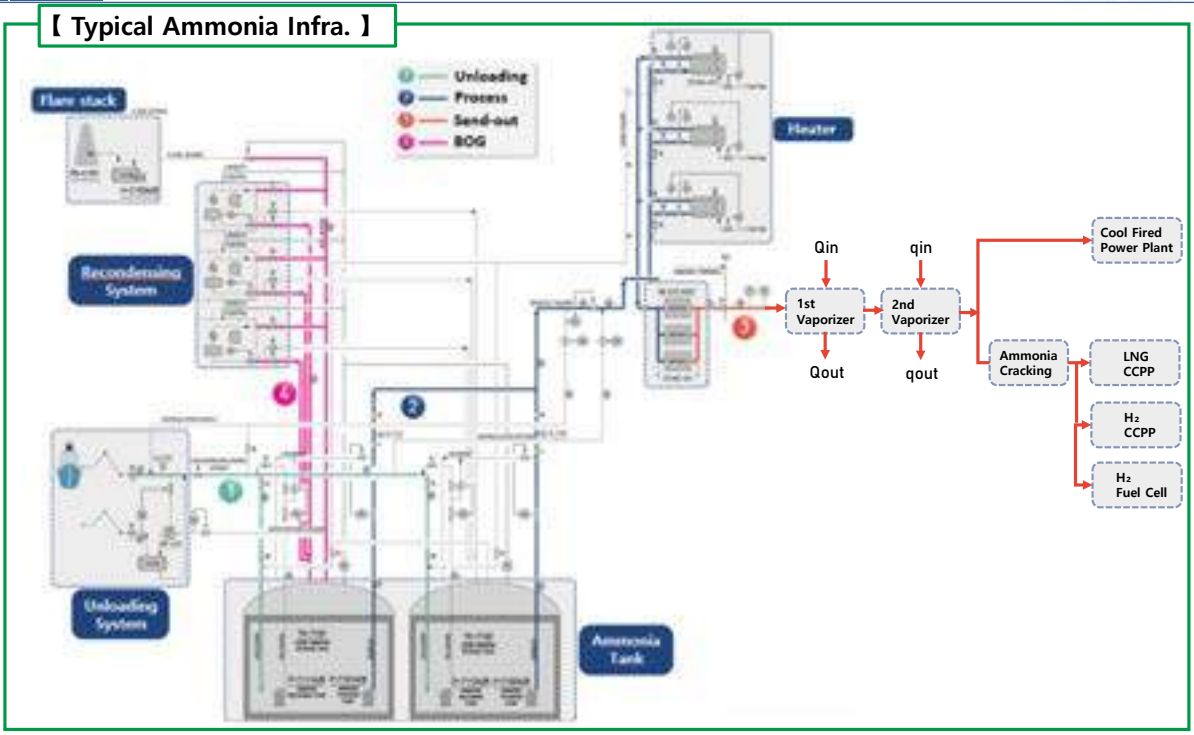
(Green or Blue) Ammonia → Applicable Lows

	Hydrogen Economy Promotion and Hydrogen Safety Management ACT (Hydrogen ACT, 수소법)	High Pressure Gas Safety Control ACT (High Press. Gas ACT, 고압가스법)	※ Urban Gas Business ACT (도시가스사업법)	Hydrogen and Hydrogen Compounds Business Bill (Hydrogen Business Bill, 수소사업법)
Bill	-	-	-	2025.01.17 (???)
New Enactment	2020.02.04	1973.02.07	1978.12.05	???
Enforcement Decree Act	2021.02.05	1973.08.16	1979.02.08	???
Enforcement Regulations Act	2021.02.05	1973.10.22	1984.08.28	???
Key Takeaways	- The purpose is to establish a foundation for promoting the transition to a hydrogen economy in which hydrogen is used as a primary energy source, to systematically and efficiently foster the hydrogen industry, and to establish necessary matters for the safety management of hydrogen products and hydrogen-using facilities, thereby promoting the development of the national economy and contributing to ensuring the safety of the people.	- Licensing standards for the manufacture, storage, and distribution of high-pressure gas, as well as manufacturers of containers and equipment. - Standards for appointing a security manager at high-pressure gas facilities. - Standards for final inspections upon completion of high-pressure gas facility installation. - Standards for the service life of high-pressure gas containers to ensure their safety. - Technical standards for preventing accidents caused by high-pressure gas.	- Establishing the scope of the gas business. - Gas retail business licensing standards. - Government approval requirements for gas rates and gas supply. - Standards for appointing safety managers for gas business operators. - Inspection standards for gas appliance manufacturers.	- The Hydrogen Business Bill sets out the licensing requirements for entry by various stakeholders into the hydrogen business. - Business operators providing pipelines or terminal are required to: provide shared access to their infrastructure for other business entities and obtain approval from the Ministry of Trade, Industry, and Energy (MOTIE) for pipeline/terminal facility usage fees and other terms and conditions of use; - Under the Bill certain hydrogen business entities must submit a five-year hydrogen (compound) supply plan annually. Based on these plans, the Government forecasts hydrogen (compound) supply and demand and imposes stockpiling obligation on designated hydrogen (compound) stockpile entities.
(Green or Blue) Ammonia	Hydrogen Compounds (수소화합물)	Ammonia	-	Hydrogen Compounds (수소화합물)

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4. Process Flow

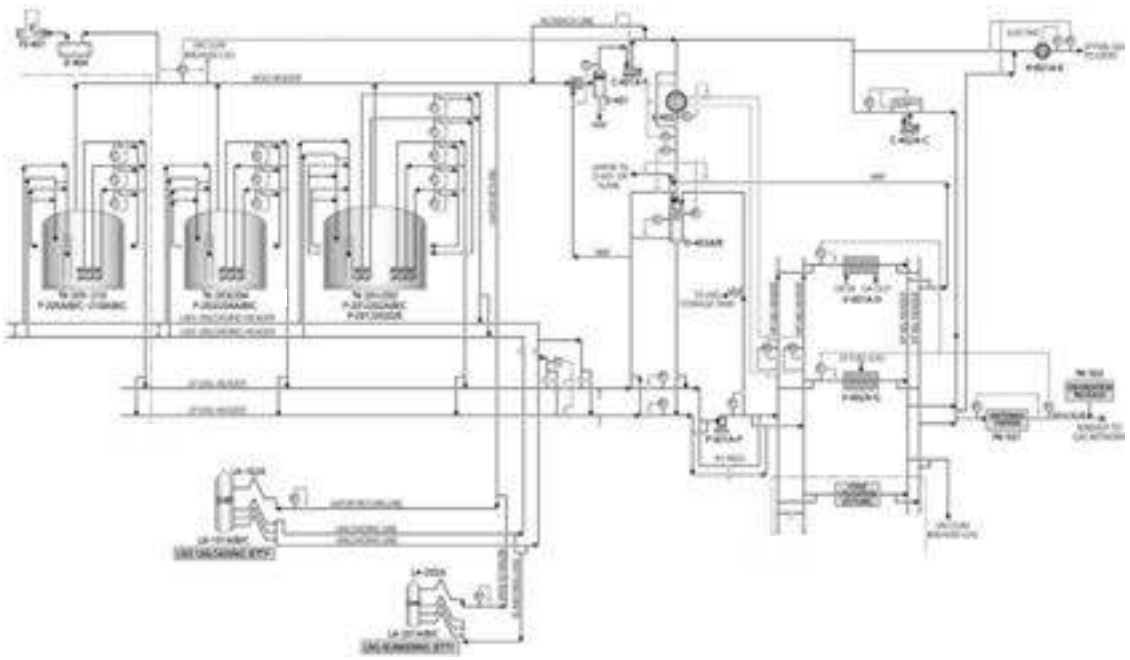
【 Typical Ammonia Infra. 】



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4. Process Flow

【 Typical LNG Terminal 】



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5. Ammonia Import & Send-out Conditions

Import			Send-out	
General	▷Phase : Liquefied Ammonia ▷Temp. : -33℃ ▷Press. : Cargo Pump Press.	Ammonia Infra.	NH_3 Coal Fired Power Plant	▷Phase : Gaseous Ammonia ▷Temp. : 40~50℃ ▷Press. : 3~5barg ▷Comp. : Same as Import
Composition(wt%)				
Gray Ammonia	【Domestic(LOTTE, Namhae)】 ▷NH_3(99.5~), H_2O(~0.5), Oil(5~10ppm)			
	【Overseas(PETRONAS, OCI)】 ▷NH_3(99.5~), H_2O(0.1~0.5), Oil(10ppm)			
Green & Blue Ammonia	【Green - Yara Pilbara PJT(Austrialia)】 ▷NH_3(~99.5), H_2O(0.2~0.5), Oil(10ppm)		H_2 LNG CCPP H_2 CCPP H_2 Fuel Cell	▷Phase : Gaseous Ammonia ▷Temp. : TBC ▷Press. : TBC ▷Comp. : Same as Import
	【Green - NEON PJT(Saudi Arabia)】 ▷NH_3(99.5~99.9), H_2O(0.1~0.5)			
	【Blue - Mesaieed PJT(Qatar)】 ▷NH_3(99.5~99.9), H_2O(0.1~0.5)			

saman

5. Ammonia Import & Send-out Conditions

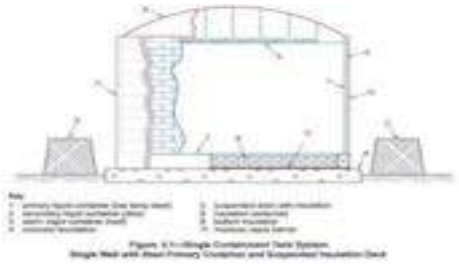
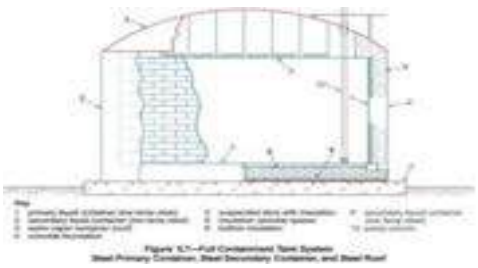
【 Typical LNG Compositions 】

Component	Algeria	Abu Dhabi	Australia	Malaysia	Indonesia	Brunei	Indonesia	Alaska	Algeria
Nitrogen	0.278%	0.100%	0.014%	0.320%	0.030%	0.000%	0.000%		1.400%
C1H4	91.395%	87.074%	87.822%	91.131%	89.180%	89.400%	90.600%	99.800%	89.800%
C2H6	7.874%	11.410%	8.304%	4.284%	8.580%	6.300%	6.000%	0.100%	6.000%
C3H8	0.443%	1.271%	2.982%	2.873%	1.070%	2.800%	2.480%		2.200%
i-C4H10	0.064%	0.062%	0.400%	0.703%	0.240%				0.350%
n-C4H10	0.046%	0.079%	0.475%	0.661%	0.271%	1.300%	0.830%		0.500%
i-C5H12	0.000%	0.001%	0.000%	0.010%	0.020%	0.000%			0.000%
n-C5H12	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.010%		0.000%
Total	100.000%	100.003%	99.997%	100.000%	99.901%	99.800%	100.000%	99.900%	100.000%
HHV Gas, Btu/SCF	1,078.4	1,123.6	1,142.9	1,118.5	1,107.1	1,021.0	1,110.4	1,010.8	1,088.1
Wobbe Index	1,393.0	1,439.4	1,451.0	1,414.6	1,417.0	1,423.8	1,411.3	1,398.2	1,390.2
GPM C2+	2.25	3.44	3.32	2.35	2.95	2.86	2.54	0.03	2.40

Component	Oman	Trinidad	Qatar	Confidential	Confidential	Indonesia	Confidential	Confidential	Confidential
Nitrogen	0.000%	0.000%	0.190%	0.050%	0.430%	1.002%	0.000%	0.015%	0.307%
C1H4	87.664%	92.266%	89.870%	92.070%	84.550%	96.379%	91.425%	92.629%	91.021%
C2H6	9.710%	6.394%	6.650%	6.890%	10.930%	2.004%	7.419%	6.888%	7.534%
C3H8	2.037%	0.909%	2.300%	0.970%	3.210%	0.451%	0.872%	0.348%	0.949%
i-C4H10	0.286%	0.214%	0.410%	0.000%	0.470%	0.069%	0.075%	0.022%	0.081%
n-C4H10	0.297%	0.225%	0.570%	0.000%	0.380%	0.090%	0.088%	0.033%	0.081%
i-C5H12	0.000%	0.000%	0.010%	0.020%	0.020%	0.003%	0.042%	0.022%	0.014%
n-C5H12	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.041%	0.042%	0.042%
Total	100.000%	100.000%	100.000%	100.000%	99.990%	100.000%	100.000%	100.000%	100.000%
HHV Gas, Btu/SCF	1,127.6	1,082.1	1,135.6	1,077.4	1,156.7	1,025.6	1,082.9	1,070.6	1,082.8
Wobbe Index	1,421.5	1,386.9	1,417.6	1,363.6	1,432.1	1,353.1	1,386.2	1,398.5	1,393.6
GPM C2+	3.36	2.10	2.72	2.11	4.08	0.71	2.28	1.97	2.33

6. Ammonia Storage Capacity

【 Storage Tank Type (LNG & Ammonia) 】

	Single Containment	Full Containment
API 625		

【 Storage Capacity 】

▣ LNG Terminal Case (Urban Gas Business Act)

LNG Storage Capa. = Ship Capa. + Seasonal Variation + Emergency Stockpile − Ship Adjust Quantity

☞ Storage Capacity : 30 days (Urban Gas Business, Direct Importer, Natural Gas Shipping Business, etc.)
☞ Emergency Stockpile : 9 days (Urban Gas Business only)

▣ Ammonia Infra. (Hydrogen Business Act not Enacted)

☞ Coal Fired Power Plant Case : Coal(15~30 Days), Ammonia(?)
☞ LNG CCPP, H_2 CCPP, H_2 Fuel Cell : Ammonia(?), H_2(?)

7. System Configuration of Ammonia Process

Major Equipment		Design Basis	Equipment Capacity		
			Unit Capa.	Q'TY	Configuration
Unloading	Unloading Arm	Depending on the ship max. unloading rate	2,000㎥/hr	2	50% x 2 = 100%
	Jetty Drain Drum		10~20㎥/hr	1	100% x 1 = 100%
	Vapor Return Arm	Reloading case	4,000㎥/hr	1	100% x 1 = 100%
Storage	Storage Tank	Depending on the Hydrogen Business Act	30000~50000 ton	2	50% x 2 = 100%
Send-out	Pump	Depending on the ammonia demand	100t/hr	2/tank	100% x 2 = 200%/tank
	1st Vaporizer		100t/hr	3	50% x 3 = 150%
	2nd Vaporizer		100t/hr	3	50% x 3 = 150%
	Gas Heater		100t/hr	3	50% x 3 = 150%
Reliquefaction	BOG Reliquefaction	BOG rate when unloading	3.5t/hr	3	50% x 3 = 150%
Flare	Flare Stack	Emergency Analysis	100t/hr	1	100% x 1 = 100%
Utility	N2, Air, Water, etc.	-	-	-	-

saman
15



Global Technology and Policy Trends for the Expansion of Clean Ammonia 6

Ammonia Adsorbents as Key Enabling Technologies for a Clean Ammonia Society



KwangBok Yi
Professor, Chungnam National University

Education
2000-2004, Ph.D., Chemical Engineering, Louisiana State University, Baton Rouge, USA
1998-2000, M.S., Chemical Engineering, Chungnam National University, Daejeon, Korea
1990-1997, B.S., Chemical Engineering, Chungnam National University, Daejeon, Korea

Professional Career
2010-Present, Professor, Chemical Engineering Education, Chungnam National University, Daejeon, Korea
2006-2010, Senior Researcher, Korea Institute of Energy Research, Daejeon, Korea
2004-2006, Postdoctoral fellow, Institutt For Energiteknikk, Norway

Research Interest
Ammonia adsorbent for ammonia cracking process and maritime ammonia fuel
CO adsorbent for energy conversion and production
CO2 adsorbent for direct air capture
NOx conversion to NH3 and enrichment process

Speech Summary
This talk presents an integrated pathway for clean hydrogen from ammonia. Introduces high-efficiency cracking, advanced adsorbent-based NH_3 removal, and scalable purification. Especially, it highlight material innovations enabling <0.1 ppm NH_3 H_2 production for industrial deployment.

Company Introduction
Chungnam National University: a leading national research university in Daejeon, Korea

2025 Hydrogen Deep Dive

Ammonia Adsorbents as Key Enabling Technologies for a Clean Ammonia Society



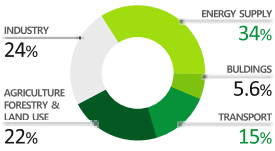
Chungnam National University
Kwang Bok Yi

2025. 12. 5.

Eergy Trends

Accelerated Global Warming

GREENHOUSE GAS EMISSIONS



Energy·Mobility(49%)
↓
Industry (24%)
↓
Agriculture/Forestry (22%)

Carbon Neutrality Policy



- GB, France, New Zealand (2019, Legislation)
- Sweden (2017, Legislation)
- EU (2020, LEDS)
- Canada (2019, Presidential Statement)
- Korea, Japan (2020, Presidential Statement)

Energy Paradigm Shift

CO_2 Net-Zero Emissions



Limits of CCUS techs
↓
Obstacles to Hydrogen Society
↓
Carbon free ammonia based Energy·Mobility re-organization

Utilization of Ammonia

Ammonia Adsorbents
2025 Hydrogen Deep Dive

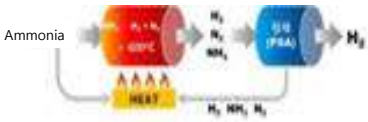
Green NH_3



Secured H_2 Carrier position

- 1/3 energy loss of LH_2
- Liquefaction at 8.5 bar room Temp.
- High E density with long term stability

H_2 Extraction



Drawbacks of extracted H_2

- Inevitable E loss in Extraction process
- Residual NH_3 treating required
- Expensive Catalyst Cost

Direct NH_3 use



Co-firing

- Boiler (with Coal or H_2)
- NOx and N_2O



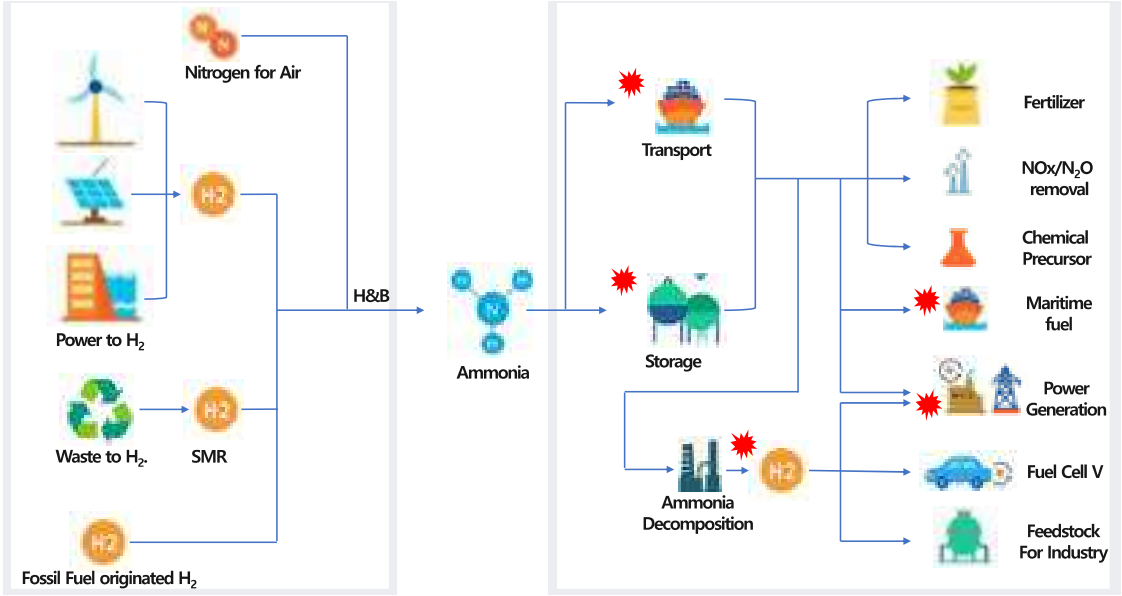
NH_3 direct FC

- NH_3 to Electricity
- Immature Tech
- NOx

Ammonia Value Chain

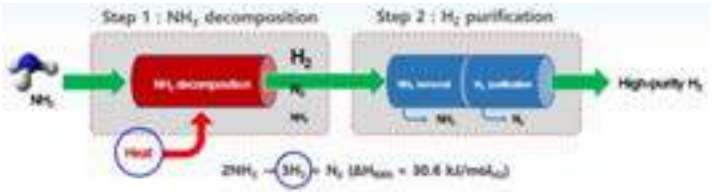
Residual NH_3 treatment required

Ammonia Adsorbents
2025 Hydrogen Deep Dive



Where in needs of NH_3 treatment (On-shore industry)

Ammonia Adsorbents
2025 Hydrogen Deep Dive



Ammonia based hydrogen production process

- Catalysts development
- System configuration
- Ammonia scavenging technology

R&D Activities (Korea)

- KIST
- KRICT
- Wonik Materials
- Doosan Enerbility
- Panasia
- POSCO

R&D Activities (Multinational)

- Syzygy
- Starfire
- H2site
- Amogy
- Topsoe
- Thyssenkrupp Uhde

600 ~ 3000 ppm of NH3 in exit stream of decomposition reactor

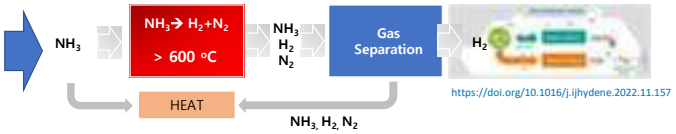
Where in needs of NH_3 treatment (Maritime use)

Ammonia Adsorbents
2025 Hydrogen Deep Dive



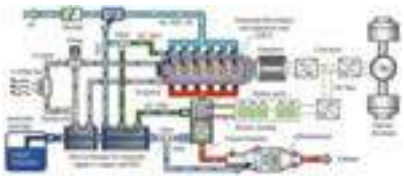
Source:

Hydrogen extracted from Ammonia for Fuel cell (Down stream protection)



https://doi.org/10.1016/j.ijhydene.2022.11.157

Ammonia Powered Engine (NH_3 catch system)

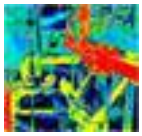


https://doi.org/10.1016/j.etran.2023.100288

Ammonia leak in vessels (Safety issue)



North shore news



BS-shipmanagement.com



https://www.reddit.com/r/CatastrophicFailure/

Currently available NH_3 removal techs and trends

Wet Acid Scrubbers

- Types: Spray tower, Packed bed
- High NH_3 removal efficiency, ammonium salt production
- ppm ~ % level NH_3 slip after cracking
- Small scale only, waste water, not suitable for ultra pure H_2

Dry Adsorption / Solid Acid

- Solid **acid-functionalized** adsorbents and NH_3 traps
- Critical for **ultra-high-purity H_2** (PEMFC)
- No moisture/ion contamination
- Not suitable for continuous process (No regeneration)

Ammonia Slip Catalysts (ACS)

- Converts residual NH_3 to N_2 at low temp
- Used in SCR systems with cracking + combustion units
- Only available when SCR already exist
- Complicated and large facilities

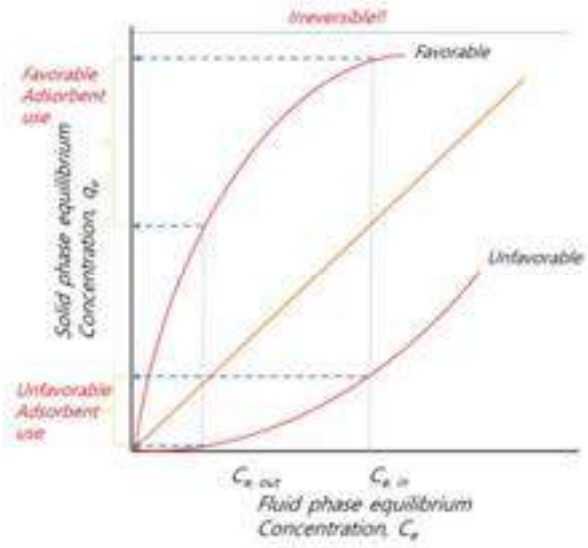
Not sufficient for high purity H_2 production!
(~ 99% max. removal)

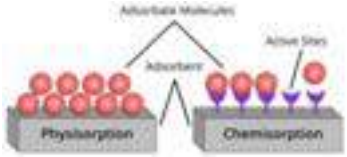
- Scrubing + recovery of NH_3
- Integrated Cracking-Combustion-SCR
- Hybrid Systems for Small Scale Application

Other miscellaneous techs

Reverse Osmosis (Liquid treatment)
Precipitation(Liquid, Fertilizer)
Biological treatment
Photocatalysis

Ammonia adsorbents (Basic concept)



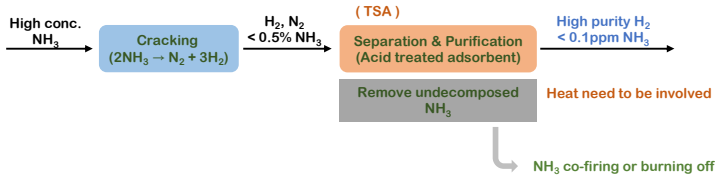


Isotherm characteristics deciding factors

- Surface acidity
- Surface interaction with adsorbate
- Pore shape and size distribution
- Specific surface area

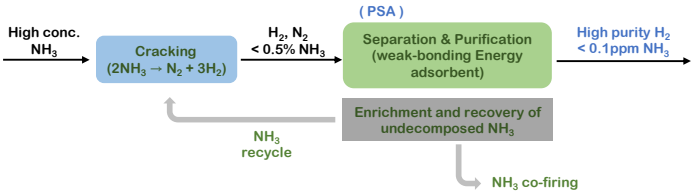
PSA or TSA

Ammonia Adsorbents
2025 Hydrogen Deep Dive



TSA

- Intermittent operation
- Utilize heat for regeneration
- Suitable for safety maintenance (ex. Maritime)
- Variety of applicable adsorbents



PSA

- Continuous operation
- Utilize pressure for regeneration
- Suitable for industrial use (Energy production)
- Limited adsorbents

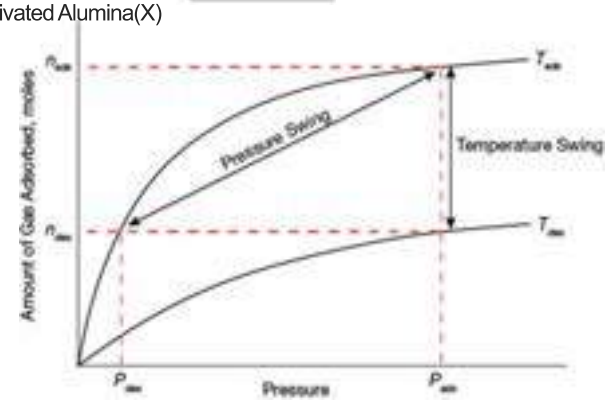
- Ammonia is not suitable for PSA process due to the its strong basic properties. → **Controlling degree of interaction?**
- If so, PSA can be applied for NH_3 removal and enrichment

Selection of adsorbents

Ammonia Adsorbents
2025 Hydrogen Deep Dive

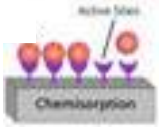
Acidic solid (X) Zeolite (Δ)
Activated carbon(X)
MOF (Δ)
Silica(X)
Activated Alumina(X)





Controlling surface interaction

- Modifying surface functional group
- Utilizing amine complex formation

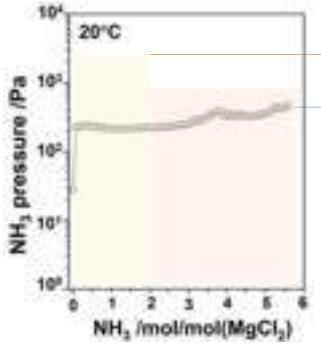


Acidic solid (O) – 13X
MOF (?)
Activated Alumina (Δ)

Metal halide vs. NH_3 (Amine Complex Formation for PSA)

Ammonia Adsorbents
2025 Hydrogen Deep Dive

P-C isotherm for $MgCl_2$-NH_3 system



1~5mol/mol, 2000~4000ppm
(1/3000 of P_{NH3})

NH3 Fuel Conference 2016
September 18-21, 2016, Los Angeles, CA
(9:05-9:30, September 20, 2016)
Yoshitsugu Kojima
Hiroshima University
Institute for Advanced Materials Research

Amine coordination reaction

$$M\,gCl_2(s) + NH_3(g) \rightleftharpoons M\,g(NH_3)Cl_2(s)$$
$$M\,g(NH_3)Cl_2(s) + NH_{3(g)} \rightleftharpoons M\,g(NH_3)_2Cl_2(s)$$
$$M\,g(NH_3)_2Cl_2(s) + 4NH_{3(g)} \rightleftharpoons M\,g(NH_3)_6Cl_2(s)$$

Stepwise and discrete intercalation

Mechanism

- P ↑ → μ(NH_3) ↑
- Void/interlayer expansion -> X- coordination ↓
- M-(NH_3)x coordination formation
- ΔHr ~-55 kJ/molNH_3 (physisorption region)

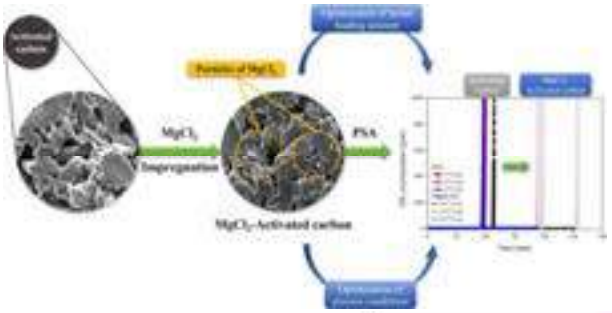
Metal and halide anion can be chosen accordingly based on their electronegativity and its gap.

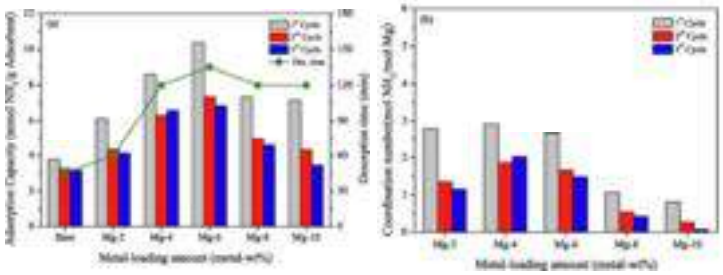
Drawback! → low penetration due to its dense structure.

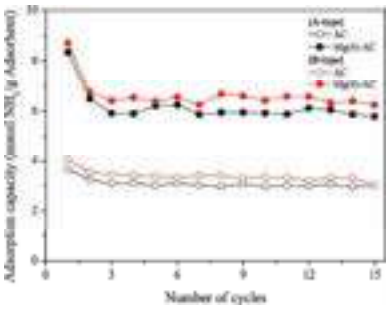
Coating of Metal halides on porous material ?

PSA operation with M-X/AC

Ammonia Adsorbents
2025 Hydrogen Deep Dive







< 1 ppm of NH_3 in effluent stream

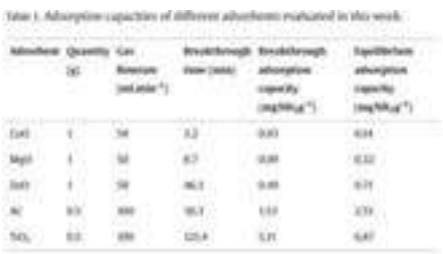
< 0.1 ppm of NH_3 with guard bed

M.W. Hong et. Al., J. Ind. Eng. Chem, 2023

Metalsilicate for TSA application

Metal Oxide as NH_3 ads.

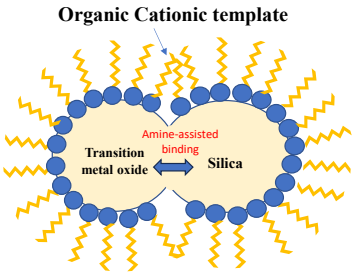
- High selectivity
- Rapid mass transfer
- Thermal/Chemical stability
- NH_3 active surface defects
- Oxygen vacancies for N attraction



E. Rezaei et. Al., J. Env. Chem. Eng., 2017

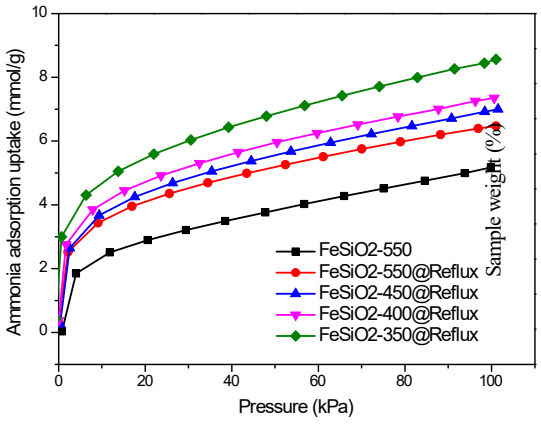
Improving Surface Properties Strategies

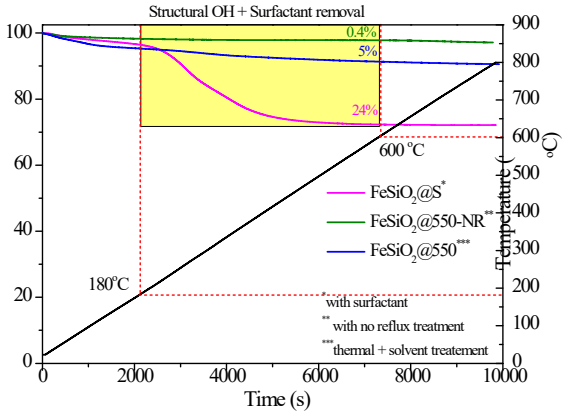
- Surface area → by applying porous materials
- Particle size and shapes → by organic templates
- Surface acidity → Transitional metal hybrid with silica



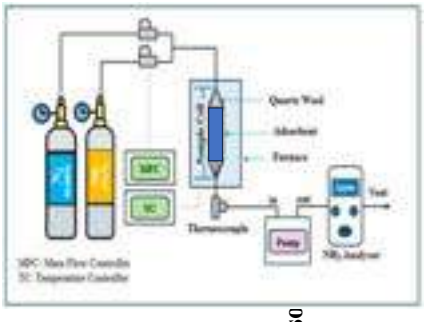
Strategy: Highly porous metal embedded silica with Oxygen vacancy holding surface

Effect of reflux on surface modifaction

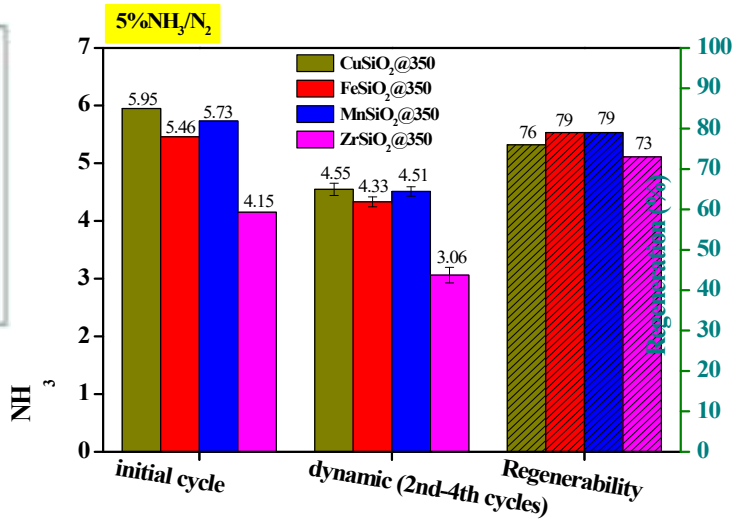




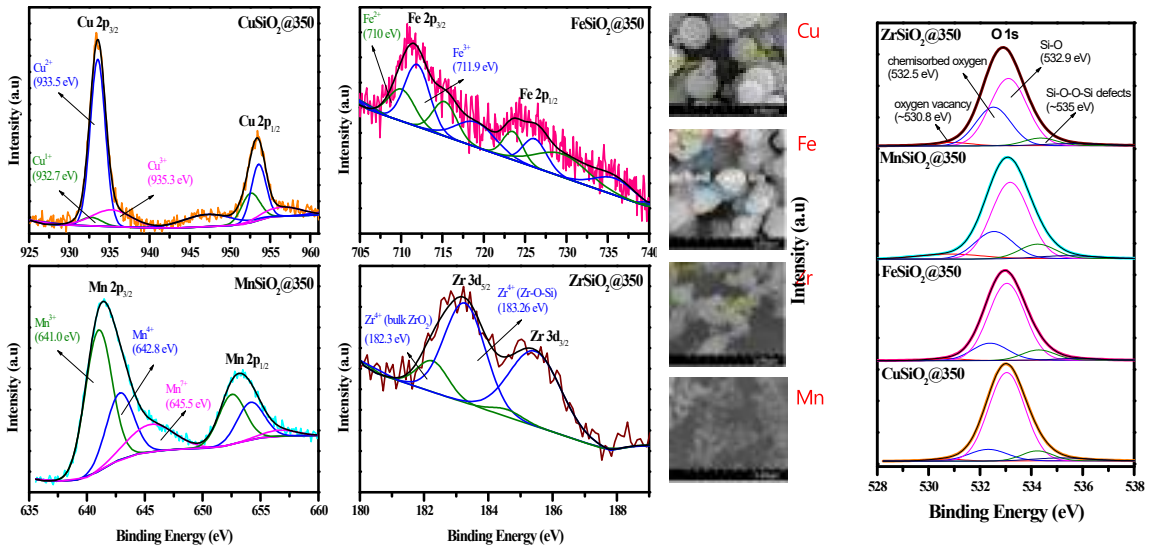
Adsorption capacity of metal silicate in TSA condition



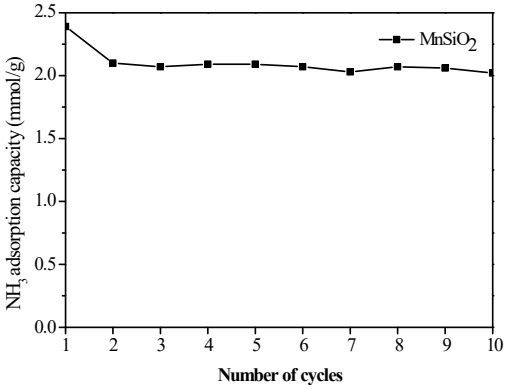
Breakthrough Conditions			
Adsorption		Desorption	
T	P	T (°C)	P
25°C	0 barg	80 (Water bath)	0 barg

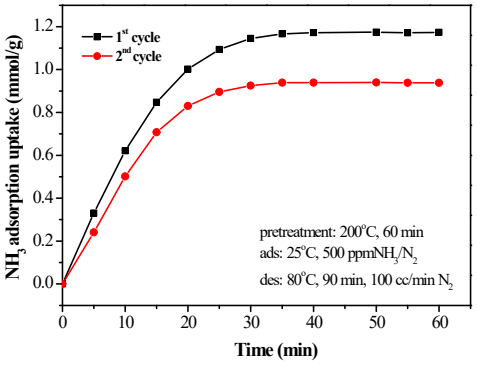


Oxygen vacancies vs. particle size



Low Conc. NH_3 adsorption stability of $MnSiO_2$





Dynamic adsorption (exclusive of 1st cycle) was stable at 96%
Average adsorption capacity of 2.07 mmol/g

Dynamic Adsorption efficiency can be stable at 1-1.2 mmo l/g for 500 ppm NH3 adsorption

Mass production of NH_3 adsorbents



Factors for optimization of mass production process



What kind of binder do we choose?

What would be the binder content?

Calcination Temperature?

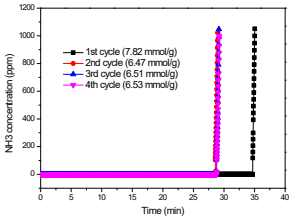
Dough making sequence?

More additive?

Additive doping sequence?



Every steps need to be checked if we sacrifice too much adsorption capacity



Ammonia Adsorbents
2025 Hydrogen Deep Dive

Thank you for your attention.

Panel Discussion

Technological and Economic Challenges for Clean Ammonia Utilization

Moderator



KwangBok Yi
Professor, Chungnam National University

Panelists

Alexander Oliver Bower
Global Head of Marketing & Sales,
Gentari Hydrogen Sdn Bhd



SeongHoon Woo
CEO, Amogy



HoKi Lee
Vice President, Samsung Heavy Industries



Colin Loubser
CEO, Hive Energy Africa



KwangJun Kim
Senior Executive Director, Saman Corporation

WORLD HYDROGEN EXPO 2025 6th
Conference

Hydrogen Deep Dive V：
Hydrogen：Future to TECH

WORLD HYDROGEN EXPO 2025 6th Conference

Breakthroughs in Hydrogen Production Techniques

Breakthroughs in Hydrogen Production Techniques 1

From Waste to Value: CCUS & Sustainable Hydrogen Pathways for Industrial Decarbonization



Marat Mayan
Founder & CEO, Airovation Technologies

Education
- 2002 B.A., Business Administration & Human Resource Management, Ben-Gurion University
- 2011 M.A., Government & Counter-Terrorism, Reichman University – Lauder School of Government
- Graduate Studies in Political Science & Security Studies, Hebrew University of Jerusalem
- Senior Command & Leadership Training, in collaboration with Israeli Defense Forces

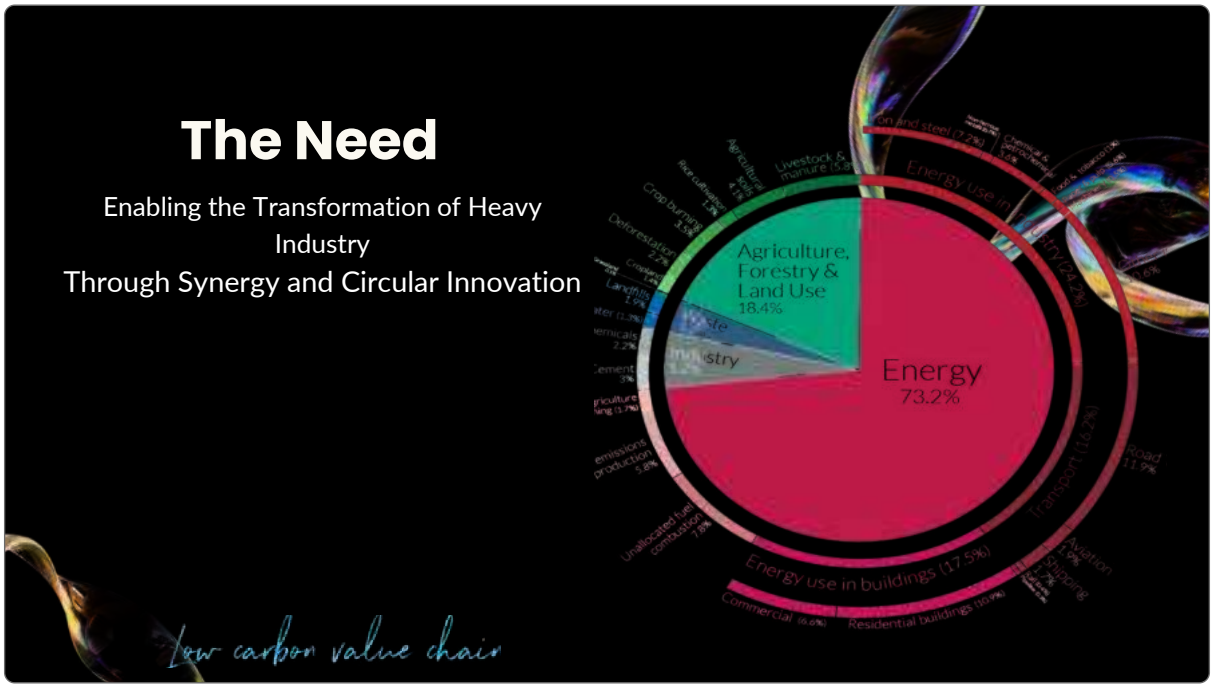
Professional Career
- 2017–Present: Founder & CEO, Airovation Technologies & Airosphera – Leading disruptive CCUS & hydrogen innovation; partnerships across Israel, Japan, Korea, India, Saudi Arabia, Europe.
- Multiple grants from Israel Innovation Authority; Winner, Beijing Cleantech Competition (2021); Winner, ASPER Prize (2025).
- 2013–2016: Founder & CEO, Salamandra-Zone – Fire evacuation technologies for high-rise buildings.
- 1987–2013: Lieutenant Colonel, Israel Ministry of Defense & IDF – Established Israel's first CBRN battalion; directed counter-terrorism and engineering units.

Research Interest
- CCUS and hydrogen innovation
- Circular economy & cross-sector industrial synergies
- Industrial decarbonization pathways & hydrogen economy strategies
- Climate tech scale-up & commercialization

Speech Summary
Airovation's award-winning CCUS platform transforms CO_2, Phosphogypsum, and industrial gypsum into profitable low-carbon products and affordable green hydrogen. By enabling powerful cross-sector synergies, it delivers both economic feasibility and environmental impact, supporting industries from fertilizers to cement and SAF.

Company Introduction
Airovation Technologies is a global climate-tech innovator transforming CO_2 and industrial waste into valuable low-carbon products. Supported by the Israel Innovation Authority and international partners, Airovation drives decarbonization in fertilizer, metals, cement, and hydrogen sectors.
Brief Introduction of Company (≤100 characters):
Airovation: Award-winning CCUS & hydrogen solutions turning CO_2 and waste into low-carbon value.

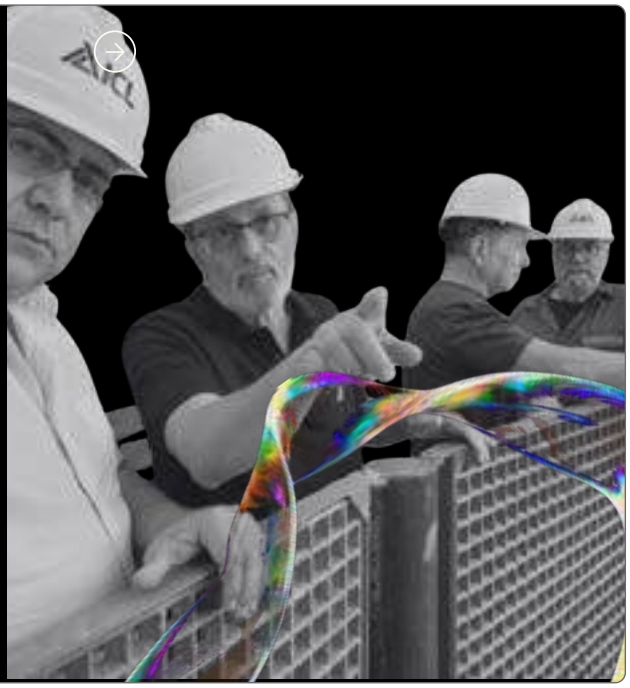

Low carbon value chain
airovation technologies
Presenting - Marat Maayan
www.airovation-tech.com
marat@airovation-tech.com
3 Horeg St Modi'in Israel

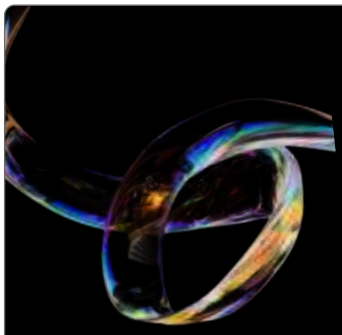

The Need
Enabling the Transformation of Heavy Industry
Through Synergy and Circular Innovation
Agriculture, Forestry & Land Use 18.4%
Energy 73.2%
Energy use in buildings (17.5%)
Low carbon value chain

INTRODUCTION

Airovation enables low-carbon, cost-competitive hydrogen production through a breakthrough CO_2-mineralization process, creating the conditions for rapid industrial adoption and scalable market demand of Hydrogen .

Low carbon value chain





Grey Hydrogen
Global Annual CO_2 By-Product Emissions
1.2 B Tons

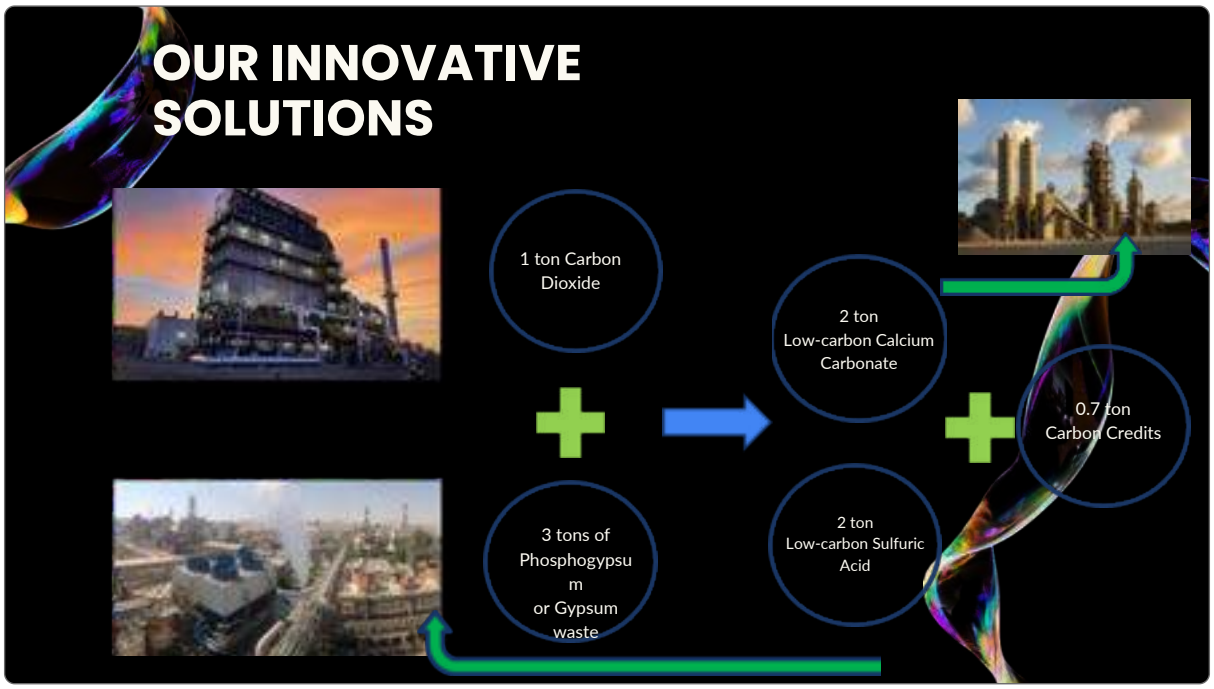


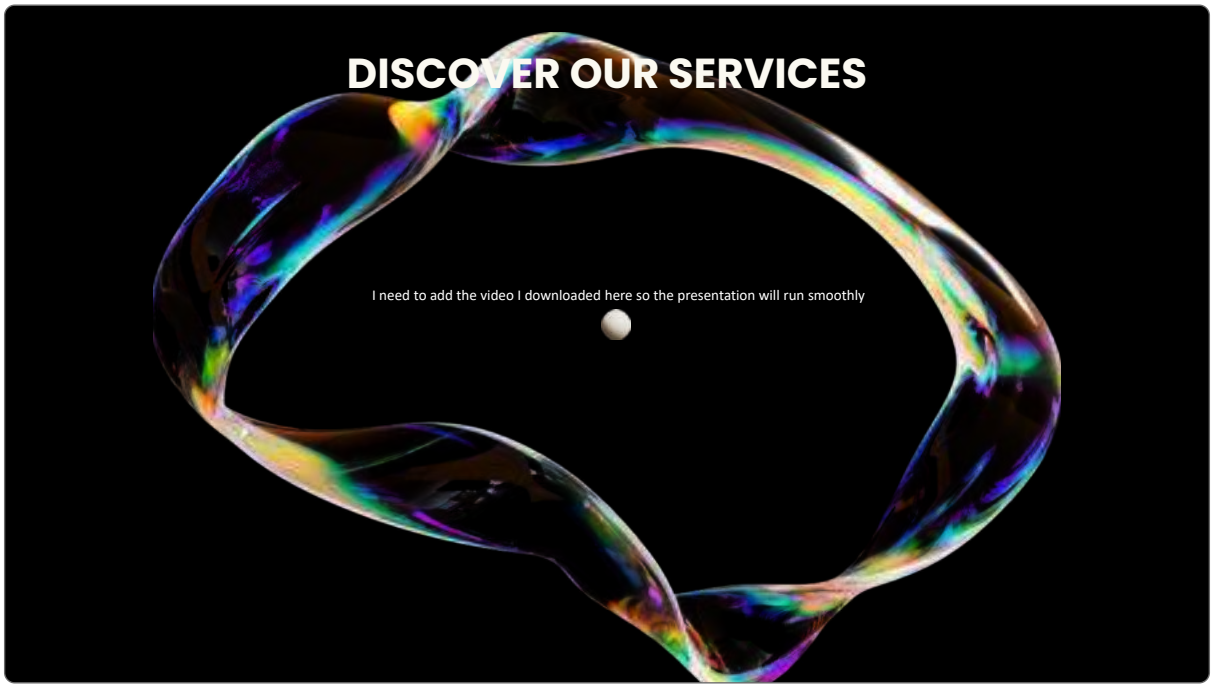
PROBLEM STATEMENT



Green hydrogen remains priced at levels that significantly limit broad commercial adoption. Despite its environmental benefits, the high production and infrastructure costs continue to slow market uptake across most industrial sectors.

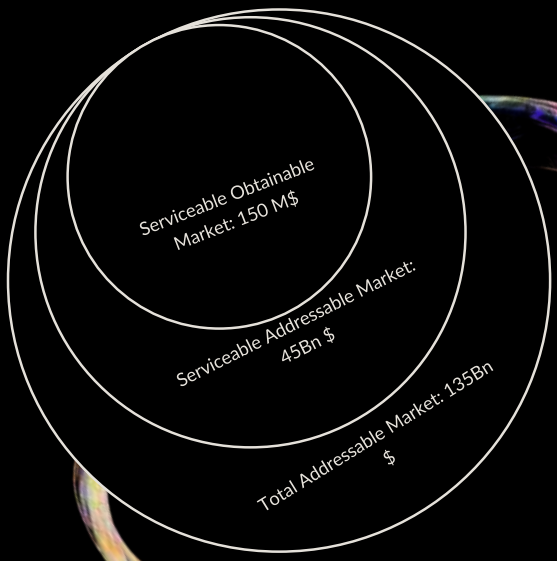
Low carbon value chain


OUR INNOVATIVE SOLUTIONS
1 ton Carbon Dioxide
3 tons of Phosphogypsum or Gypsum waste
2 ton Low-carbon Calcium Carbonate
2 ton Low-carbon Sulfuric Acid
0.7 ton Carbon Credits


DISCOVER OUR SERVICES
I need to add the video I downloaded here so the presentation will run smoothly

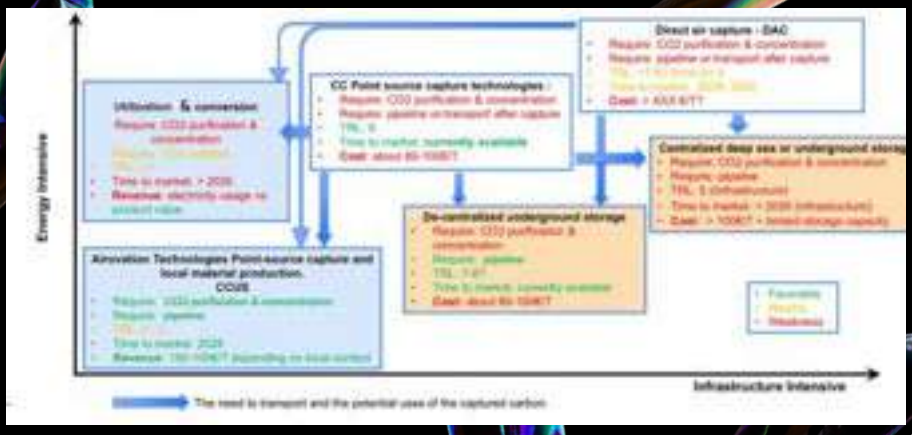
SIZE OF MARKET

Understanding the market potential is essential for Airovation. Across our target geographies, hard-to-abate industriesת, including fertilizer, steel, chemicals, energy, and waste management, represent a multi-billion-dollar opportunity for large-scale CCUS and low-carbon material solutions. Within these sectors, we estimate that over 30% of facilities face immediate regulatory and economic pressure to decarbonize, translating into thousands of potential industrial sites suitable for our CO_2-mineralization technology. Capturing even 5% of this addressable market positions Airovation for significant commercial scale, supporting a clear and strategic pathway for growth.

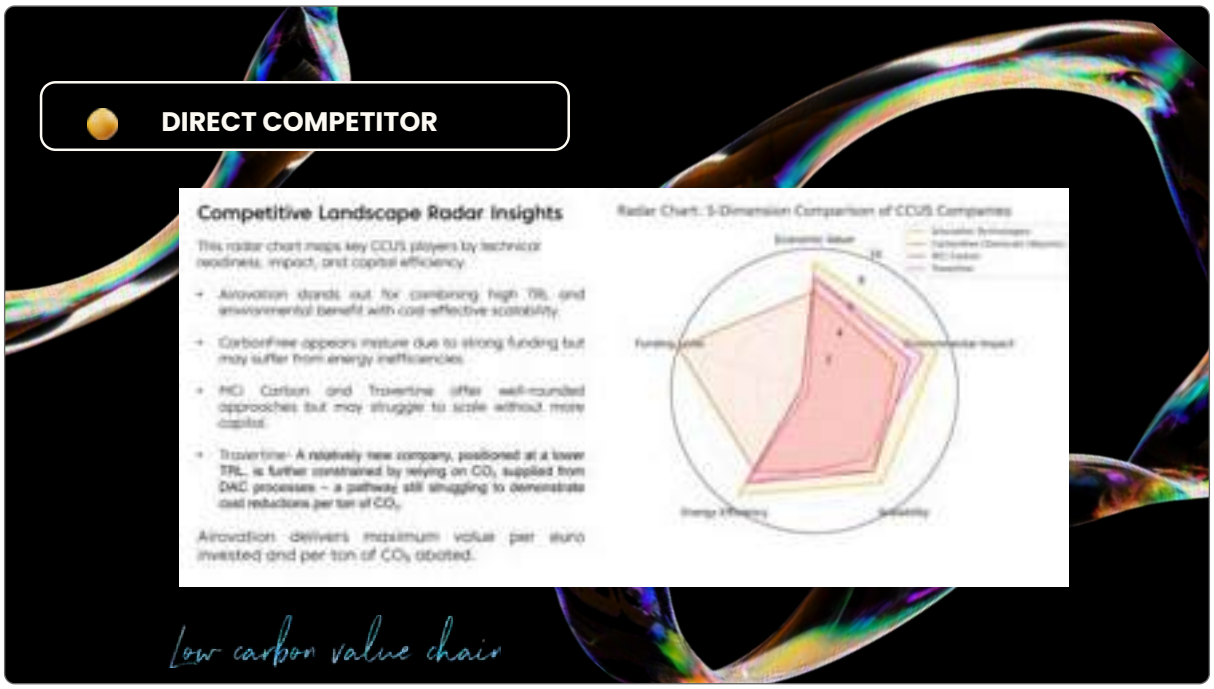


Low carbon value chain

INDIRECT COMPETITOR



Low carbon value chain


DIRECT COMPETITOR
Competitive Landscape Radar Insights
This radar chart maps key CCUS players by technical readiness, impact, and capital efficiency.
Airovation stands out for combining high TRL and environmental benefit with cost-effective scalability.
CarbonFree appears mature due to strong funding but may suffer from energy inefficiencies.
HCI Carbon and Travertine offer well-rounded approaches but may struggle to scale without more capital.
Travertine- A relatively new company, positioned at a lower TRL, is further constrained by relying on CO2 supplied from DAC processes – a pathway still struggling to demonstrate cost reductions per ton of CO2.
Airovation delivers maximum value per euro invested and per ton of CO2 abated.
Radar Chart: 5-Dimension Comparison of CCUS Companies
Low carbon value chain


KEY COMPETITIVE ADVANTAGES
2027-2030
ICL
airovation technologies
NM
Fertilizer Plant
3 mt/y Phosphogypsum
CCUS
SMR
100kt/y H2 = 1Mt/y CO2
H2
100 kt/y H2
$400M
2 M/T/Y Low Carbon sulfuric acid $140M
2.1 M/T/Y Low Carbon Calcium carbonate $60M
Total $600M
Low carbon value chain

TRACTION



Two major low-carbon hydrogen collaborations were secured this year 2025 with leading industrial partners, marking a significant step forward in Airovation's commercial expansion.

Four additional projects are currently in advanced validation stages, further expanding our low-carbon hydrogen deployment pipeline and reinforcing market demand for our solution.

Reaching commercial-scale production of tens to hundreds of thousands of tons of low-carbon hydrogen is planned from 2030 onward, positioning Airovation as a major enabler of large-scale decarbonized hydrogen deployment.

Low carbon value chain

Low carbon value chain

THANK YOU

for your time and attention

Presented by Marat Maayan

www.airovation-tech.com
marat@airovation-tech.com
3 Horeg St. Modi'in Israel

Breakthroughs in Hydrogen Production Techniques 2

Project Helios - Cement Production Decarbonisation through Green Hydrogen



Robert Saunders
Managing Director, Elecseed

Education
Bachelor of Engineering (Hons) – Energy Engineering 1992-1996
London South Bank University (United Kingdom)
Circular Economy and Sustainability Strategies 2022
University of Cambridge

Professional Career

Managing Director (2022 – present)
Elecseed Pty Ltd (Australia)
Director (2025 – present)
Elecseed Lab (Korea)
Board Member – Australian Korean Chamber of Commerce, AustCham, (2025 – present)
(Korea)
WSP Calibre (2017 – 2022)
General Manager Renewables
(Australia)

BG Group (2016 - 2017)
General Manager Building Services and Renewables
(Australia)
WSP Opus (2012 - 2015)
National Building Sector Leader
(Australia)
Ashburner Francis (2008 – 2011)
Chief Operating Officer
(Australia)
Saunders Specialised Services Ltd
Managing Director
(United Kingdom)

Research Interest
Green Hydrogen Production and Wastewater treatment enabling the delivery of the UN sustainable development goals – 2020
Bi-Facial Photovoltaics and the Albedo Effect Research Project – Queensland University of Technology, Australia, 2023

Speech Summary
300 Word Version
Due to Korea's physical nature and climate, its ability to produce green hydrogen is limited within its own shores. Korea has therefore turned its attention in seeking to invest internationally in the production of Green Hydrogen with friendly nations who do have the natural resources and skills available, such as Australia.
Cement manufacturing accounts for 8 % of global carbon emissions a year, mostly through the heating of limestone to create the main ingredient, called clinker. Australia consumes about 12 million tonnes of cementitious products annually, with around half of this imported.
Project Helios is located in South Australia in partnership with the Korean Government and local partners and aims to produce green cement through the use of the redundant fly ash from a coal fired power station. This involves drying the flyash via large scale ovens which traditionally would occur via fossil fuels like Natural Gas/ However, in the case of Project Helios, the drying process uses Green Hydrogen produced via Korean Electrolysis technology and investment adjacent to the facility.
This decarbonised cement will be used locally in construction, roads and mining and could create a new export industry for South Australia to nations such as Korea.
The project is supported by the South Australian Government who are signatories to a Statement of Cooperation signed in 2023 between Elecseed, Korea Hydro Nuclear Power and Hallett Group and aims to reduce Australia's total carbon dioxide emissions by 1% annually through the generation and use of green hydrogen.
The speech will focus on the journey so far and how Australia and Korea have collaborated on this globally intriguing project, the use of Korean technology and project programme.

300 Character Version
Cement accounts for 8 % of global carbon emissions a year, through a heating process. Project Helios is in partnership with the Korean Government and produces green cement through the use of redundant fly ash from a coal fired power station. The flyash moisture is removed by drying with Green Hydrogen using Korean Technology.

Company Introduction
Elecseed is a progressive Renewable Energy Developer and Consultancy providing innovation, technical eminence, funding, and multifaceted solutions to deal with the paradigm shift in how we generate, manage, and consume energy.
With offices in Seoul Korea and Brisbane and Adelaide in Australia, Elecseed identifies and leads specific market needs, not only to propel our drive to a greener future but also satisfy the immediate economic needs and demands. We have experience across the Asia Pacific in bringing the right partners to develop solutions across renewables including Photovoltaics, Wind, Hydrogen and Battery Storage technology, leveraging off strategic financial and engineering expertise.



Presenting today / 발표자



Robert Saunders | 로버트 손더스

B.Eng (Hons) Energy Engineering
London South Bank University
United Kingdom

Managing Director Elecseed | 일렉시드 호주법인장

Brisbane Australia
robert.saunders@elecseed.io

Presentation Index

- Elecseed
- Climate Change
- Supply and Demand
- Elecseed Masterplan
- Project Helios
- Scale up and Export

elecseed

Welcome to Elecseed

We are living in a significant time as nations and companies decarbonise their assets to meet aligned global targets and provide for a cleaner future.

Elecseed is a progressive Renewable Energy Developer and Consultancy providing innovation, technical eminence, funding, and multifaceted solutions to deal with the paradigm shift in how we generate, manage, and consume energy.

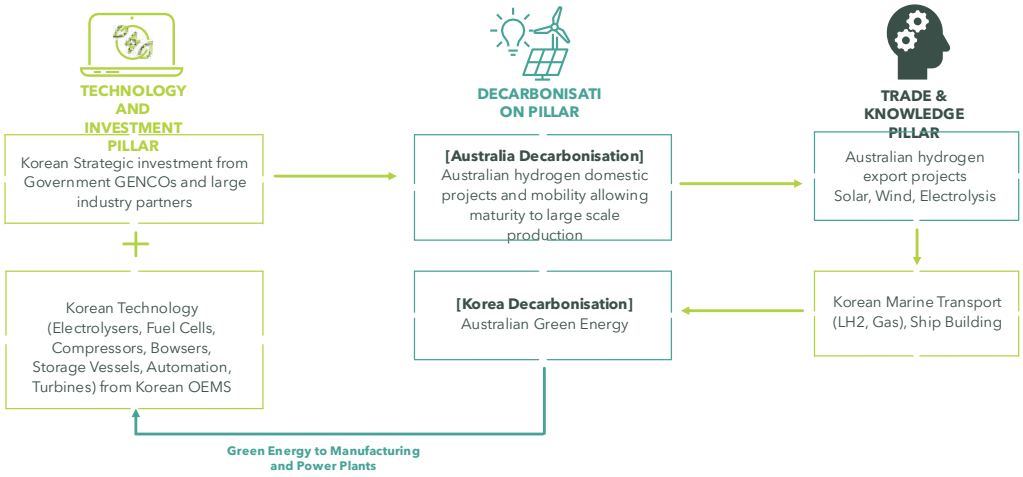
With offices in Seoul Korea and Brisbane Australia, Elecseed identifies and leads specific market needs, not only to propel our drive to a greener future but also satisfy the immediate economic needs and demands.

We have experience across the Asia Pacific in bringing the right partners to develop solutions across renewables including Photovoltaics, Wind, Hydrogen and Battery Storage technology, leveraging off strategic financial and engineering expertise.

Join us in our tenacious journey to a more sustainable and responsible world, driving the future of renewable energy solutions.



The "Closed Loop" between our nations – A Unique Mutual Opportunity





Global Concerns around the Environment





Environmental
- Climate change
- Resource depletion
- Waste
- Pollution
- Deforestation

Social
- Human rights
- Modern slavery
- Child labour
- Working conditions
- Employee relations

Governance
- Executive pay
- Corruption and bribery
- Board membership, diversion and inclusion

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You cannot ignore the Science

Greenhouse gas increase: Atmospheric concentrations of major greenhouse gases like carbon dioxide and methane are at their highest levels in at least two million years, largely due to human activities.

Observed warming: Global temperatures and sea surface temperatures have clearly risen since the 1800s. This warming is happening faster than at any point in recorded history.

Rising sea levels: Global mean sea levels are continuing to rise at an accelerating rate.

Ocean acidification: Oceans are becoming more acidic as they absorb excess carbon dioxide, which poses risks to marine life.

Extreme weather: The frequency and intensity of some extreme weather events are increasing. This includes more extreme heat events on land and in oceans, longer fire seasons, and decreased snow cover in alpine regions.

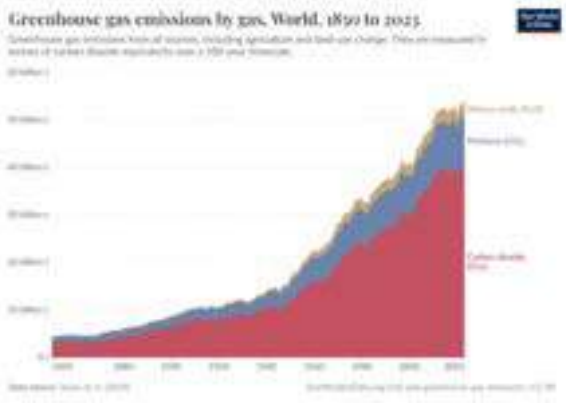
Glacial Melting: Melting glaciers are a significant consequence of human-caused climate change, primarily due to rising temperatures from greenhouse gas emissions

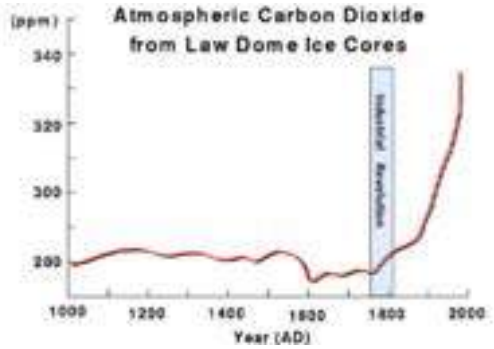


"Climate Change is destroying our path to sustainability. Ours is a World of looming challenges and increasingly limited resources. Sustainable development offers the best chance to adjust out course"

Bank Ki-moon
8th Secretary-General of the United Nations from 2007 to 2016

Climate Change and the Industrial Revolution





Human attribution: Human activities are responsible for virtually all the global heating over the last 200 years, with the burning of fossil fuels being the largest contributor.

Concentration of Carbon Dioxide from trapped air measurements for the DE08 ice core near the summit of Law Dome, Antarctica. (Data measured by CSIRO Division of Atmospheric Research from ice cores supplied by Australian Antarctic Division)



Australia – (The Supply)

- Global Demand for Green Hydrogen expected to increase rapidly as nations decarbonise.
- The Transformation to Hydrogen cannot occur without a stable green energy market and supply
- In the Southern Hemisphere, in particular Australia, that will be primarily through photovoltaics (solar)
- Australia with its land space, existing skills in the gas sector, port infrastructure and sunshine, is well placed to be a "**Food Bowl**" for Green Hydrogen production.
- Abundance of Critical Minerals





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Australia – A Green Energy "Super-Power"



Six Forms of Renewable Energy are easily supported in Australia

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The Republic of Korea – (The Demand)



- Enviable Manufacturing Capabilities
- Increasing Energy Requirements
- Globally Leading Technology
- Worldwide Investment Appetite

Total electricity production in Korea

Total, 2023

604580

Trend

↑109%



Source : International Energy Agency (IEA)

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The Republic of Korea – Green Hydrogen and Ammonia Demand

□ Source : The 11th Basic Plan for Electricity Supply and Demand (Draft)

Classification	Year of 2030	Year of 2038
Power Generation (Proportion)	15.5TWh(2.4%)	38.5TWh(2.4%)
Hydrogen and Ammonia Demand (Quantity Converted to Ammonia)	**6,650 Thousand. tons**	**16,520 Thousand. tons**

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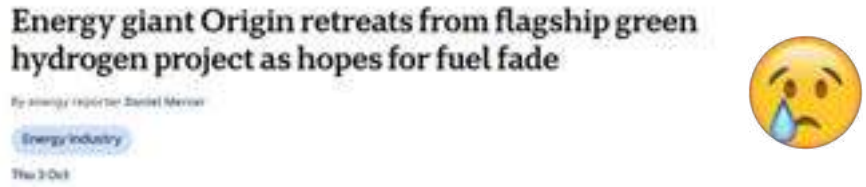
Negativity

- CQH2 - Queensland
- Trafigura – South Australia
- Origin Energy Hunter Valley
- AGL Torrens Island Hydrogen Hub
- Woodside
- Gibson Island


Developers dump Gladstone's Central Queensland Hydrogen Project CQH2

By Jasmine Hines · ABC Capricornia · Hydrogen Fuel

Mon 30 Jun


Energy giant Origin retreats from flagship green hydrogen project as hopes for fuel fade

By energy reporter Daniel Mercer

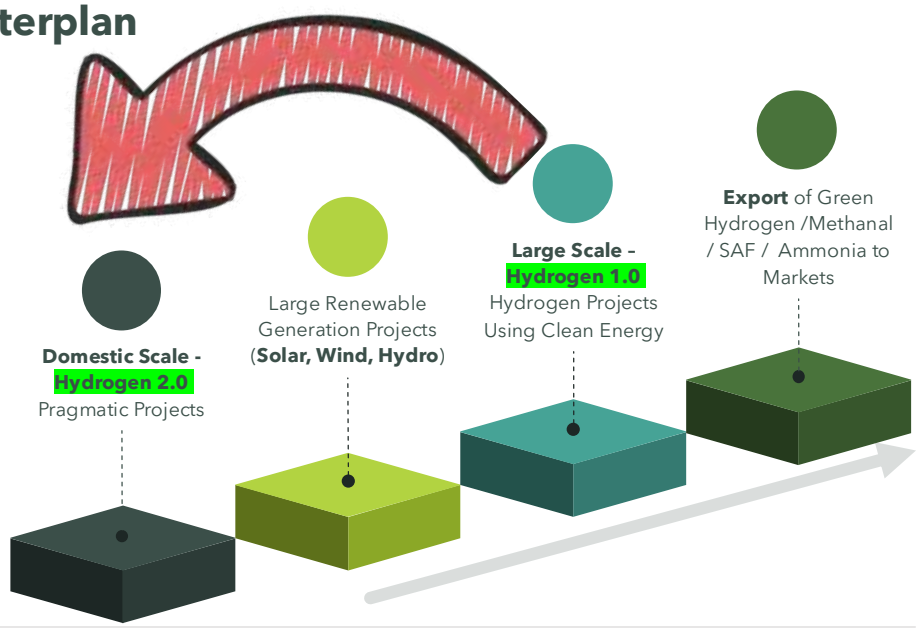
Energy Industry

Thu 3 Oct

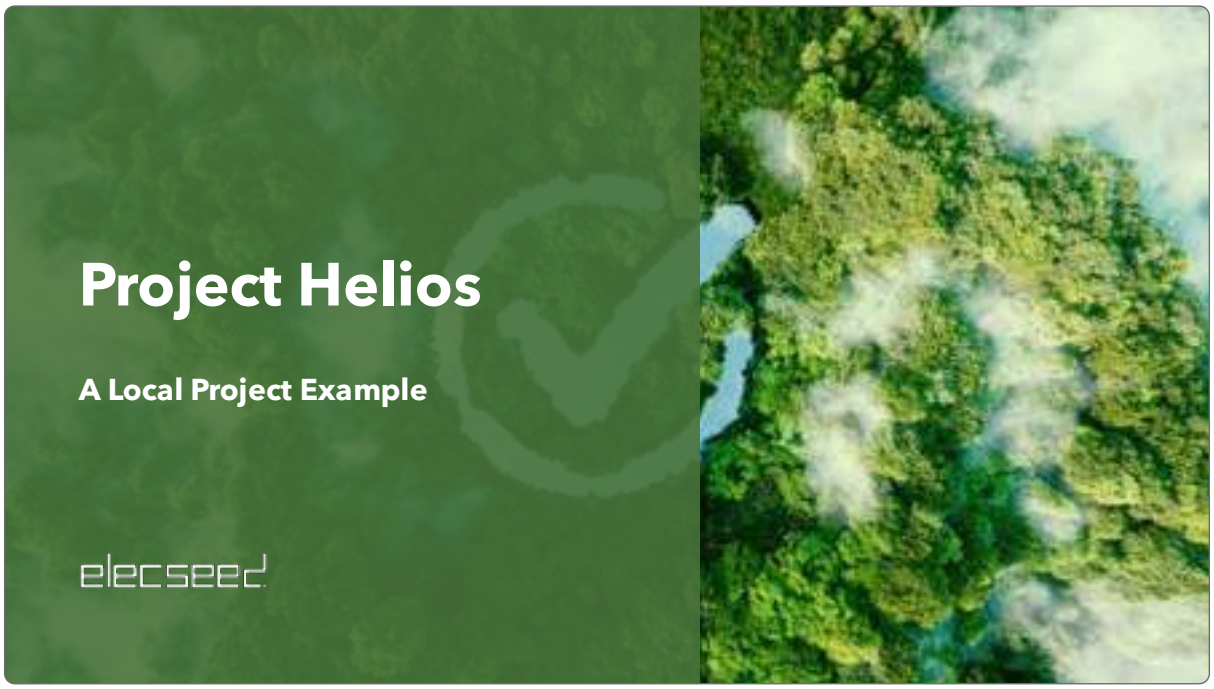
Several Large Scale Failed Projects – All Export Focused

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Masterplan



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Project Helios - Korea & Australia Collaboration



Elecseed
Developer & Investor
(Australian-Korean Business)

Hallett Group
Hydrogen Off-Taker
(Australian Business)

Korea Hydro & Nuclear Power
Strategic Investor
(Korean Government GENCO)

South Australia Government
Permitting, Support, Grant
(Australian State Government)

Cement Drying Process

Green Hydrogen made on site

Korean Technology and Strategic Investment

Global First

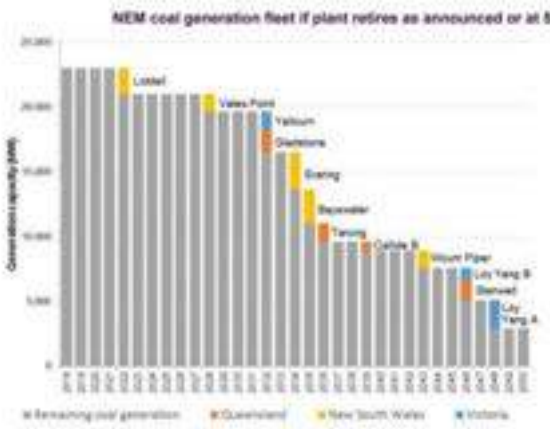
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Project Helios - A Cement Industry Project

- **In 2021**, world-wide emissions from making cement produced about **2.9 Billion metric tonnes of CO2**. For perspective, if the cement industry was a country, it would be **the fourth largest national emitter in the world**, behind China, the US and India (Source : CSIRO)
- Global Demand for concrete and cement is predicted to grow **12 to 23 %** above todays levels by 2050 (Source : Scientific America) – although in Korea has declined in 2025 due to a construction recession
- **Coal Fired Power Stations are being closed** around the World and **leaving layers of flyash**, used as a **feedstock for supplementary cementitious materials (SCM)**
- **Australia currently consumes around 12 million tons per annum** of cement with around half of this imported in the form of finished (powdered) cement or cement clinker.
- The Helios project will use existing and proven technology to manufacture supplementary cementitious materials (SCMs) that can **replace greater than 50% of traditional high CO_2 emitting** clinker-based cement.

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Australian Coal Fired Power Station Closure - Flyash





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Project Helios Site – 40 Years Supply of Flyash



Circular Economy

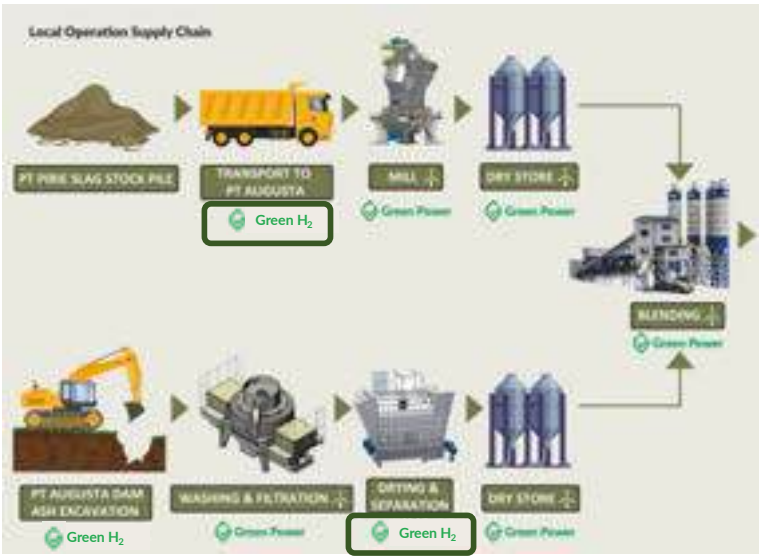
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Approximately 22 to 5% Moisture through a Drying Process



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Overall Project Flow



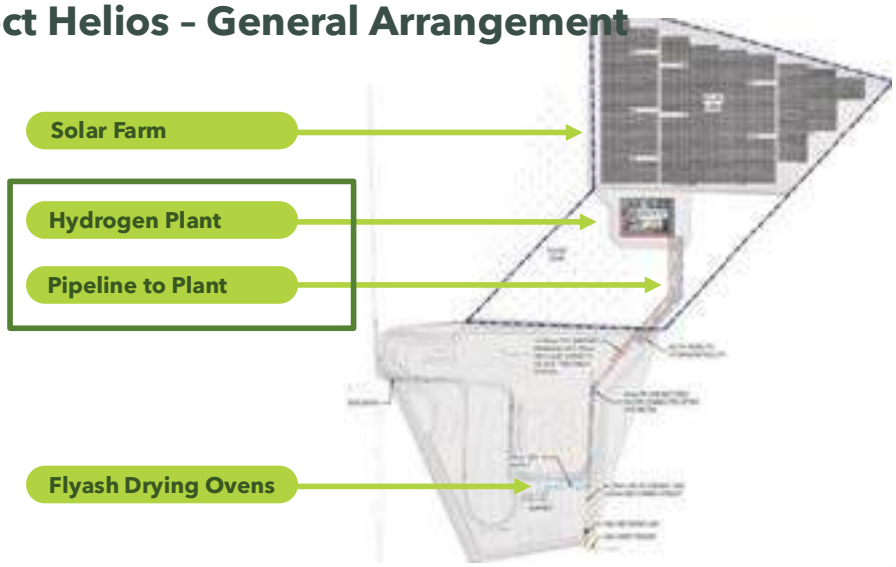
Rail





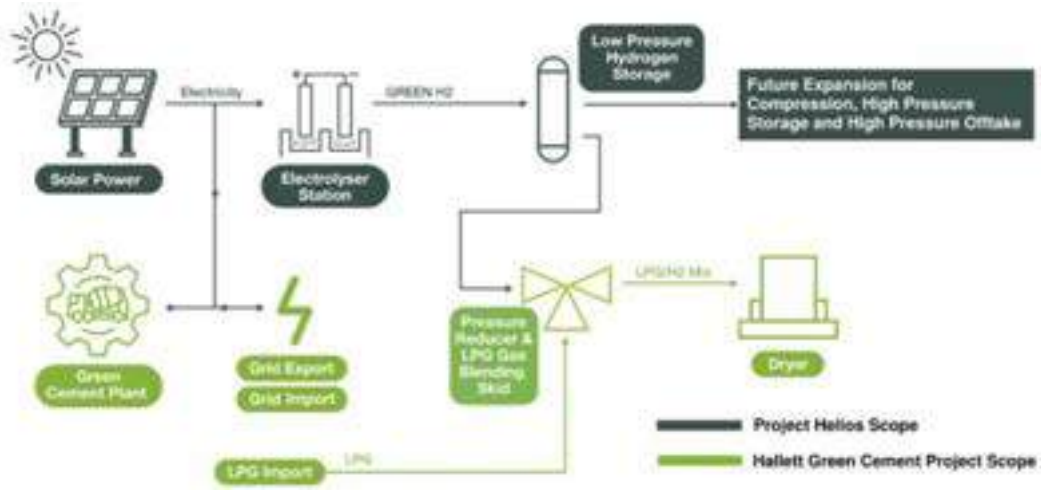
H_2 &/or Electric Truck

Project Helios – General Arrangement



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Blend – then scale up



South Australia – a Critical Minerals Super Hub





Green Cement → Critical Mineral Mines → Export to Korea





Multiple Domestic Applications

(Gas, Diesel, Oil Replacement)



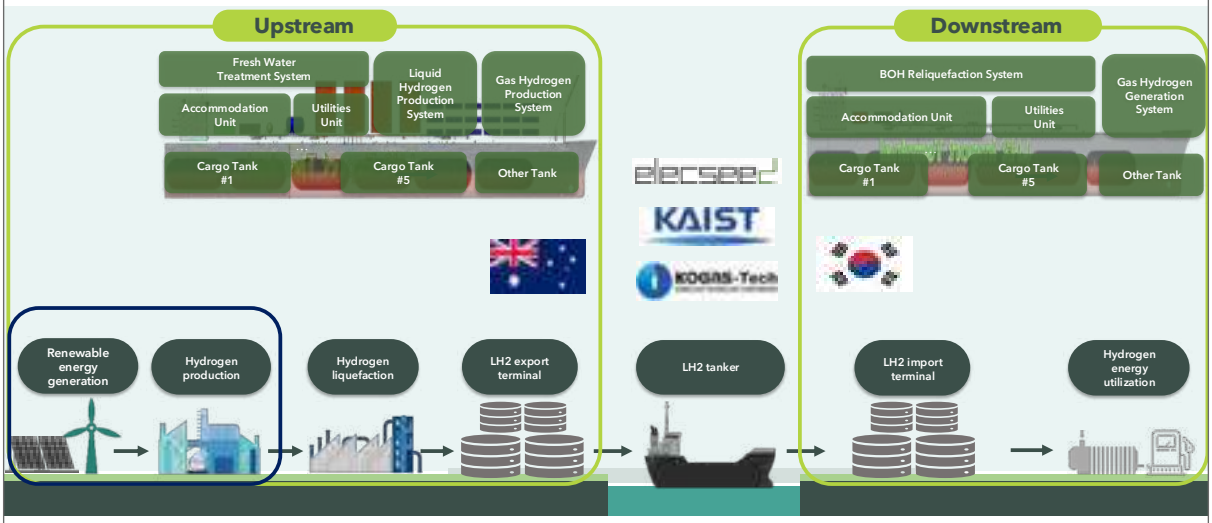
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Scale up and Export

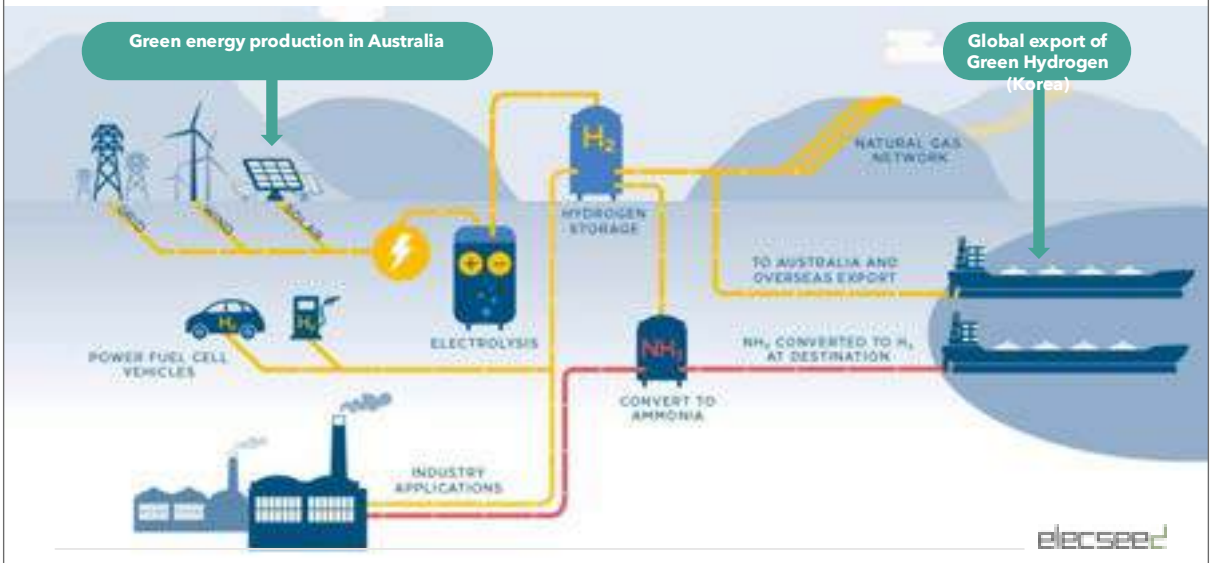


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Logistics - KETEP National Study (에너지기술평가원 지원과제)



Green Hydrogen – Export, The Big Picture



Adjacent to Deep Sea Port Location



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elecseed

Thank you
감사합니다



Driving future energy

Breakthroughs in Hydrogen Production Techniques 3

Catalyzed heat exchanger for fuel processing



Amin Mehdipoor
Business Development Manager, Catator AB

Education
2011-2008, M.S., Innovative & Sustainable Chemical Engineering, Chalmers University of Technology, Gothenburg, Sweden
2007-2002, B.S., Chemical Engineering, Amin Kabir University of Technology, Tehran, Iran

Professional Career
2025 – now, Business Development Manager, Catator AB, Sweden
2025-2021, Technical Sales Manager, Grolman Group, Sweden
2021-2020, Business Development Manager, Iris.ai
2020-2018, Algol Chemicals, Sweden
2018-2015, Johnson Matthey, Sweden
2015-2014, Nordic Sugar, Denmark
2014-2013, Encubator AB, Sweden
2008-2006, Tam Irankhodro, Iran

Speech Summary
Showcasing Catator's advanced catalyzed heat exchanger for efficient catalytic fuel processing, and our catalytic burner series for off gas combustion—delivering compact and robust hydrogen solutions for next-gen energy systems

Company Introduction
Catator develops advanced catalytic solutions for efficient, clean hydrogen energy systems.



Content

Company Overview
Core Technology: CataLite Coatings
Fuel Cell applications: CataLite Reformers
Electrolyzer applications: CataLite Burners

Catator in brief

World-leading contract development partner for commercialization of hydrogen

- Based in Lund, Sweden and at the forefront of hydrogen-related catalysis for three decades.
- Based on the CataLite Coating technology and innovative designs for reactors, reformers, and burners, we deliver catalyzed hardware to industry leaders.
- We deliver solutions for Electrolyzer & Fuel Cell Manufacturers, Syngas & E-fuel production, and Fuel Reforming & Processing.



3

Integrated Catalyzed Hardware



CataLite® Coatings
Structured catalysis

Patented multi-stage technology enabling the application of catalysts to virtually any metal surface, ensuring strong adhesion of a highly porous and active catalytic layer, enhancing heat and mass transfer and enabling smaller catalyst volumes and reactor sizes.



Contract Development Services
Unmatched application expertise

More than 30 years of in-house application experience, design expertise and track record as a development partner to leading hydrogen technology pioneers.



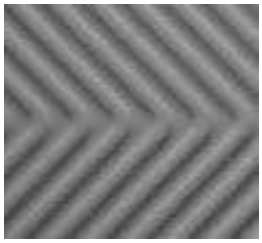
Hardware
Integrated solutions

From design, construction, prototyping, and manufacturing, we serve as an integral part of the customers' supply chain to deliver ground-breaking Reactors, Reformers, Burners, and Fuel Processing Systems.

4

Catator

Technology platforms



CataLite® Synreactors

Reactor cells reimagined

Compact reactors for decentralized, small-scale production of e-fuel.



CataLite® Reformers

Thermally integrated fuel reforming

Efficient reformers for conversion of e-fuels to hydrogen or other reformates.



CataLite® Burners

Compact combustion. Zero emissions.

Catalytic burners for combustion in P2X and X2P applications.



CataLite® Systems

Efficient e-fuel processing systems

Complete systems for processing of e-fuels and their off-gases.

Catator

Content

Company Overview

Core Technology: CataLite Coatings

Fuel Cell applications: CataLite Reformers

Electrolyzer applications: CataLite Burners & DeOxo units

Catator

CataLite® Coatings

Unprecedented levels of performance and design freedom

The CataLite® technology enables a highly adhesive, nano-porous, and structured Catalytic layer that can directly integrated with advanced reactors, reformers and burners.

Benefits

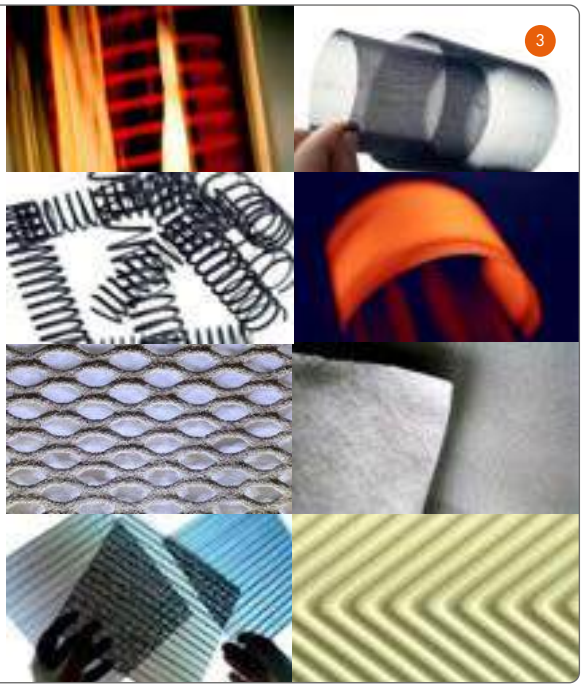
Reduced reactor size. Up to 80% size reduction compared to conventional catalysts due to higher mass and transfer capacity

Enhanced efficiency. Reduced thermal losses due to compact reactor geometry and integrated process solutions

Long-lasting performance. Unmatched thermo-mechanical durability and heat conductivity, extending system lifespan and ensuring uniform conversion

Limitless scalability and design freedom. Ability to dimension to any capacity requirement. Higher performance through tailoring of geometrical structure for each application.

7



Coating Stability

Thermal Cycling CataLite® Plates

Catalyst specification

Plate material: AISI 310

Catalyst comp.: Stabilized Platina on γ-Al_2O_3

Test method

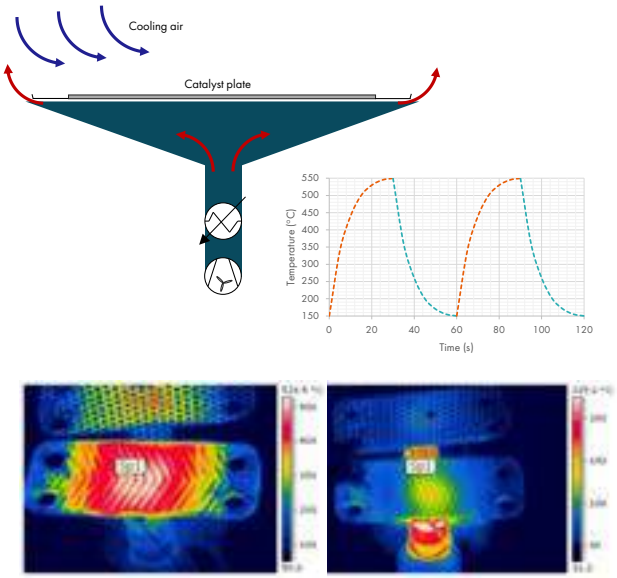
Continuous temperature cycling between 150 and 550°C

Conditions: 1020 cycles of 60 s each

Conclusions

Catalyst coating highly stable, weight loss of catalyst < 1 wt%

8



Catator

Coating Stability

Wire mesh vs metal monolith substrate

Catalyst specification

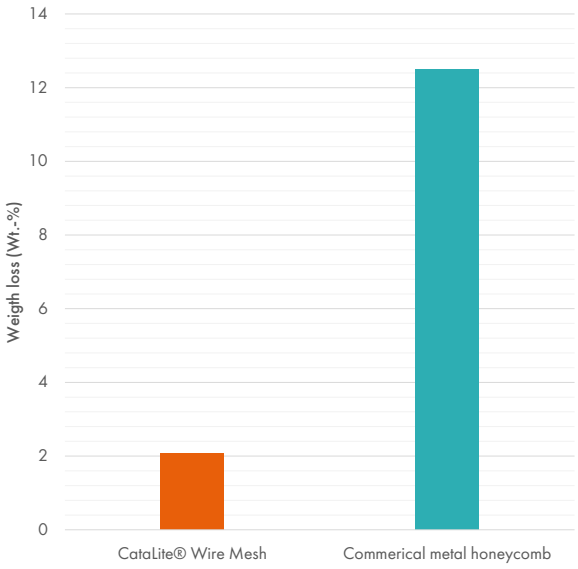
Mesh material: High temperature ferritic stainless steel EN 1.4767
Wire diameter: 0.5 mm
Mesh opening: 1.3 mm
Catalyst comp.: Stabilized Platina on γ-Al_2O_3

Test method

Catalyst heated in oven at 1000°C for 24 h followed by ultrasonic treatment of catalyst in room temperature.

Conclusions

Commercial automotive metal monolith catalyst shows approx. 6 times higher weight loss than the wire mesh CataLite® catalyst



Catator

9

Catalyst Performance

Case example Natural Gas combustion: Long-term performance at elevated temperatures

Catalyst specification

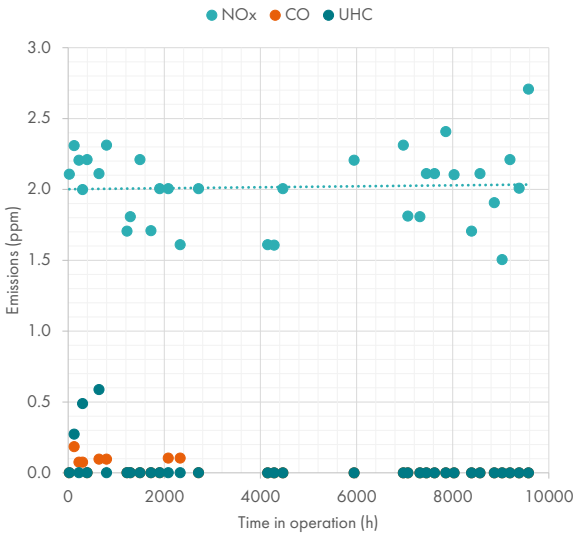
Mesh material: High temperature ferritic stainless steel EN 1.4767
Catalyst comp.: Stabilized Platina on CeO_2/γ-Al_2O_3

Test method

Combustion of natural gas over a CataLite® burner for 10,000 h
Estimated operating temperature between 800-1000°C

Conclusions

Very stable emission levels over the entire test period. Expected life above 20,000 h on stream.



Catator

10

Content

Company Overview

Core Technology: CataLite Coatings

Fuel Cell applications: CataLite Reformers

Electrolyzer applications: CataLite Burners & DeOxo units

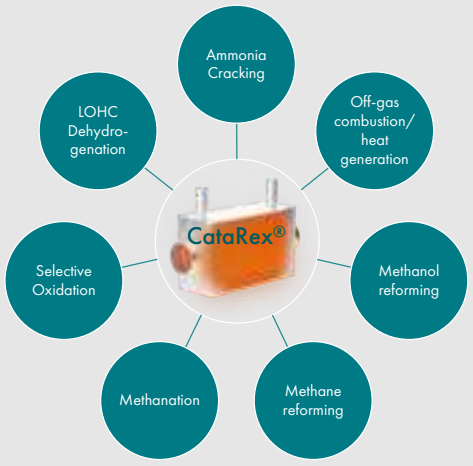
Catator

CataRex® Reactor technology

For production and reforming of electro-fuels

- Catalyzed Heat Exchange Reactor
- Integrates catalytic reactions and heat exchange to produce heat, synthesize, or reform e-fuels.
- Shell-and-tube or shell-and-plate heat exchangers with CataLite® coating on one or both sides of the tubes or plates
- CataRex® allows for the integration and close thermal coupling of exothermal and endothermal reaction into a single system, enabling process intensification and space savings.





Catator

CataLite® Reformers

Case Example: CataRex Ammonia Cracker

- Ammonia Fuel Processing Unit with integrated Thermal Processing to produce hydrogen for an SOFC
- Based on the CataRex® technology

Shell-and-plate or tubular design

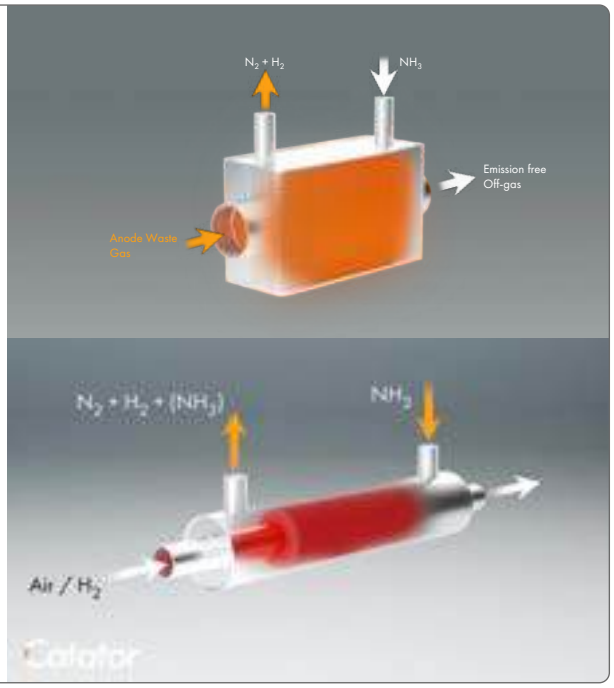
Shell-and-plate design

- Very compact solution optimal for low pressure operation i.e. a few bars
- Extremely high heat transfer capacity
- Pressure drop control on both sides through dimension of gap between plates

Tubular design

- Very robust solution optimal for operation at elevated pressures
- Tube in tube principle - combustion in the centre tube and reforming over coated mesh-type of catalysts placed in the outer tube

13



Content

Company Overview

Core Technology: CataLite Coatings

Fuel Cell applications: CataLite Reformers

Electrolyzer applications: CataLite Burners

14

Catator

CataLite® Burners





Case Example: Off-gas Burner for Electrolyzer

- **Hydrogen Production:** H2 emissions during upstart and transient conditions
- **Syngas production:** CO emissions during upstart and transient conditions

Case Example: Anode Off-gas Burner for Fuel Cells

- Catalytic combustion of Anode off-gas



15

Catator

Catator

Catator AB
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SE-226 60 Lund, Sweden
info@catator.com
catator.com

Breakthroughs in Hydrogen Production Techniques 4

Precision hydrogen flow measurement in SOFC and SOEC applications



Peter Brouwer
Market Developer Renewable Energy,
Bronkhorst High-Tech B.V.

Education
1997 - 2000, M.S., Electrical and Electronic Engineering, Twente University, Enschede, The Netherlands
1994 – 1997, B.S., Electrical and Electronic Engineering, Hanzehogeschool, Groningen, The Netherlands

Professional Career
2025-Present, Head of Product Management and Market Development, Bronkhorst High-Tech B.V., The Netherlands
2023-2025, Market Developer Renewable Energy, Bronkhorst High-Tech B.V., The Netherlands
2023-Present, Board Member NWBA (Dutch Hydrogen and Fuel Cell Association), The Netherlands
2014-2023, Manager Education and Research, HAN University of Applied Sciences, School OF Engineering & Automotive, Arnhem, The Netherlands
2001-2014, Senior Engineer and Team Leader R&D, Bronkhorst High-Tech B.V, The Netherlands

Research Interest
Neutral-color Transparent Solar Cells for Smart Window
Optically Enhanced Flexible Crystalline Silicon Solar Cells
Hybrid Energy Conversion and Storage Devices
Joule-heating based Solar Steam for Water Purification and Desalination

Speech Summary
Solid Oxide FC/EC technology is very promising for stationary hydrogen application, mainly because of its high efficiency compared to PEM or alkaline technology. It is no surprise that there is increasing focus on this technology.
However, high temperatures, water vapor and sensitive system components makes hydrogen flow measurement and control challenging in these systems. Bronkhorst offers flow measurement solutions with advanced functionality, specifically designed to adapt to these demanding applications. Additionally, our flow meters can be calibrated in a circulation rig with hydrogen, eliminating the need for surrogate gas and ensuring the lowest measurement uncertainties.
We invite you to join our presentation to learn more about these innovative solutions and how they can benefit your applications. Don't miss this opportunity to gain valuable insights and ask any questions you may have.

Company Introduction
We are the low-flow specialists.
We offer the most extensive range of low-flow (mass) flow meters and controllers on the market. From standard models to tailor-made solutions, our instruments are designed to meet the demands of laboratories, machinery, industrial applications, and even hazardous environments—ensuring precision and reliability in every process.

Bronkhorst®

The low-flow specialists

© Bronkhorst | 26-11-2025

Precision hydrogen flow measurement

in SOFC and SOEC applications

Peter Brouwer| Seoul | 5 December, 2025



Bronkhorst®

Introduction



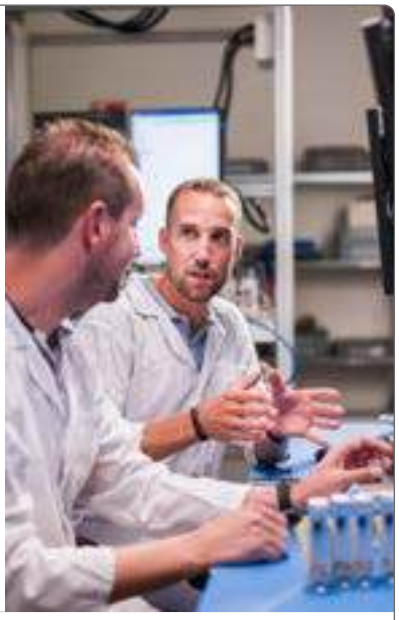
Product and Market Development Manager

Peter Brouwer

"Shaping the future means delivering the right solutions for tomorrow's market;
driven by innovation, guided by sustainability."

Innovative low-flow specialist

- Bronkhorst is a PIONEER
  … in the field of innovative, micro- to low-flow gas and liquid metering instruments. We are setting new standards, not following others.
- Bronkhorst is a CREATOR
  … developing and manufacturing the most extensive range of low flow instruments. Not available doesn't mean impossible. Put us to the test!
- Bronkhorst is committed to COLLABORATION
  … in designing and producing innovative, customized configurations. Our skilled engineers go above and beyond to assist our customers around the world.



Extensive expertise in many markets



Place your subtitle here

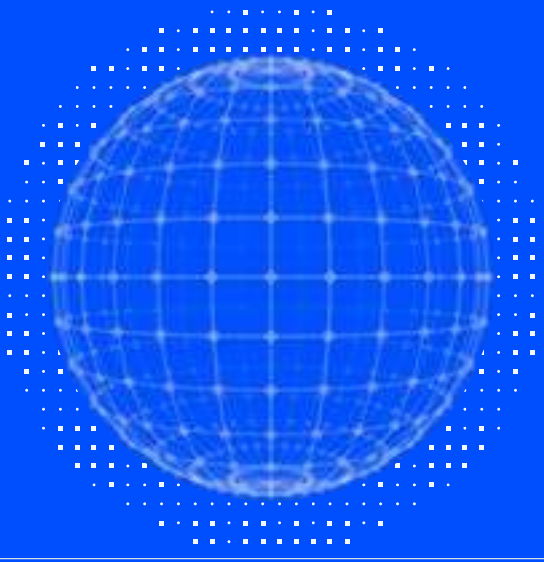
Our worldwide presence

40+ years experience in Mass Flow & Pressure

800+ employees corporatewide

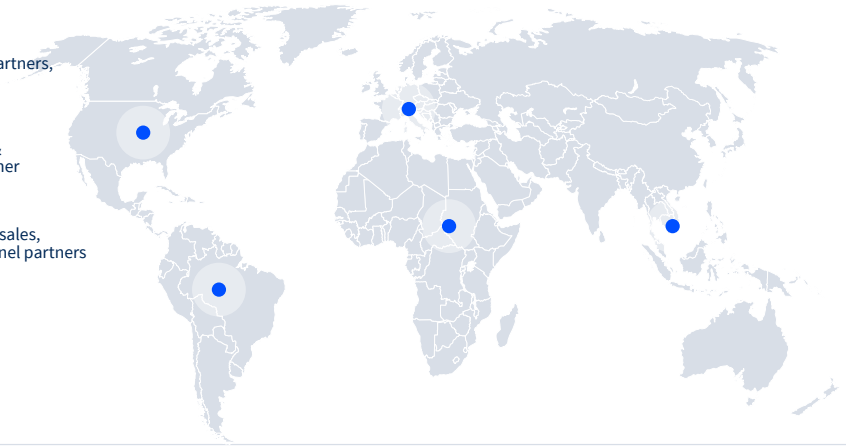
24H round-the-clock technical support

1 mln+ instruments in the field



Worldwide sales & support

- **Europe**
  5 subsidiaries, 17 channel partners, 4 production locations
- **North America**
  1 subsidiary (sales, service & production), 1 channel partner
- **Asia & Oceania**
  6 subsidiaries, 1 subsidiary (sales, service, production), 8 channel partners
- **South America**
  2 channel partners
- **Africa & Middle East**
  2 channel partners



Introduction into

Solid Oxide technology

Solid Oxide is…

A technology…

- In development
- To build
  - Electrolyser cells (SOEC)
  - Fuel cells (SOFC)
- Has a solid oxide electrolyte
  - Activated at high temperatures (700+ °C)
  - Transporting O^{2-} ions



Core products - Ceres Power Holdings plc

Advantages of Solid Oxide technology



High Efficiency

Up to 85% efficient
(when reusing heat)



Simultanious CO_2 electrolysis

Syn gas production for e-fuel synthesis



Fuel Flexibility

A Solid Oxide Fuel Cell can be operated with many fuels, not only hydrogen

Research topics on solid oxide technology



Thermal management

Temperature gradients
Thermo-mechanical stress
Dynamic strategies



Stability

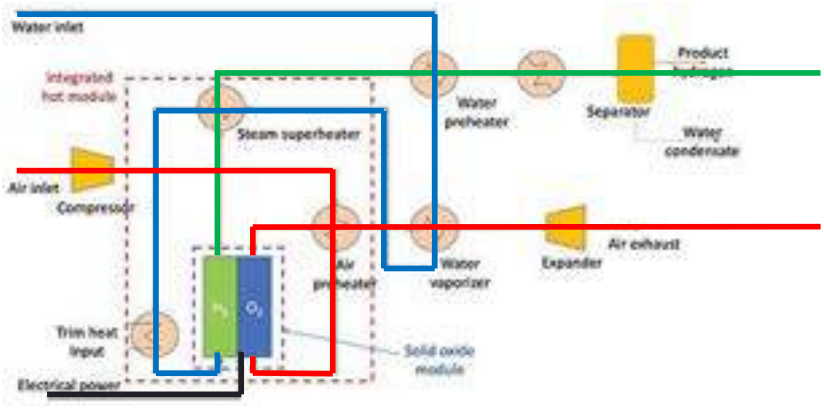
Material degradation
New materials
Integration techniques



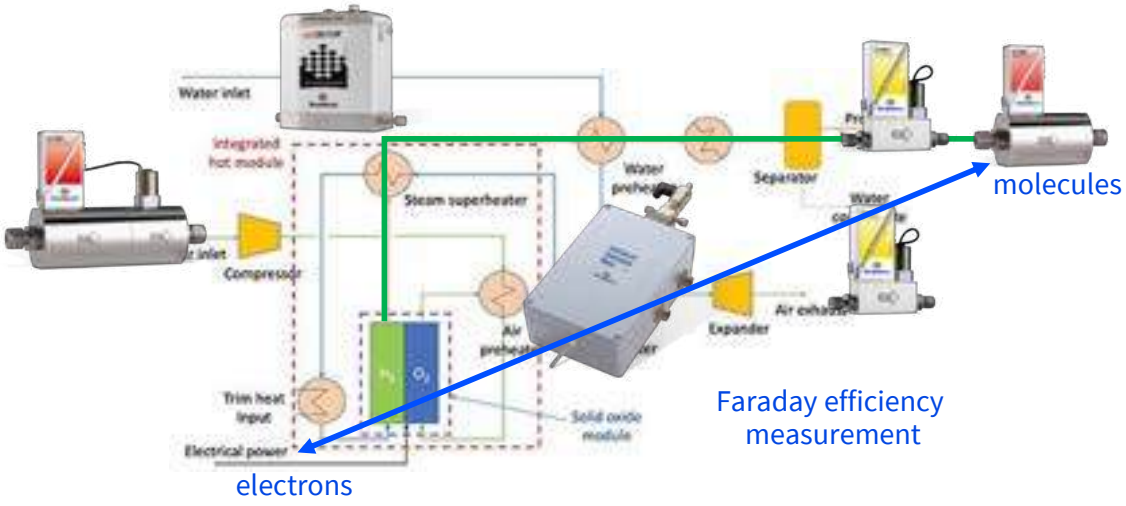
Faraday Efficiency

Percentage of electrons used for chemical reaction
Measure for leakages and side reactions

Typical Balance of Plant for SOEC



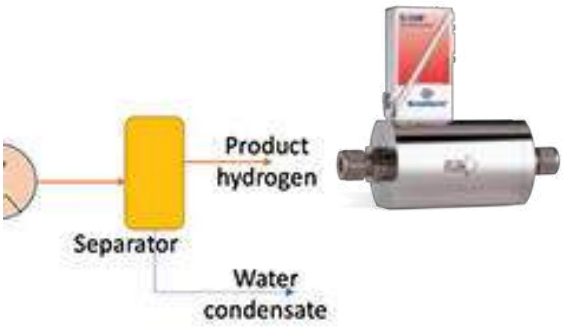
Instrumentation for research on SOEC



Hydrogen flow measurement

Requirements
- High accuracy
  - For Faraday efficiency

Challenges
- High temperature
- Temperature gradients
- Humidity, ‘wet hydrogen’



Measurement tips

Starting points

1. Choose an accurate flow meter
2. Prevent temperature gradients
3. Dry the gas as much as possible

Subsequent steps

1. Calibrate instrument
2. Convert for mixture with water vapor
3. Create stable environment



Our solutions

Real gas calibration

- Bronkhorst offers hydrogen real gas calibration as option
  - for new products
  - (re)calibration
- Range 1 ml_n/min up to 200 m^3_n/h H_2
- Closed loop gas recirculation system
- Best possible accuracy!



Real time gas conversion

- FLUIDAT® on board available in
  - EL-FLOW Prestige
  - FLEXI-FLOW Compact
- Mixtures can be created in the instrument, e.g. H_2 and H_2O
  - Ratio can be modified in real time for variable gas mixtures!
- Relative humidity sensor can be used as input for gas mixture modification



Product Announcements

→ EX-Flow X200



- The next generation of intrinsically safe gas flow meters and controllers designed for hazardous environments
- The new EX-FLOW design makes the integration into your system simpler and cost-effective
- Compact, for IECEx Gb and ATEX zone 1 applications
- Direct hookup to safety barriers, no need for expensive cables or control units
- Scheduled for release in 2026

IN-FLOW upgrade



- High flow and high accuracy are main specifications for electrolysers / fuel cell test equipment
- New electronics and sensor design enables faster response and higher accuracy
- FLUIDAT on board for easy reconfiguration
- Integrated Mass Flow Controller up to 1000 m3n/h
- Scheduled for release in 2026

Conclusions

- We are the low flow specialists
- Our focus is on energy transition
- Solid Oxide technology is very promising
- Development requires accurate instrumentation, but flow measurement is challenging
- We offer solutions
  - Real gas calibration
  - Real time conversion of changing mixtures
- We develop new instruments for demanding hydrogen applications





Thank you for your attention!

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www.bronkhorst.kr

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Bronkhorst

Meet us in Hall: B5 Stand: 5F70

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Breakthroughs in Hydrogen Production Techniques 5

Accelerating clean hydrogen solutions with High-efficiency heat exchangers



MyoungSoo Shin
Professional of Sales Manager,Alfa Laval

Education
2024-2010, bachelor's degree, Naval Architecture & Ocean Engineering, Inha University, Seoul, Korea

Professional Career
2010-2014, Assistant manager, Offshore structural design team, STX Offshore & Shipbuilding
2015-2018, Assistant manager, Sales team, Jone Crane Korea
2018-present, Professional, ENERGY Div.-BU WHE&GPP, Alfa Laval Korea

Research Interest
AFC, PAFC, FEMFC system R&D
International Standard for Fuel cell
Catalysts and MEA research
Physical mobility for hydrogen fuel cell system

Speech Summary
Alfa Laval's hydrogen leadership accelerates the clean hydrogen economy. By focusing on energy efficiency, system optimization, and scalable technologies, Alfa Laval aims to reduce production costs and support global projects like flagship, NEOM and HOPE. Their advanced heat transfer solutions support a key role in enabling sustainable hydrogen applications across industries.

Company Introduction
Alfa Laval is a global clean energy solutions company that pursues energy efficiency and sustainability based on heat exchange, fluid handling, and separation technologies.

Accelerating clean hydrogen solutions



August 2023

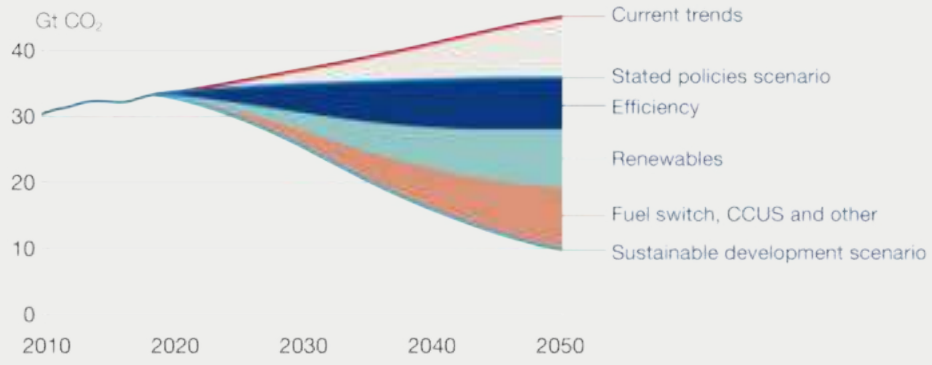
Classified by Alfa Laval as: Business

17/11/2025

Alfa Laval

Transition to clean energy

2 |



Decarbonization requires a two-folded strategy

3 |

Make existing industry more sustainable



Enable the transition to clean energy and circularity



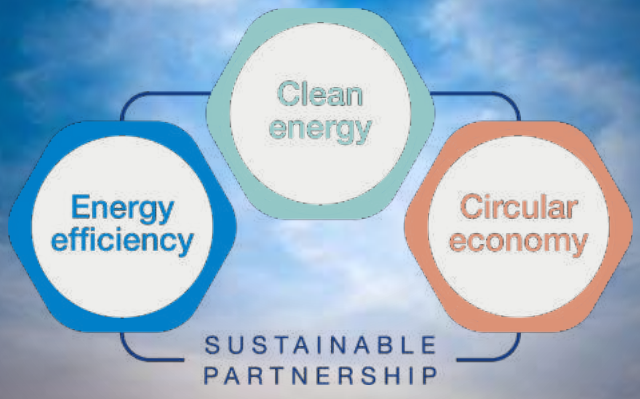
Accelerating clean hydrogen solutions

Alfa Laval

Sustainability focus areas in Alfa Laval

4

with customers



Accelerating clean hydrogen solutions

Alfa Laval

Alfa Lavals offering in Clean energy

5


Energy Hunter

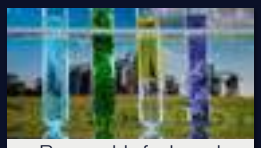

Hydrogen


Carbon capture utilization and storage


Energy storage


Data center


District Energy


Renewable fuels and chemicals

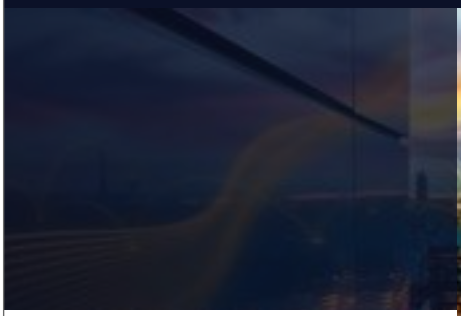
Accelerating clean hydrogen solutions

Alfa Laval

Accelerating decarbonization through energy efficiency

6

Alfa Laval as a part of the Energy Efficiency Movement



Energy Efficiency Movement
An open-door initiative bringing stakeholders together to raise awareness and accelerate actions to increase global energy efficiency – our 'first fuel' to a decarbonized future. We just need to make it happen, together!

Join us and be part of the solution!
www.alfalaval.com/energyefficiencymovement



Energy savings

Resource savings

Emission savings

READ MORE >


Watt's it worth?
Energy savings
50 GW
Emission reduction
25 MT
10 million
households
Paris
Accelerating clean hydrogen solutions
Alfa Laval


Accelerating clean hydrogen solutions
8
Alfa Laval as supporting member of the Hydrogen Council
Hydrogen Council
Alfa Laval, together with the about 140 other members share a united vision and long-term ambition: for hydrogen to foster the clean energy transition for a better, more resilient future.
With Alfa Laval's proprietary technologies and heat transfer expertise in combination with our global manufacturing capabilities, we enable the acceleration of a hydrogen economy through energy efficient and scalable solutions.
Hydrogen Council
Energy savings
Resource savings
Emission savings
READ MORE >

Accelerating clean hydrogen solutions

9

Alfa Laval as supporting member of the most important Hydrogen and energy efficiency organizations



Decarbonization drives the clean hydrogen market

10

More than 90 countries with **Net-Zero targets**

Key enablers for the energy transition:

- Massive electrification
- Clean molecules
- Energy efficiency

Over 50 countries have introduced **hydrogen strategies**

Upp to 20% of global energy from hydrogen 2050



Clean hydrogen – a future energy carrier

- Hydrogen demand continues to grow as it holds huge potential for **enabling the energy transition** – in particular for the hard-to-abate sectors
- Renewable hydrogen is a **zero-emission solution** for industrial processes, power or heat generation and as fuel in the transportation sector
- Alfa Laval **offers a wide portfolio** of heat transfer technologies for compact, efficient and scalable clean hydrogen production, distribution, storage and end-use applications.



Accelerating clean hydrogen solutions



Accelerating clean hydrogen solutions

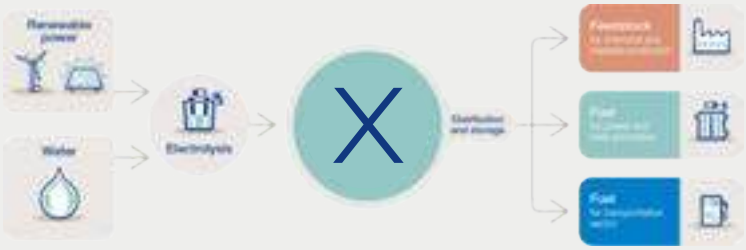
Alfa Laval

Heat transfer optimization across the value chain

13

Renewable hydrogen production:
- Electrolyser cooling
- Process water desalination
- Post-treatment cooling
- Plant cooling
- Waste heat recovery

End-use applications:
- Hydrogen refuelling stations
- Fuel cell development
- Industrial use, power-to-X
- Waste heat recovery



Accelerating clean hydrogen solutions

Alfa Laval

Innovative heat transfer technologies

14

combining outstanding performance with remarkable compactness



Alfa Laval gasketed plate-and-frame heat exchangers



Alfa Laval printed circuit heat exchangers



Alfa Laval freshwater generators



Alfa Laval fusion-bonded plate exchangers

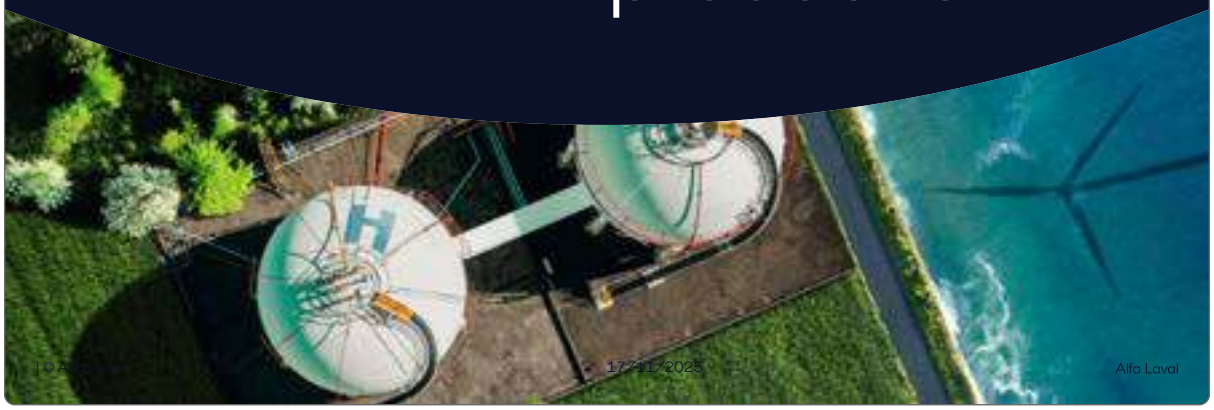


Alfa Laval finned tube air heat exchangers

Accelerating clean hydrogen solutions

Alfa Laval

Renewable hydrogen production



Innovative heat transfer technologies

16

combining outstanding performance with remarkable compactness



Alfa Laval gasketed plate-and-frame heat exchangers



Alfa Laval printed circuit heat exchangers



Alfa Laval freshwater generators



Alfa Laval fusion-bonded plate exchangers



Alfa Laval finned tube air heat exchangers

Heat transfer technology across the value chain

17



Heat transfer needs:

1. Electrolyte cooling
2. Gas cooling
3. Process water desalination
4. Post-treatment cooling
5. Overall plant cooling
6. Waste heat recovery
7. End-use applications

Accelerating clean hydrogen solutions

Alfa Laval

Heat transfer technology connected the stack

Alfa Laval plate heat exchangers for electrolyser cooling

- ✓ Maximizing electrolyser performance
- ✓ Optimizing equipment lifetime
- ✓ Securing oxygen-safe operation

Alfa Laval portfolio

Innovative heat transfer technology

Wide range from small to large

Material expertise



Alfa Laval gasketed plate-and-frame heat exchangers



Alfa Laval fusion-bonded plate exchangers



Accelerating clean hydrogen solutions

Renewable hydrogen production insights

19

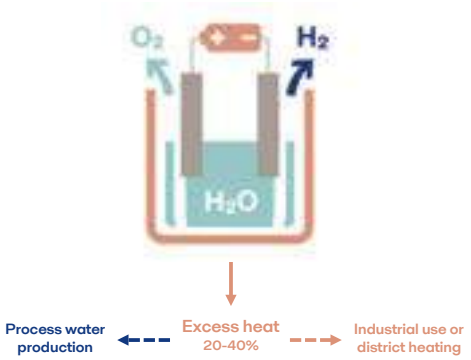
Alkaline and PEM technologies



Electrolysis generate **20-40% excess heat**. Optimized temperature control is crucial for maximizing process efficiency and equipment lifetime



Every 10 MW electrolyser capacity needs around **50-60 m³/day of clean water**. Process water desalination crucial to maximize electrolyser performance



Accelerating clean hydrogen solutions

Alfa Laval

Process water generation for electrolysis

20

Thermal desalination with Alfa Laval freshwater generator



Combining cooling and water generation with
- ✓ Smallest footprint
- ✓ Minimized chemicals
- ✓ Minimized electricity consumption
- ✓ Low maintenance needs

Desalination with conventional reverse osmosis



Accelerating clean hydrogen solutions

Alfa Laval

Accelerating desalination performance

- **Alfa Laval fresh water generators** for process water desalination
  - ✓ Enabling a smaller footprint
  - ✓ Reducing chemicals
  - ✓ Reducing electricity consumption
- **Alfa Laval portfolio**
  - Innovative heat transfer technology
  - Offshore and onshore applications
  - Wide range: capacity 2.0 - 7000 m^3/day
  - Material expertise, titanium plates
  - High quality freshwater, <<2ppm TDS

Accelerating clean hydrogen solutions



Alfa Laval MEP



Alfa Laval AQUA

Renewable hydrogen as a beacon of hope

22

Thyssenkrupp, Germany





A pioneering electrolysis pilot reduces CO_2 emissions in both steelmaking and chemical production. Heat exchangers from Alfa Laval cool the hydrogen, oxygen and catholyte as well as condense the moisture.



Energy savings

Emission savings

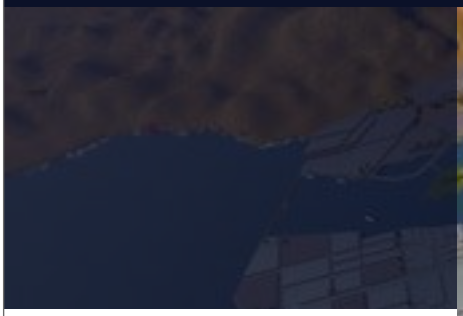
Technology shift

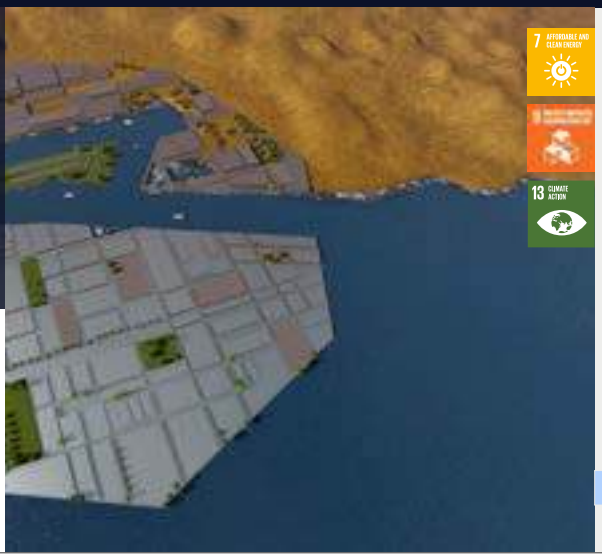
READ MORE >

Cooling the world's largest green hydrogen plant

23

NEOM, Saudi Arabia





Cooling both the electrolyser, the gases and the plant itself, Alfa Laval plate heat exchangers will provide reliable and efficient cooling in the world's largest green hydrogen plant, which is to be located in the city of NEOM in Saudi Arabia.



Energy savings

Emission savings

Cost savings

READ MORE >

Power-to-X



Power-to-X

- Power-to-X (P2X) is a key component in decarbonizing the chemical, marine and aviation industries by converting electricity into gaseous or liquid fuels or chemicals
- "X" refers to: clean ammonia, e-methanol, methane, renewable hydrogen and syngas
- Power-to-X can enable more sustainable industry, transportation and energy storage while utilising existing infrastructure, as well as provide an important energy storage solution.
- Alfa Laval's efficient heat exchangers have a proven record of securing highly cost-effective production from the chemical industry



Accelerating clean hydrogen solutions

Alfa Laval's Power-to-X offering

26

E-methanol

- Combining renewable hydrogen with a CO_2 source opens up the path to e-methanol
- Apart from being used as fuel and energy storage, e- methanol is also instrumental for decarbonizing the chemical industry
- Alfa Laval supports smaller scale markets with the same high quality of solutions and services as for mega-sized plants
- Our compact technologies are suitable for a wide range of applications; steam generation, reactor interchangers, distillation section exchangers including reboilers and condensers, as well utility cooling and heating

Clean ammonia

- Ammonia is well established as a cornerstone of the fertilizer industry, but it also plays a significant role in refrigeration systems
- Clean ammonia is creating new possibilities for areas like fuel and energy storage
- Alfa Laval has a long track record of supporting the ammonia industry
- Our process heat transfer are suitable for a wide range of applications in green ammonia: waste heat boilers, steam drums and ammonia condensers, as well as utility cooling and heating to maximize energy efficiency

Accelerating clean hydrogen solutions

Alfa Laval

Alfa Laval's Power-to-X offering

27

combining outstanding performance with remarkable efficiency



Alfa Laval gasketed plate-and-frame heat exchangers



Alfa Laval Compabloc



Alfa Laval Olmi process gas boiler



Alfa Laval Wet Surface Air Coolers (WSAC)



Alfa Laval Packinox

Accelerating clean hydrogen solutions

Alfa Laval

Heat transfer technology clean Ammonia production

28



Alfa Laval portfolio Hydrogen

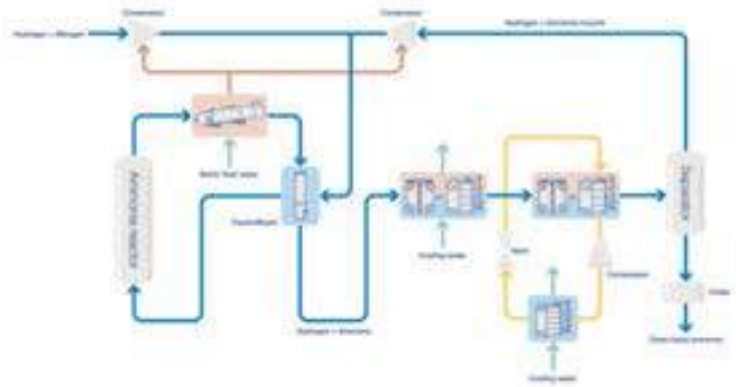
Heat transfer needs:

- Steam generator for compressors
- Feed/effluent
- Ammonia condensers
- Overall plant cooling
- Waste heat recovery

Alfa Laval

Clean Ammonia production

29



Heat transfer needs:

1. Steam generator for compressors
2. Feed/effluent
3. Ammonia condensers
4. Overall plant cooling
5. Waste heat recovery

Accelerating clean hydrogen solutions

Alfa Laval

Heat transfer technology e-methanol production

30



Heat transfer needs:

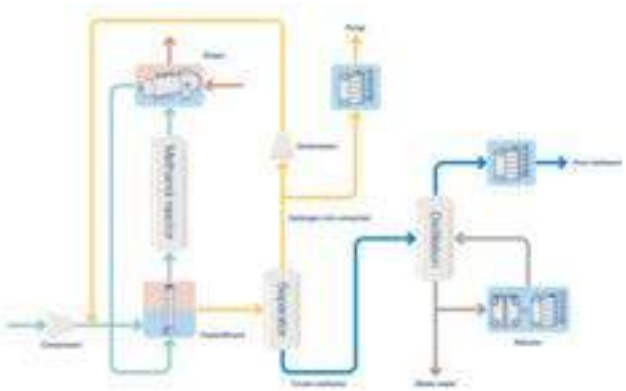
Steam generator for compressors
Feed/effluent coolers
Purge coolers
Reboilers & condensers
Overall plant cooling
Waste heat recovery

Alfa Laval portfolio Hydrogen

Alfa Laval

e Methanol production

31



Heat transfer needs:

1. Steam generator for compressors
2. Feed/effluent coolers
3. Purge coolers
4. Reboilers & condensers
5. Overall plant cooling
6. Waste heat recovery

Accelerating clean hydrogen solutions

Alfa Laval

e methanol as fuel to reduce carbon emissions

32

- Alfa Laval as investor and partner to Liquid Wind, Sweden





Liquid Wind aims to develop commercial-scale e-Methanol facilities through a partnership consortium. Alfa Laval is their heating & cooling partner, bringing expertise in heat balance and energy optimization of the complete system.



SIEMENS energy TOPSOE

Energy savings

Emission savings

Cost savings

READ MORE >

Hydrogen refuelling Stations

Hydrogen refuelling insights

Hydrogen a fuel for decarbonizing the transportation sector.

For **road transportation**, hydrogen fuel cell vehicles will complement where battery solutions face limitations:
-Heavier load
-Longer distances
-Crucial refuelling times

High demands on both time and space **efficient refuelling stations**.



Alfa Laval's pre-cooling offering

- **Alfa Laval printed circuit heat exchangers** for precooling in hydrogen refuelling serving any vehicle
  - ✓ Enabling back-to-back refuelling
  - ✓ Ensuring lowest possible customer waiting times
  - ✓ Reducing footprint with 85%
- **Alfa Laval portfolio**
  - Reliable and proven technology
  - Wide range; H35 and H70 standards
  - Design pressure up to 1,250 bar (18,125 psi)
  - Operating temperatures down to -70°C (-94°F)

Accelerating clean hydrogen solutions



Alfa Laval HyBloc™







Product range

36

The HyBloc™ range comprises different models, offering solutions for all capacity needs.

HyBloc – for gas hydrogen / liquid coolant applications
Extended standard range includes model 3,6 | 5 | 7,5 | 18

HyBloc C – for gas hydrogen / CO2 coolant applications
Extended standard range includes C 3,6 | C 5 | C 7,5

Liquid hydrogen special PCHE

We help you select the ideal model according to your cooling fluid, capacity requirements and further aspects to maximize performance.

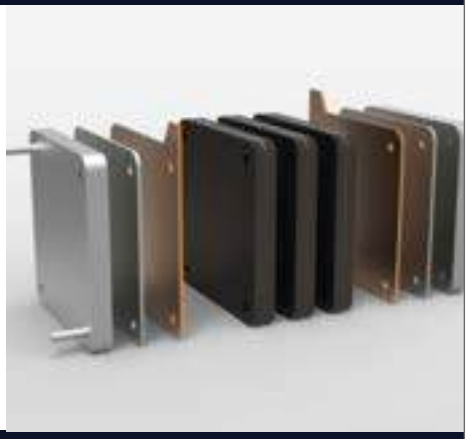
Alfa Laval

Fuel Cells

Fuel cells

38

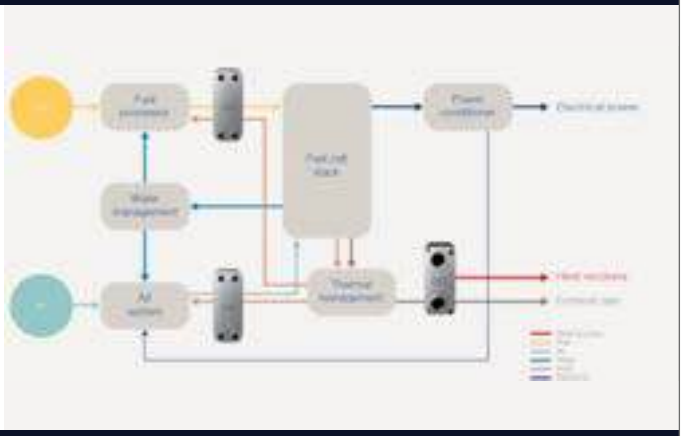
- The transformation of the world's energy systems is going to entail a wide range of solutions
- Fuel cells are going to be a fundamental part of our clean energy transition
- Fuel cells will be used for everything from distributed power to power generation for the every-growing data center sector
- Alfa Laval offers thermal transfer technologies ensuring strong fatigue resistances under the high temperatures and thermal stress for all types of fuel cell technologies (PEM, SOFC etc.)



Fuel cells

39

- Heat transfer solutions for all types of fuel cells technologies
  - Fusion-bonded heat exchangers that can handle temperatures above 600°C
  - Gas-to-liquid heat exchangers for uneven flow requirements
  - Innovations in higher gas-to-gas temperatures



Alfa Laval's fuel cells offering

40

combining outstanding performance with remarkable efficiency



Alfa Laval brazed plate heat exchangers



Alfa Laval fusion-bonded plate heat exchangers



Alfa Laval gas-to-liquid plate heat exchangers

The right solution every time

41

Performance Simplified

Alfa Laval – Only supplier offering a complete range.
Expertise in all technologies.
Alfa Laval will help you save time in equipment selection as we will help your project teams select the right technology for every position.



Accelerating clean hydrogen solutions

Alfa Laval

Breakthroughs in Hydrogen Production Techniques 6

Scaling Economic Industrial Decarbonization: How Utility Global H2Gen® Technology is delivering Decarbonization without Compromise for the Hard-to-Abate Sectors



Vladimir Novak
Chief Commercial Officer, Utility Global, Inc.

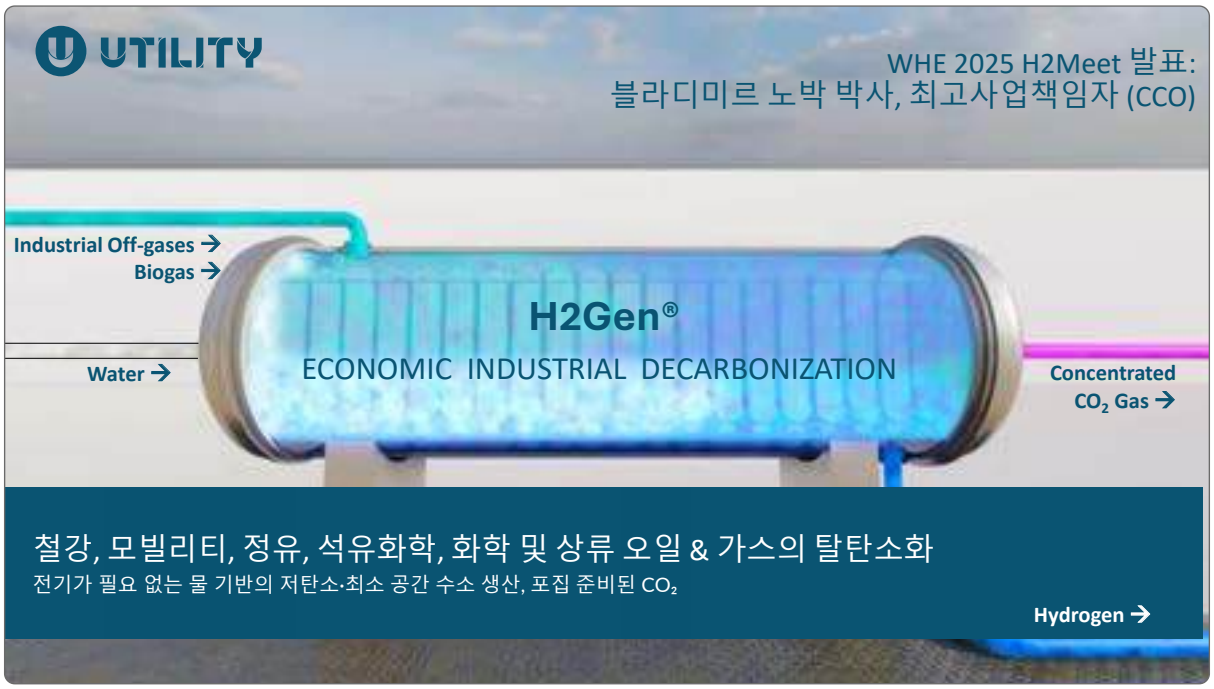
Education
2009 – 2011, Executive MBA (Magna cum Laude), Rice University – Jesse H. Jones Graduate School of Business, Houston/USA
2002 – 2006, Doctor of Philosophy (Ph.D.), Mechanical Engineering – Fusion Energy (Magna Cum Laude), Georgia Institute of Technology, Georgia/USA
2000 – 2002, Master of Science, Mechanical Engineering (Summa cum Laude), Georgia Institute of Technology, Georgia/USA
1993 – 1998, Bachelor of Science, Mechanical Engineering, Univerzitet u Beogradu, Belgrade/ Serbia

Professional Career
2024 – Present, Chief Commercial Officer, Utility Global, Houston/USA
2023 – 2024, Co-Chief Executive Officer, CT-Coating, Seattle/USA
2022 - 2023, Chief Commercial Officer, USNC, Seattle/USA
2008 – 2022, Director, Strategic Partnerships (2019 – 2022), Adviser to the President (2017 – 2019), Commercial Business Manager (2015 – 2017), Group Leader – Chevron Technology Ventures(2010 – 2015), Chevron, San Francisco, Houston/USA
2006 – 2008, Lead Energy Systems Engineer, GE, USA
2000 – 2006, Research Engineer – Fusion Energy, U.S. Naval Research Laboratory, USA
1991 – 2000, Tennis Professional, ATP Tour

Research Interest
Ph.D. focus: Fusion Energy, Thermal Sciences, Thermodynamics, Heat Transfer, Fluid Mechanics, Experimental R&D, Numerical 3D modelling

Speech Summary
- Utility Global is leading the charge to effectively decarbonize hard-to-abate sectors such as steel, mobility, refinery/chemical, and upstream oil & gas
- With a world-class team of industry leaders and advisors, and the support of some of the most significant investors in industrial decarbonization, Utility is successfully commercializing and scaling its technology globally
- Steel Focus: Arcelor Mittal, Brazil
- Biogas/H2 Mobility Focus: Maas Energy, USA
- Korea Focus: Frontier Korea (Certification & Demonstration), Utility Korea subsidiary, Seongnam, Korea
- The H2Gen® reactor is a revolutionary, versatile, easily scalable technology that harnesses the energy in industrial off-gases and biogases to produce pure hydrogen from water, and concentrated carbon dioxide streams without electricity
- H2Gen® sits at the intersection of gas processing and electrolysis without the complexity and cost
- Korea, the perfect market for H2Gen®: Strategy implemented into action, Korea is a global force in the maritime, refinery, chemical, steel sectors and a world leader in hydrogen ecosystems for biogas, mobility, power generation, hydrogen derivative fuels.
- Strategic Partnerships, the key to our success: Utility has built and continues to build powerful partnerships with significant companies and investors for the greatest decarbonization impact.
- Join us on our journey to decarbonize the world

Company Introduction
Utility delivers practical solutions that drive economic industrial decarbonization across industries such as steel, mobility, refining, chemicals, and upstream oil & gas. The company's breakthrough H2Gen® technology harnesses energy from industrial off-gases and biogases to produce application-specific high-purity, low-to-negative carbon intensity hydrogen on-site from water, without electricity, using its proprietary electrochemical process. H2Gen® also produces a high-concentration carbon dioxide stream, which can eliminate or reduce the cost of carbon capture. H2Gen® systems are modular, scalable, and operationally flexible, integrating seamlessly into existing hard-to-abate industrial assets with a record small footprint, enabling practical, economic decarbonization.



경제적 산업 탈탄소화스케일업 및 첫 번째 프로젝트 영상



https://media.utilityglobal.com/videos/economic-industrial-decarbonization

UTILITY

Utility
소유주, 프로젝트 및 회사 존재감

H2 Innovation Award
H2Meet 2024

TIME WORLD'S TOP GREEN TECH COMPANIES 2025
유틸리티 순위: 59



소유주

Ara Built to Decarbonize.
aramco
ArcelorMittal
SAMSUNG
ONTARIO POWER GENERATION
SAINT-GOBAIN



UTILITY

유틸리티는 전 세계 배출량의 20% 이상을 탈탄소화할 수 있음
시장 초점: 전략적 난감(감축이 어려운) 산업

	주요 시장		미래 성장		
	철강	운송수단	석유화학, 화학	정유공장	오일 & 가스(상류)
					
총 배출 비율	**7%** 석탄 & 가스 원료 기반 배출	**5%** 매립지, 폐수, 농업에서 발생하는 바이오가스	**4%** 원료 기반 배출	**3%** 원료 기반 배출	**3%** 석유 생산 중 연소되는(플레어링 되는) 가스
시장 규모	$225 Billion[1]	$870 Billion[2]	$200 Billion[3]	$100 Billion[3]	$15 Billion[3]

시장을 대표하는 기업들의 예

ArcelorMittal, STELCO, TATA STEEL, thyssenkrupp, JFE, CLIFFS, posco
REPUBLIC SERVICES, TOYOTA, HYUNDAI, WM
LYB, OXY, Chevron Phillips, DUPONT, Celanese
aramco, TOTAL, ENI, ExxonMobil, ConocoPhillips
aramco, Chevron, SHELL, ExxonMobil, TOTAL

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1) 2050년 시장 규모는 "IEA Steel Roadmap" 보고서를 기반으로 함
2) 2050년 시장 규모는 McKinsey & Company, Global Energy Perspective 2023: Hydrogen Outlook 기반
3) 2035년 시장 규모는 McKinsey & Company, Global Energy Perspective 2023: Hydrogen Outlook 기반

세계적 수준의 산업 자문단

- Dr. Henrik Adam (유틸리티 이사회 자문 – 철강)



- Tata Steel Netherlands Holding BV 회장
- Tata Steel UK 회장
- Tata Steel Europe CEO
- ThyssenKrupp Electrical Steel CEO
- 현 EUROFER(유럽철강협회) 회장
- 현 독일 철강연구소 VDEh 회장
- 기계공학 박사(자동차 기술 분야)

- Eric Duchesne (유틸리티 이사회 자문 – 정유/석유화학)



- TotalEnergies 자본 프로젝트 실행 & 운영 총괄, 다운스트림 CTO
- 정유·석유화학·재생에너지 분야 35년 경력
- 전 세계 수십억 달러 규모 프로젝트에서 2,000명의 엔지니어를 이끌음
- 정유 및 석유화학 자산 탈탄소화 집중
- 혁신적 변혁 기술의 산업화를 이끈 검증된 실적
- 장비 공급업체, EPC, 투자자들과의 강력한 네트워크 보유

- Tetsuya Shioda (수석 자문 & 일본 대표 – 철강)



- 일본제철(Nippon Steel Corporation)에서 40년 이상 근무
- 일본 및 세계적으로 잘 알려진 철강 산업 전문가
- NSC 탈탄소화 리더(HBI, 수소, 바이오 탄소, CCUS 등)
- 경영진 대상 상업·기술 자문으로 신뢰받는 전문가
- 전략적 의사결정팀 멤버: US Steel, ArcelorMittal/Nippon Steel India, Usiminas DD 및 운영 계획
- 전 일본제철(NSC) 유틸리티 글로벌 챔피언: 철강 탈탄소화에서 H2Gen® 우위 공식 이사회 승인 주도

- 곧 발표 예정 – 바이오가스

UTILITY

H2Gen® 글로벌 상용화 가속화

2025년 11월 – 휴스턴에서 Frontier H2Gen 플랜트 가동



- 다양한 고객 공급가스 조성을 테스트하기 위한 상업용 플랫폼
- 상업 배치 이전의 향후 기술 발전을 위한 가속 상용 수준 테스트베드

2025년 10월 – 한국 인증 및 데모 플랜트



- 성남시 하수처리장 바이오가스를 활용하는 Utility H2Gen® 프로젝트 발표
- 데모에서는 연료전지 등급 수소가 판매·배송·사용되며 수소 모빌리티에 활용됨, H2Gen® 리액터는 KGS 기준을 통과할 예정

2025년 6월 – 청정 수소 프로젝트 공동 보도자료 발표



- 건화 E&C는 한국의 선도적인 엔지니어링 및 컨설팅 회사
- 초기 협력은 H2Gen®을 중·대형 모빌리티용 지역 바이오가스-수소 허브에 배치하는 데 중점

2025년 4월 – 바이오가스 → 수소 Pre-FEED 연구 보도자료 발표



- 한국 개발사 및 EPC인 한화 E&C 인프라사업부와 협력
- 2030년까지 총 3억 달러 이상 규모의 20개 설치 잠재력,프로젝트 자본 투자 기회는 약 1억 달러 이상

2025년 하반기 – 프로젝트 계약 발표

ArcelorMittal
- 약 2.5 TPD 수소 프로젝트Pre-FEED 엔지니어링 설계 시작을 위한 계약 체결7월 29일 보도자료 발표
- 브라질 프로젝트는 투자자 권리 계약에 따라 향후 글로벌 대형 프로젝트로 확대될 예정

MAAS
- 약 3.5 TPD 수소 프로젝트 – 미국 캘리포니아 Maas Energy후속 프로젝트가 파이프라인에 있으며 10월 7일 보도자료 발표
- 글로벌 오프테이커들과 3건의 초기 오프테이크 계약 체결 → 초기 프로젝트 용량을 초과하는 수요 확보

임박한 프로젝트 계약들

글로벌 선도 철강회사	▪ 구두 승인 완료:1 TPD H2Gen® 상업용 데모 프로젝트 (FEL 범위 및 예산 확정)~62 TPD 대규모 수소 프로젝트
글로벌 선도 철강회사	▪ 첫 번째 프로젝트에 대한 구두 승인 확보:목표 규모 약 14 TPD 수소

강력하고 성장하는 상업팀

약 55명의 총 직원60% 엔지니어 / 과학자

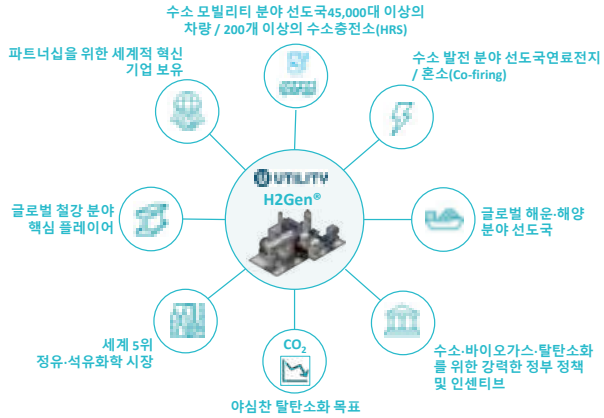
- 최근 영입을 통해 경영 및 상업팀을 지속 강화:
  - Dr. Henrik Adam, 철강 산업 이사회 자문
  - Eric Duchesne, 정유·석유화학·화학 자문

UTILITY

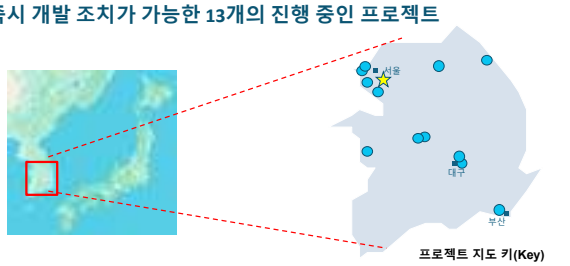
한국 시장 진입: 바이오가스 기반 수소 모빌리티 프로젝트

한국은 H2Gen®에 완벽한 시장임을 입증함

한국의 수소 & 탈탄소화 시장 동인



즉시 개발 조치가 가능한 13개의 진행 중인 프로젝트



프로젝트 지도 키(Key)
>1.5 TPD 수소 프로젝트
데모 및 인증 프로젝트 부지성남 데모 및 인증 프로젝트 개발 중

공동 프로젝트 개발사

- 바이오가스/바이오매스 자산을 보유하고 있고,
- 기존 또는 신규 수소 수요가 있는 지자체들과 중요하고 빠르게 진행되는 협업
- 한국 최초 모빌리티 프로젝트를 포함한 혁신적 배치 사례
- 중공업 탈탄소화 협업 개시

UTILITY

7

첫 번째 프로젝트 (캐나다)

UTILITY

모듈형, 확장 가능, 공장 제작, 소형 설치 면적(40피트 길이 ISO 컨테이너)





휴스턴 “Frontier” 시설





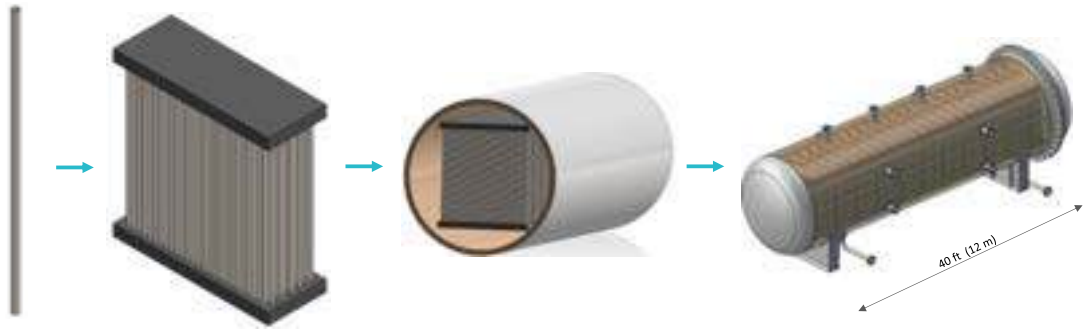

고객 방문이 가능한 확장형 H2Gen 시설

목적: Frontier 시설은 고객을 위한 H2Gen® 기술 쇼케이스 캠퍼스로, 두 가지 주요 목적을 수행함:
1) 신규 시장 진입을 지속하는 과정에서 다양한 고객 공급가스 조성을 테스트할 수 있는 상업용 플랫폼
2) 상업 배치 이전에 계획된 및 향후 기술·제조 발전을 위한 가속 상업 수준 테스트베드

규모: Frontier의 리액터는 유틸리티의 다중 톤급 수소 생산 상업 시스템의 축소 버전으로, 2028년 초 COD 예정. 하루 최대 50 kg의 순수 수소를 생산하며, 다양한 원료(feedstock)를 시뮬레이션해여러 시장 적용 분야에서 고객 사업장의 실제 운영 조건을 재현할 수 있음.

주요 구성 요소: H2Gen 시스템 및 시설은 2028년 가동·시운전 예정이며 현재 FEED 중인상업용 전체 규모 시스템과 동일한 구성 요소를 포함함 — 리액터, 셀 팩, 제어 장치, BOP, 안전 시스템 등.또한 쇼케이스 캠퍼스에는 셀 및 셀 팩 제조 공정도 포함됨.

H2Gen® 리액터 디자인



Single Cell
(단일 셀, 튜브)

Cell Pack(셀 팩)

셀 팩은 압력용기
(예: ISO 컨테이너)에 삽입됨

H2Gen 리액터
(기본적으로 길이 40피트)

리액터 용량은 가스 내 전기화학적 에너지에 따라 달라짐(예: 바이오가스는 희석된 고로가스 대비 더 높은 에너지 함량을 가짐)

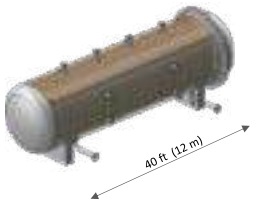
UTILITY

플랜트 규모 확장 (Plant Size Scale Up)

표준화된 공장 제작 리액터로 모든 규모의 적용처 제공

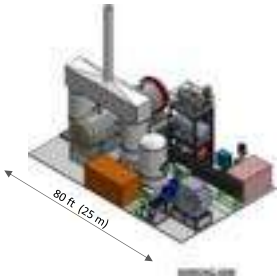
표준화된 리액터

- 공장 제조
- 높은 생산성, 낮은 비용, 짧은 제조 시간에 최적화



단일 리액터 플랜트

- 2–5 TPD 수소 범위를 위한 대부분 표준화된 플랜트
- 바이오가스 → 모빌리티 적용에 가장 가능성이 높음



대형 적용을 위한 플랜트

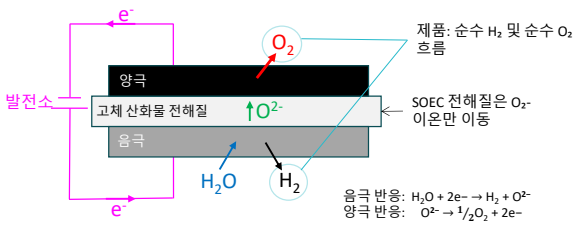
- 10–500 TPD 수소
- 대규모 플랜트 용량을 위해 표준 리액터들을 연결
- 작은 설치 면적, 경쟁력 있는 비용



UTILITY

기술 기본 원리: 전기 없이 물에서 수소 생산

기존 전기분해

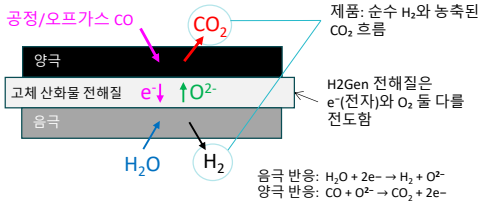


SOEC

Solid Oxide Electrolysis Cell

- 전기를 사용하여 H_2O에서 H_2 생산
- **새로운 전력 인프라 필요**
  - **높은 비용**
  - **제한된 규모**
  - **빠른 성능 저하**
  - **큰 설치 면적**

UTILITY 독자 기술



H2Gen®

전기 없이 물(H_2O)에서 수소 생산

- 가스 내 전기화학적 에너지를 이용한 H_2O → 수소 생산
- **기존 산업 자산과 통합됨**
  - **저비용**
  - **낮거나 음(負)의 탄소 집약도**
  - **전기 필요 없음**
  - **작은 설치 면적**

UTILITY

바이오가스 → 모빌리티 비교: H2Gen® vs. 스팀 메탄 개질(SMR)

더 낮은 수소 비용 및 제로 탄소 집약도

전환 과정	CI 점수 (kg CO_2e / kg H_2)	주요 요약 사항
SMR (스팀 메탄 개질) 바이오가스 공급원 → 표준 전처리 → RNG로 업그레이드 (CH_4를 CO_2에서 분리) *(H2Gen에는 고가의 업그레이드 장비가 필요하지 않음)* → SMR 수소 생산 *(SMR은 RNG를 H_2로 전환)* → H_2를 CO_2 & N_2에서 분리 *(H2Gen에는 고가의 후처리가 필요하지 않음)* → 순수 수소	6.9	**SMR** ▪ 고메탄 함량 가스만 전환할 수 있으므로 RNG 플랜트가 필요함 ▪ RNG 플랜트는 공정에 복잡성과 비용이 증가하는 추가 단계를 더함 ▪ RNG로 업그레이드 시 필요한 전력 및 관련 배출로 인해 CI가 증가함 ▪ 공정 가스 혼합물에서 H_2를 분리해야 하므로 비용이 증가함 ▪ 메탄 누출 때문에 RNG+SMR 경로는 PTC 요건을 충족하지 못함
독자 기술 H2Gen® 바이오가스 공급원 → 표준 전처리 → *(H2Gen은 업그레이드가 필요하지 않음)* → H2Gen 수소 생산 *(H2Gen은 바이오가스를 한 단계로 H_2로 전환)* → *(H2Gen은 고가의 분리 공정 없이 고순도 수소를 생산함)* → 순수 수소	~0[1]	**UTILITY H2Gen®** ▪ H2Gen은 인센티브를 극대화함 ▪ 운영적으로 단순하며, H2Gen에 필요한 표준 전처리 단계 ▪ H2Gen의 작은 설치 면적은 기존 인프라에 영향을 주지 않으며, SMR 설치 면적의 약 1/3 ▪ 복잡성 감소와 소형화로 인해 큰 비용 절감 ▪ SMR 대비 감소된 자본 비용(capex)

UTILITY

H2Gen은 SMR보다 훨씬 단순하고, 비용이 낮으며, 배출량도 적은 옵션을 제공함

[1] 분석은 매립지 가스를 기준으로 수행됨.축산(낙농) 바이오가스의 경우 탄소 집약도(CI) 점수는 매우 음(負)값임.

가장 어려운 산업 부문의 경제적 탈탄소화

가스 투입물

- 공정 가스
- 오프가스
- 바이오가스
- H_2O



농축된 CO_2 흐름

- ✓ 농축 CO_2 흐름(30%–95%)
- ✓ CCUS를 위한 포집 지점을 통합함

고순도 수소 사용 산업

- 이동수단
- 철강
- 화학
- 청정 액체 연료(SAF, 메탄올 등)

고객에게 제공되는 가치(Value Add)

- 기존 인프라와 공정을 탈탄소화
- 저가치 오프가스를 사용하여 물에서 청정 수소 생산
- 소형 설치 면적과 높은 운영 유연성을 가진 경제적 현장 수소 생산

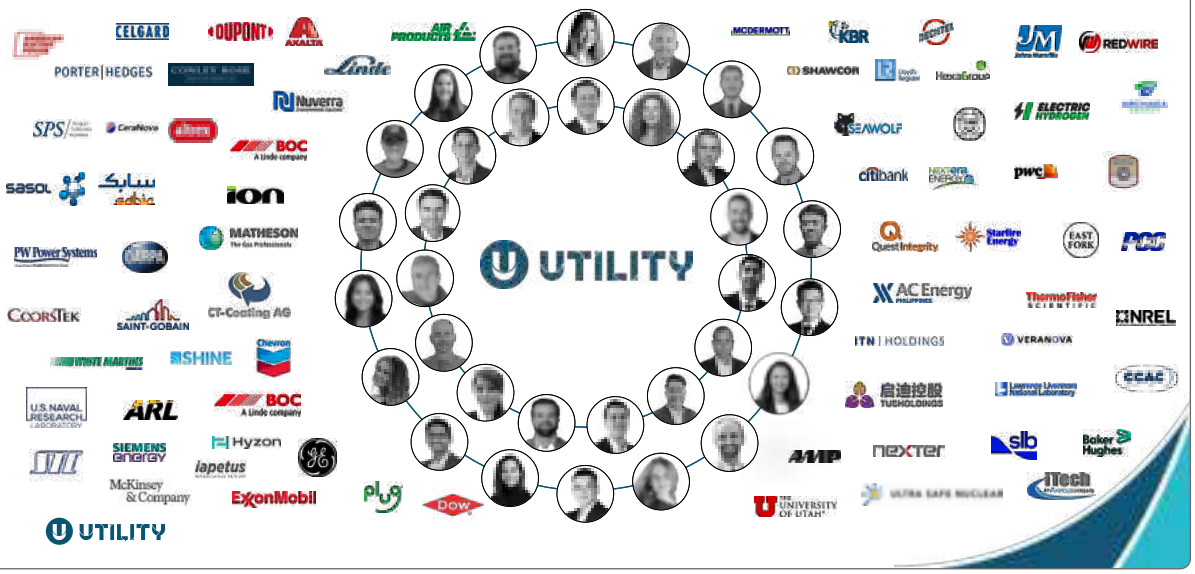
투자자에게 제공되는 가치

- 동일한 H2Gen 시스템으로 여러 산업의 탈탄소화 수요를 해결
- 높은 프로젝트 확실성 – 수소 생산에 전력이 필요 없고, 새로운 전력 인프라나 인허가도 불필요
- 소규모부터 대규모 생산 능력까지 경쟁력 보유

UTILITY

주요 자본 프로젝트 및 기술 상용화 경험을 갖춘 기업가적 문화

제조, 프로젝트 수행, 다양한 공학 분야, 세라믹, 전기화학, 다중 물리 시뮬레이션 분야 전문성



감사합니다.



연락처

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UTILITY

WORLD HYDROGEN EXPO 2025 6th Conference

Exploring New Hydrogen Storage and Distribution Solutions

Exploring New Hydrogen Storage and Distribution Solutions 1

Materials challenges in the Hydrogen Economy



Jens Eichler
Hydrogen Technology and Business Architect, 3M

Education

1995-2000 studied Materials Science at Technical University Darmstadt, Germany
2001-2003 PhD in Materials Science at Technical University Darmstadt, Germany in collaboration with Bosch
2004 Post- Doc at Indian Institute of Science, Bangalore, India

Professional Career

2005-2007 Senior Specialist for non-oxide ceramic materials at ESK, Kempten, Germany
2007-2013 Director Research and Development at ESK, Kempten, Germany
2011-2014 Lecturer at University of Applied Sciences, Kempten, Germany
2014-2024 Senior Scientist in the Corporate Research Materials Lab at 3M, Neuss, Germany
Since 2025 3M Hydrogen Technology and Business Architect at 3M Ventures, Neuss, Germany

Research Interest

Previous: Ceramics and Ceramics Processing
Functionally particle filled polymers for thermal management and interactions with electromagnetic waves
Additive Manufacturing
Current: Adhesives and Sealants for the assembly of electrolyzer and fuel cell
Adhesives for the assembly of liquid hydrogen tanks and system components
Materials science challenges in the hydrogen economy – materials for extreme conditions

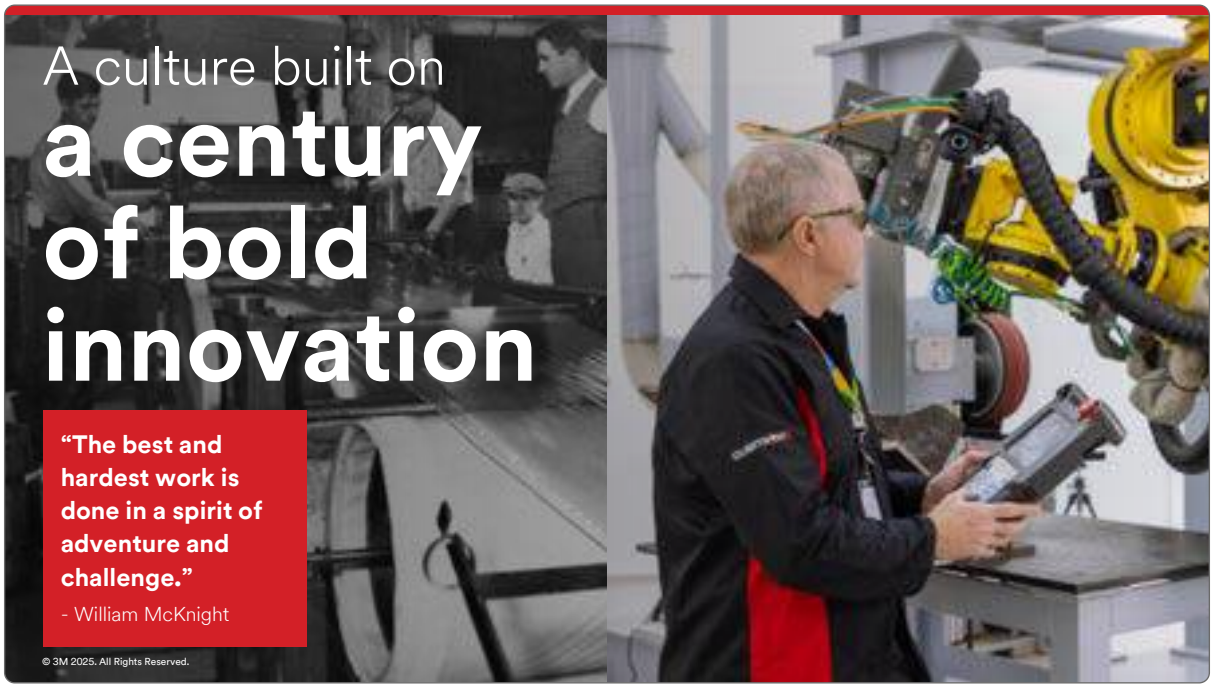
Speech Summary

The Hydrogen Economy along the full value chain provides materials science challenges that can potentially be solved applying 3M's 49 technology platforms. Based on the customer need profile examples will be given how product optimization can solve these challenges.
In the case of storage and distribution one of the key challenges is assembly and insulation of liquid hydrogen tanks. To improve insulation performance of large storage tanks glass bubbles have proven to be an effective insulator combined with improved operational performance.
Epoxy adhesives provide low hydrogen permeability and superior performance at 20 Kelvin to allow assembly of components into a liquid hydrogen tank.
For compressed hydrogen tanks improved matrix resin can optimize the weight and/or hydrogen volume of the tank and adhesives assist in the assembly of the tank.
All these examples show how solving specific materials science challenges can offer potential to improve hydrogen system component performance relevant to the industry.

Company Introduction

3M was founded in 1902 in Minnesota, USA, and today is considered one of the most innovative companies worldwide. With 63,000 employees, the multi-technology company has a presence in many countries around the globe. The foundation of its innovative strength is the diverse use of 49 proprietary technology platforms. Today, the portfolio includes a wide range of products for almost every area of life. 3M can proudly look back on more than 132,000 patents over the course of its corporate history. The company has research and development facilities in 29 countries worldwide.


3M Science. Applied to Life.™
Materials Challenges in the Hydrogen Economy
Dr. Jens Eichler, Hydrogen Technology & Business Architect
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A culture built on
a century of bold innovation
"The best and hardest work is done in a spirit of adventure and challenge."
- William McKnight
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#3MEnergy investment is broad based



Emissions Reduction

$620B
2023 Global Investments in Energy Efficiency[1]

150
Countries with Net Zero Energy Targets Underpinned by Legislation or Policy[2]



Carbon Capture, Utilization & Storage

$175B
Annual investments in CCUS by 2035[3]

40%
Projected U.S. Market Share in 2035[4]



Energy Transition

$1.7 T
2024 Global Investment Low-Carbon Energy Transition[5]

1,420
Announced H2 Projects worth $570B through 2030[6]



Climate Adaptation

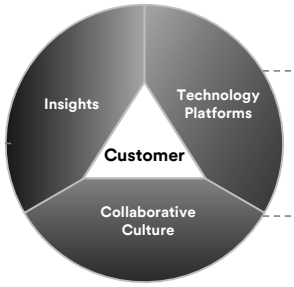
$63B
2022 Global Adaptation Finance increasing 28% YOY from 2021[7]

25%
A quarter of the world's population currently faces extreme water stress[8]

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The essence of 3M innovation



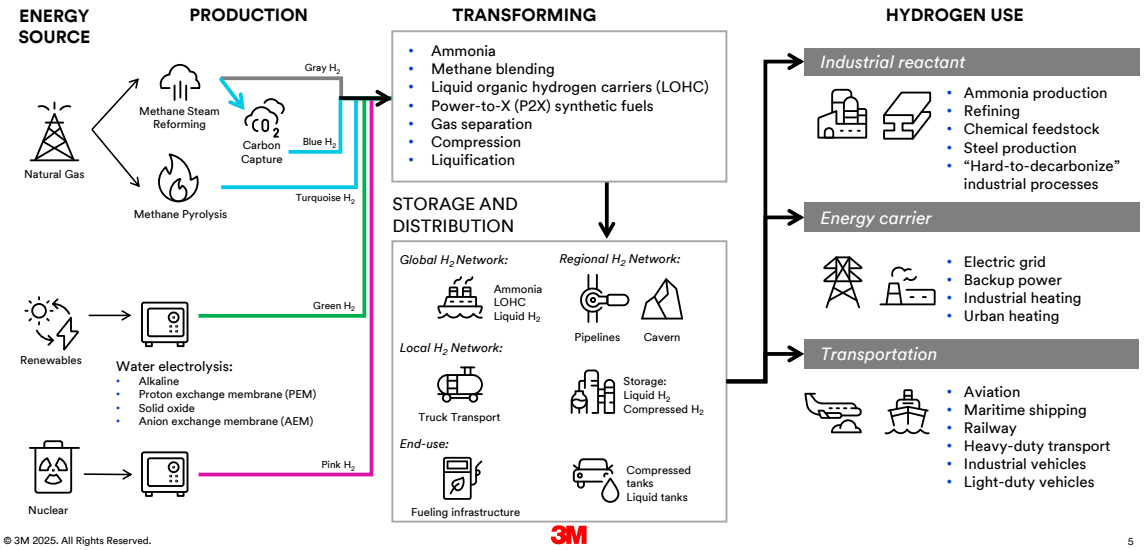






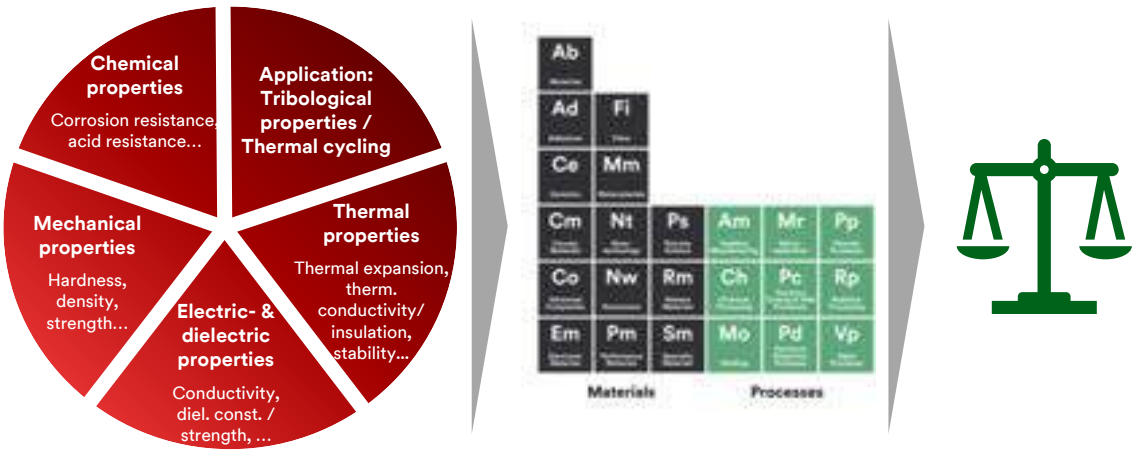
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Opportunities Along the Hydrogen Economy Value Chain



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Materials Optimization Challenge



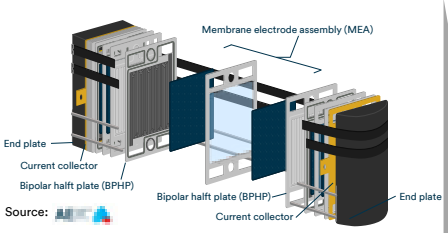
Customer need profile

3M Material & Process capabilities

Product optimization

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Adhesives for assembly of Electrolyzer and Fuel Cell



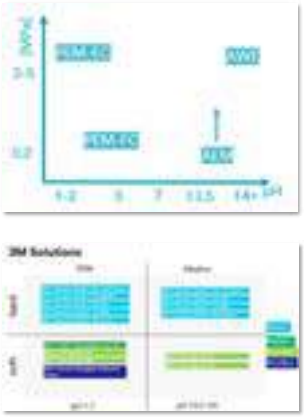
Customer need profile:

- Easy assembly at large scale
- Lifetime stability
- Enabling design
- End of life disassembly



1. Automated Assembly	▪Product form & specification ▪Application process
2. Hydrogen Readiness	▪Hydrogen specific characteristics ▪Permeability, poisoning, blistering
3. Application Requirements	▪Performance & lifetime customer specifications

3M Material & Process capabilities



Product optimization

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Evaluating 3M Material Platforms for H2

Low Hydrogen Permeability:

1. Epoxy
2. Polyurethanes
3. Acrylates
4. Silicones

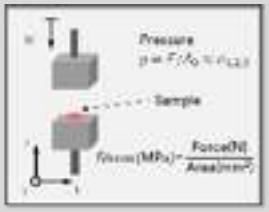
Catalyst Poisoning by Leachables or Volatiles:

Leachables and Volatiles → Analyze organic and ionic content → Evaluate effect on electro-chemical cell

Chemical & Thermal Stability:

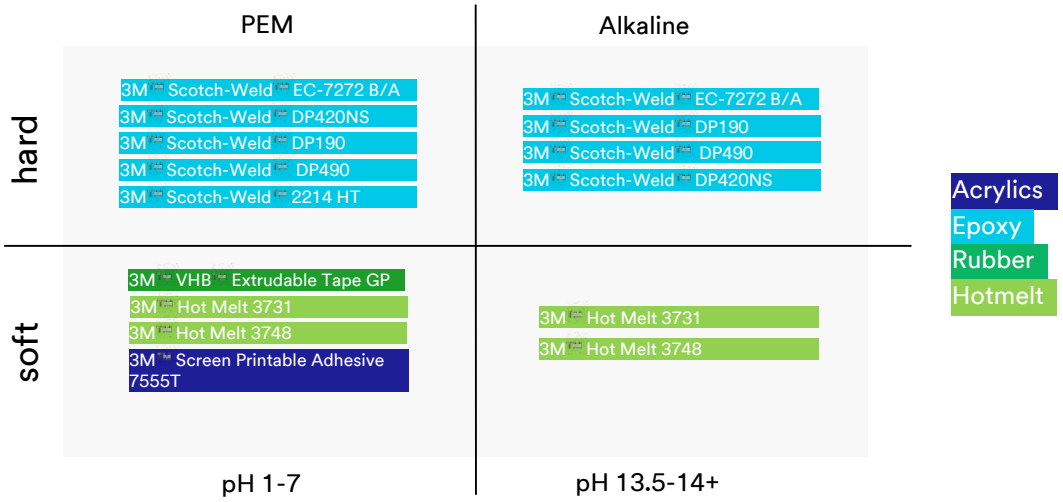


Creep Stability using Accelerated Methods:



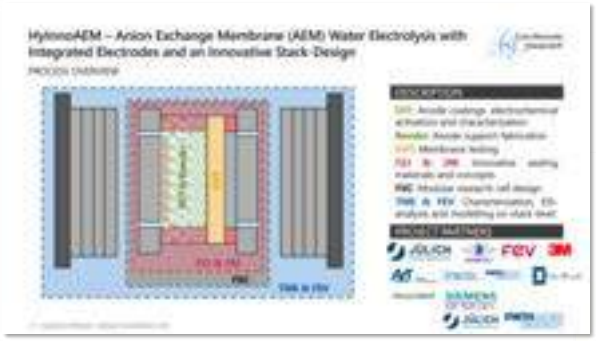
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3M Solutions



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Collaboration for Innovation: SupplHyInno Rhineland Cluster & HyInnoAEM Project







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Glass bubbles as effective and stable insulation for Hydrogen Storage Tanks Leveraging a lightweight filler common in polymers

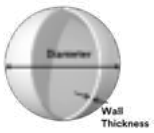


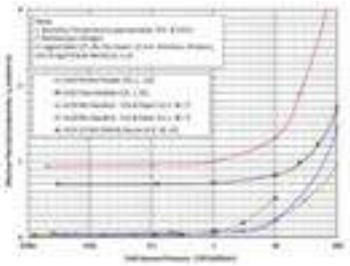
Customer need profile:
- Thermal Insulation:
  - blocking IR-radiation
  - reduced boil-off
- No thermal cycle damage
- Long term stability / package stability
- Easy / fast fill of in-between wall space



3M Material & Process capabilities

3M™ Glass Bubbles K1 for Cryogenic Insulations





Product optimization

Note: The information we are furnishing you is based on tests performed by a third-party at their facility and may be based on a limited sample size. Your results may vary due to differences in test types, conditions, systems, and facilities. See www. https://ntrs.nasa.gov/citations/20180006604 for more information.

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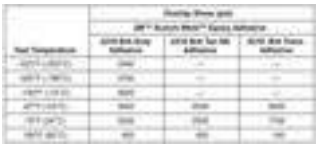
Adhesives for assembly of Liquid Hydrogen Storage Tanks



Customer need profile:
- Easy assembly of large components
- Adhesives for carbon fiber composites
- Adhesive performance from room temperature to -253°C
- Low hydrogen permeation

Low Hydrogen Permeability:

1. Epoxy
2. Polyurethanes
3. Acrylates
4. Silicones



3M Material & Process capabilities



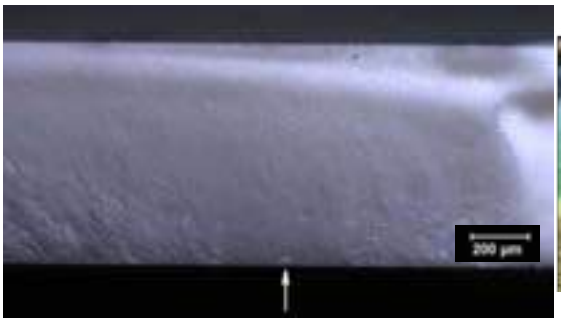
Product optimization

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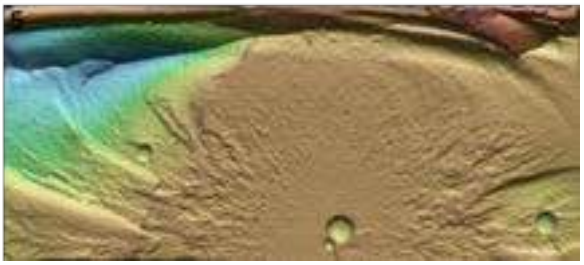
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Fracture Mechanics: Ceramics vs. Polymers @-253°C



Source: G. Quinn; J. Eichler; et al., J. Am. Ceram. Soc., 87 [3] 513–16 (2004)

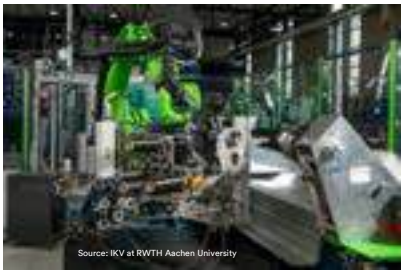


Source: 3M internal testing of 2216 under Liquid Nitrogen in 4-point-bending

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3M

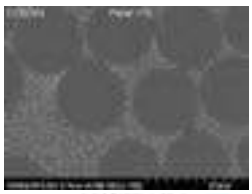
Matrix Resin for High Pressure Hydrogen Storage Tanks

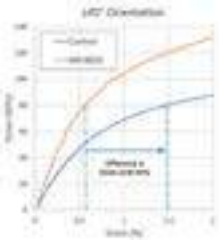


Customer need profile:

- Fast and easy processing of fibers and matrix resin
- Burst pressure 2x use pressure:
  - Fiber winding
  - Matrix resin
- Low cost – low fiber use
- Low hydrogen permeation

Status: 3M experimental material



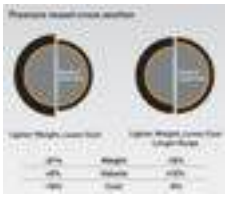


Source: J. Nelson et al., Jet Composites Magazine, N133 p.139-147 (2020)

3M Material & Process capabilities



Potential impact of 3M Matrix Resin use on Tank Design:



Product optimization

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Additional 3M Solutions for the Hydrogen Economy



3M Pipeline Infrastructure Products
3M™ Scotchkoat™
for protection & flow efficiency



3M™ Silicon Nitride &
Silicon Carbide
Gas Seal Face



3M™ Silicon Carbide for
Chemical Pumps in the
Balance of Plant



3M™ Nextel ceramic fibers
providing strength and
stiffness up to 1000°C

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3M

Exploring New Hydrogen Storage and Distribution Solutions 2

Large-scale liquid hydrogen technologies enabling intercontinental hydrogen transportation: Techno-readiness & economic assessment



Sébastien Lichtle
Director of LH2 Product Line,Air Liquide E&C

Education
Engineer's degree, Industrial Processes and Materials at INP Phelma
Grenoble (France)
1998 - 2001

Professional Career
As Director of the Liquid Hydrogen Product Line at Air Liquide Engineering & Construction, Sébastien leads a multidisciplinary team dedicated to delivering best-in-class technical solutions to customers both within the Air Liquide group and across the broader industry. His core responsibilities include managing the complete product and technology portfolio while spearheading the development of new, market-driven products.
Sébastien brings over 25 years of experience in Engineering and Cryogenic Technologies for the energy sector. His career has progressed through a variety of key roles, including
Principal Process Engineer, Manager of engineering for large-scale LNG and Natural Gas plants, and Director of Technology for LNG. A recognized expert in his field, he holds several patents for his innovations.

Research Interest
Technologies for Treatment and Liquefaction of gases, especially, Hydrogen, Helium and Natural Gas.

Speech Summary
Large-scale hydrogen liquefaction (XL LH2) is crucial for intercontinental transport. Current technologies are ready-for-offer up to 150tpd, significantly reducing TCO. Scaling to 300tpd is on track and promises TCO reductions exceeding 60%. Integration with reforming is ready, but integration with intermittent electrolysis requires developing flexible cryogenic operations.

Company Introduction
Air Liquide is a world leader in gases, technologies and services for industry and healthcare. Present in 60 countries with approximately 66,500 employees, the Group serves more than 4 million customers and patients.

Exploring New Hydrogen Storage and Distribution Solutions 3

BEYOND THE BOND, ADHESIVE SOLUTION FOR HYDROGEN APPLICATION



Hyunseob Shim
Lead Application Engineer, Henkel Korea

Education
2008~2014 Bachelor of Chemical Engineering, Soongsil Univ, Seoul, Korea

Professional Career
2009, Harvard Project for Asian and International Relationship Participant, Boston, USA
2009~2011, Soongsil International Ambassador, Soongsil Univ, Seoul, Korea
2012, New Generation Seminar, US Embassy, Seoul, Korea
2013, Internship, Henkel hotmelt adhesive R&D Center, Cheonan, Korea
2014~2019, Application Engineer of Industrial Assembly / General Manufacturing adhesive in Henkel Korea Innovation Center, Seoul, Korea
2022~Present, Lead Application Engineer of General Manufacturing / MRO adhesive in Henkel Korea, Innovation Center, Seoul, Korea

Research Interest
1. Fluid application management by Adhesive
2. Design initiative and automation solution by adhesive (Instant bonding, Light cure adhesive, 2 component silicone)
3. Pipe sealing and repair by adhesive (No need to replace new component, but by adhesive only)
4. Protective coating solution by adhesive (Chemical resistance coating, Better reliability)
5. Cost saving and value proposition by adhesive to MRO industry (Power plant, Oil and gas, Steel, Mining)
6. Chemical resistance coating solution by adhesive
7. Light weight and Design innovation by adhesive (Vehicle, Appliance, Motor)

Speech Summary
1. Customer pain point at hydrogen application – high pressure sealing & leakage
   - Compressor, Fitting, C&T sealing, Connector etc
   - Proven data for reliability at various fluid applications and industry by Adhesive
2. Traditional solution (Mechanical assembly) vs. Adhesive solution
   - Theoretical principle
   - Design guideline
3. Value point (Performance, Reliability) Adhesive vs. Mechanical parts
4. Global Case History by adhesive solution (Fluid, Hydrogen)

Company Introduction
Henkel Adhesive Technologies is world's No.1 producer in adhesives, sealants and functional coatings for industrial customers as well as consumers and craftsmen. Henkel's LOCTITE Hydrogen Ready Solutions effectively tackle the challenges in hydrogen industries. Built on over 70 years of Henkel's expertise in industrial sealants, our solutions are driven by a commitment to enhance industrial reliability and sustainability. We have been rigorously tested to ensure safety and reliability and meeting the stringent performance requirements of KIWA GASTEC QA AR 214 for admixtures up to and including 100% hydrogen gas.

LOCTITE

HYDROGEN SEALING SOLUTIONS

05.DEC,2025
LEAD APPLICATION ENGINEER
LUCAS SHIM





BEYOND *THE BOND*

HYDROGEN ECONOMY CRITICAL SUCCESS FACTORS

SAFETY & ENVIRONMENT

Leakage
Pressure hazards
Hydrogen embrittlement

COMPATIBILITY

Testing
Materials compatibility
Approvals

EFFICIENCY

System efficiency
Durability
Automation

LOCTITE

BEYOND *THE BOND*

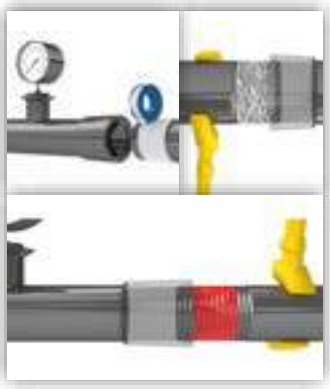
CONVENTIONAL METHOD





LOCTITE BEYOND THE BOND

CONVENTIONAL METHOD, WHY FAILED?







LOCTITE BEYOND THE BOND



THREAD SEALING

Traditional Solutions

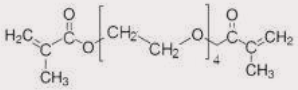


Mechanical Seal | EPDM seal | Cone & Thread

- Most H_2 pipework made of stainless and connections are typically welded or use flanged pipe connections
- Tube connections are typically assembled with costly cone & thread fittings and PTFE tape
- Certain components (like H_2 sensors) can't be welded and require threaded connections where H_2 leak prevention can be compromised:
  - Mechanical seals require tight tolerances and minor defects lead to leaks
  - EPDM seals can lose sealing properties over time
  - PTFE Tape can shred and leak
  - Cone & Threads are costly and susceptible to loosening

LOCTITE Solution

Value Proposition

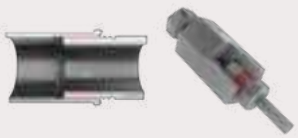


- Anaerobic sealants based on dimethacrylate esters are chemically compatible with hydrogen



- Anaerobics fill all the air spaces between the threads, resulting in an effective and reliable leak-proof, vibration-resistant seal
- Solution tested and approved both at customers and at external lab

Design Guidelines



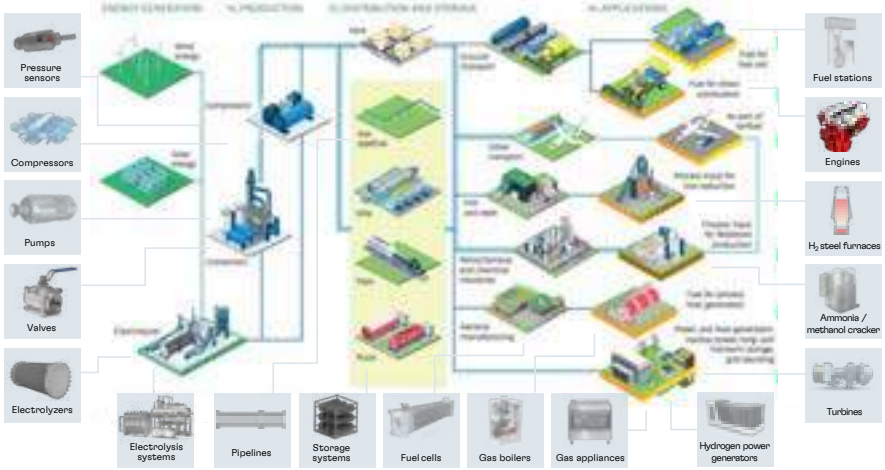
NPT (tapered threads)

- NPT connections are recommended
- When tightened, threaded connections enable metal to metal and eliminating leak pathways
- This design limits H_2 contact with the adhesive thus eliminating the contamination risk

LOCTITE

BEYOND THE BOND

HYDROGEN ECOSYSTEM AND TARGET DEVICES



LOCTITE BEYOND THE BOND

CERTIFICATION WITH KIWA

Kiwa is a Dutch **certification body** that provides testing, inspection, certification, consulting and training services in various markets.

Certified according to KIWA GASTEC QA AR 214 for use on metallic threaded joints in pressure class 8 hydrogen gas systems:

- LOCTITE 55
- LOCTITE 567
- LOCTITE 577
- LOCTITE 638

certifications available in select countries



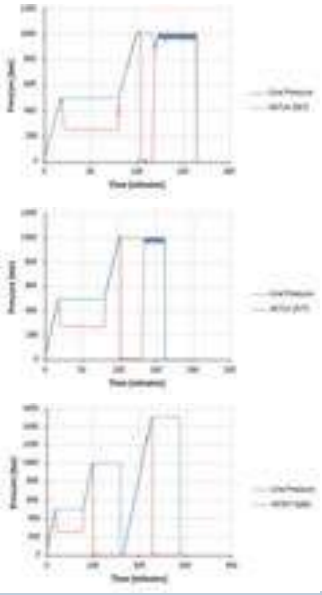
LOCTITE BEYOND THE BOND

HENKEL TEST RESULTS

High Pressure

- LOCTITE 567, LOCTITE 577 and LOCTITE 638 have been tested in this testing setup.
- Tests confirmed the ability of our products to **effectively seal threaded connections at very high operating pressures.**
- Typically, maximum operating pressures in the most demanding "real-life" applications don't exceed **700 bar**
- We therefore also have the ability to **provide a safety coefficient for the most extreme applications.**

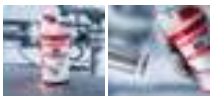




LOCTITE BEYOND THE BOND

HYDROGEN READY THREAD SEALANTS

LOCTITE 55



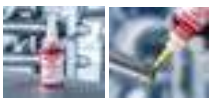
White, non-curing **thread sealing cord** provides immediate full pressure sealing. Allows reliable re-adjustments without leakage. **Ideal for BSPT and NPT pipe threads.**

LOCTITE 567



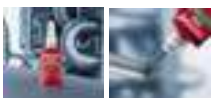
White, high viscosity **anaerobic curing paste** thread sealant. Provides instant low-pressure seal. Seals and locks metal threaded pipes and fittings. Allows for easy disassembly. **Ideal for NPT pipe threads**

LOCTITE 577



Yellow, high viscosity **anaerobic curing paste** thread sealant. Provides instant low-pressure seal. Seals and locks metal threaded pipes and fittings. Allows for easy disassembly. **Ideal for BSPT and NPT pipe threads.**

LOCTITE 638



Green, medium viscosity **anaerobic curing adhesive** with high shear strength. Typically used to retain bearings on shafts, but also ideal for thread sealing and locking applications in **high pressure and/or extreme environments.** Ideal for BSPT and NPT pipe threads.

LOCTITE BEYOND THE BOND



FLANGE SEALING

Traditional Solutions

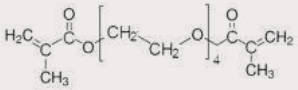


Pre-cut gasket

- Most H_2 pipework made of stainless, connections are typically welded or use flanged pipe connections. In addition many H_2 compressors and valves utilize performed gaskets on flanged connections.
- Preformed seals are costly, require tight tolerances and small defects cause leakage.
- Preformed seals / gaskets lose their sealing properties over time and may not fully conform to surface roughness, creating possible leak paths

LOCTITE Solution

Value Proposition



- Anaerobic sealants based on dimethacrylate esters are chemically compatible with hydrogen



- Anaerobics fill all the air spaces between the threads, resulting in an effective and reliable leak-proof seal
- Solution tested and approved both at customers and at external lab

Design Guidelines



- Flanges normally are flat, raised. Need to apply the product correctly to ensure the seal
- When tightened, the flanges allow for metal-to-metal contact, eliminating leak paths and increasing the stiffness and strength of the connection.
- This design limits H_2 contact with the adhesive thus eliminating the contamination risk

LOCTITE

BEYOND THE BOND

FLANGE SEALING TEST PROCESS

LOCTITE 510, LOCTITE 518, LOCTITE 574

The LOCTITE Hydrogen Ready Flange Sealants were evaluated by an independent third-party laboratory to assess their performance in hydrogen environments. Tests were performed on 304 stainless steel raised flanges, where the sealed assemblies were pressurized with 100% hydrogen gas and closely monitored for pressure drops under two sequential conditions, varying in pressure and temperature.

Product	Step 1			Step 2		
	Pressure	Temperature	Duration	Pressure	Temperature	Duration
LOCTITE 510	41 bar	Ambient	18 hrs.	20 bar	80°C	6 hrs.
LOCTITE 518	41 bar	Ambient	18 hrs.	20 bar	80°C	6 hrs.
LOCTITE 574	41 bar	Ambient	18 hrs.	20 bar	80°C	6 hrs.



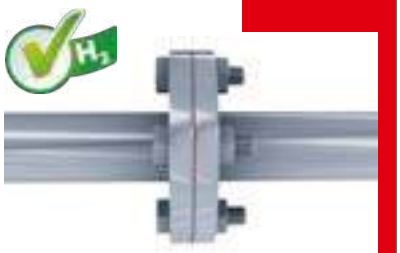


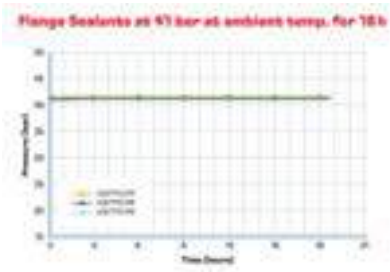
LOCTITE BEYOND THE BOND

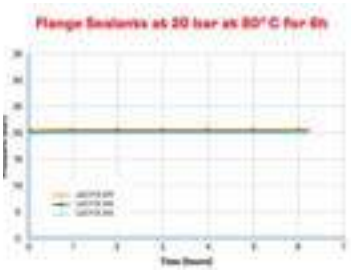
FLANGE SEALING TEST RESULTS

LOCTITE 510, LOCTITE 518, LOCTITE 574

Throughout the testing period, **no pressure drops were observed**, confirming the LOCTITE Hydrogen Ready Flange Sealants provide **consistent, reliable, and leak-free sealing performance against hydrogen** under demanding conditions.









LOCTITE BEYOND THE BOND

HYDROGEN READY FLANGE SEALANTS

LOCTITE 510



LOCTITE® 510 is a **pink** high viscosity anaerobic curing flange sealant for close fitting, rigid metal flanges. **Ideal for steel, stainless steel & cast iron surfaces**. Fills gaps up to 0.25 mm. Provides instant low-pressure seal. Resists temperatures up to **400°F (204°C).**

LOCTITE 518



LOCTITE® 518 is a **red gel**, semi-flexible anaerobic curing flange sealant for close fitting, rigid metal flanges. **Ideal for steel, stainless steel & aluminum surfaces**. Fills gaps up to 0.25 mm. Provides instant low-pressure seal. Resists temperatures up to **300°F (150°C).**

LOCTITE 574



LOCTITE® 574 is an **orange** high viscosity anaerobic curing flange sealant for close fitting, rigid metal flanges. **Ideal for steel, stainless steel & cast iron surfaces.** Fills gaps up to 0.25 mm. Provides instant low-pressure seal. Resists temperatures up to **300°F (150°C).**

LOCTITE

BEYOND THE BOND

CUSTOMER APPLICATION CASE HISTORY



THREAD SEALING HYDROGEN AT HIGH PRESSURE

(Spain)

- Compressor
- Thread Sealing H_2 @ 1000 bar
- SS (AISI 316) ¼" and ½" NPT
- Reliability, no leak issue
- Loctite 638



THREAD SEALING OF VARIOUS FITTINGS

(UK)

- Burners and heaters
- Thread Sealing of pipe fittings of heating equip. utilizing H_2
- Be DVGW EN751-1 certified
- Loctite 577



THREAD SEALING AT HIGH TEMPERATURES

(Portugal)

- Hydrogen purifier device
- Thread Sealing to withstand 250°C and 40 bar pressure hydrogen gas
- Loctite 278 and Loctite 565



HIGH PRESSURE THREAD SEALING

(Portugal)

- Hydrogen refuel stations
- Connection between H_2 bottles, compressor and refuel system (700 bar)
- Loctite 565 + tape

LOCTITE

BEYOND THE BOND

ELECTRORYSER, FUEL CELL



LOCTITE BEYOND THE BOND

THANK YOU

LOCTITE BEYOND THE BOND

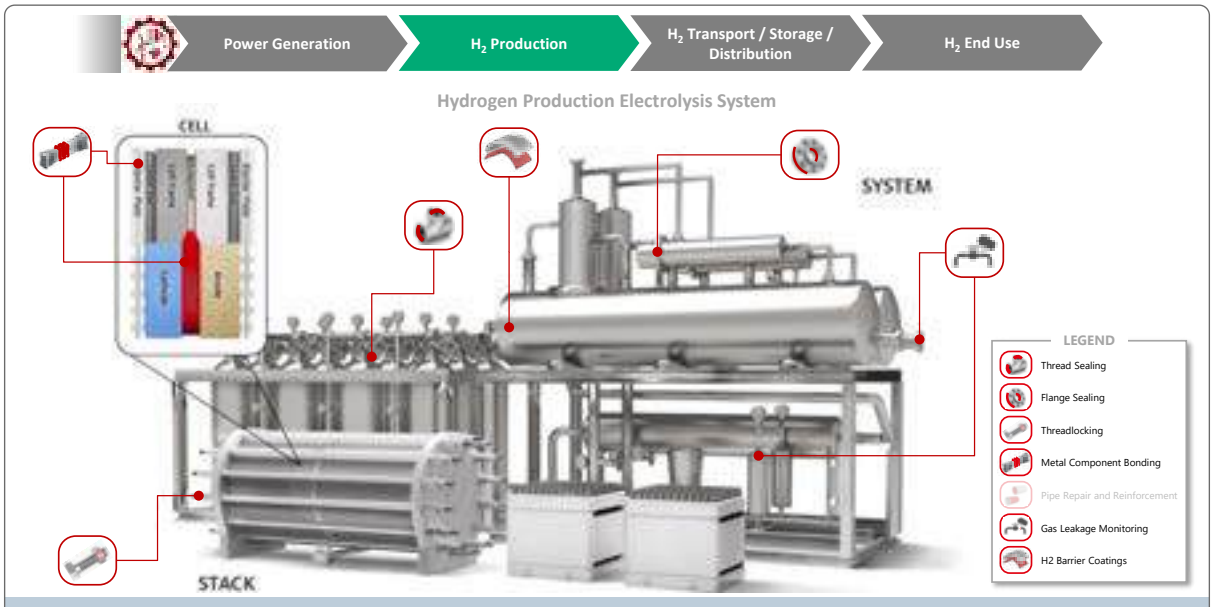
ADHESIVES, SEALANTS, COATINGS & MONITORING H_2 OPPORTUNITIES

● Available
● Under Development

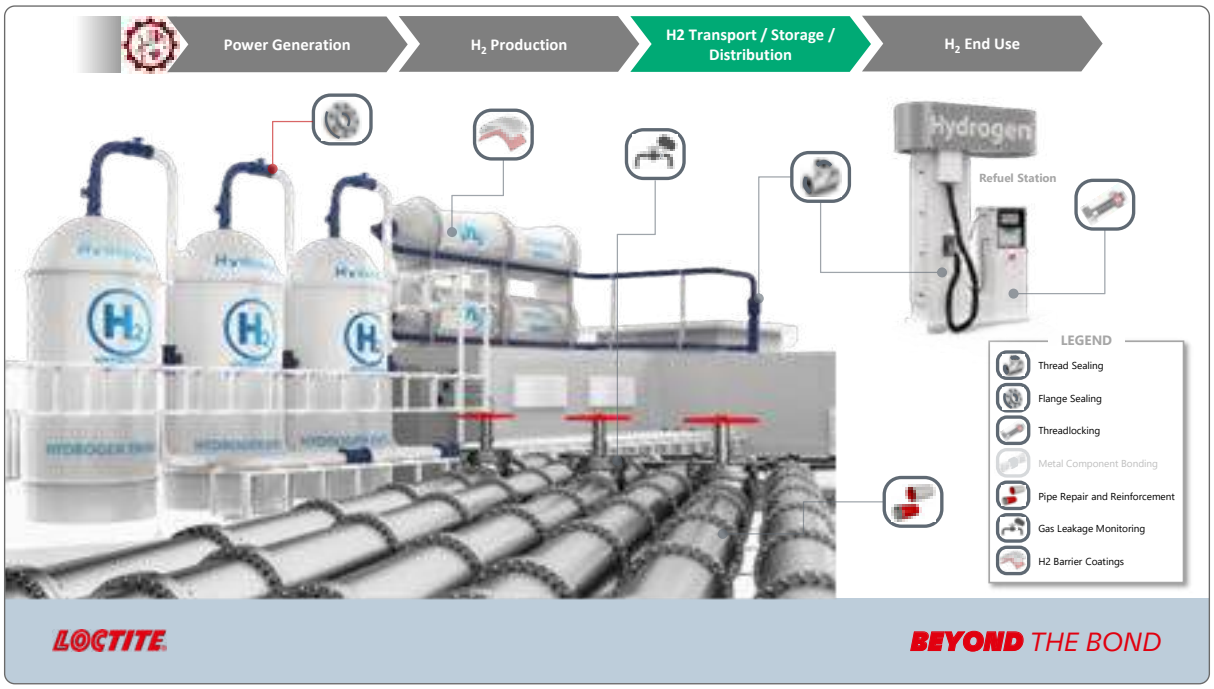
Applications / Target Device	H_2 Production		H_2 Transport / Transmission / Storage / Distribution								H_2 End Use								
	Electrolyzers	Electrolysis Systems	Valves	Compressors	Pumps	Pressure Sensors	New H2 Pipelines	Current CH4 Pipelines	Storage Systems	Fuel Stations	Fuel Cells	Gas Boilers	Gas Appliances	Engines	Power Generators	Turbines	Ammonia Crackers	Steel Furnaces	Mobility Drive Trains
Thread Sealing	●	●	●	●	●	●			●	●	●	●	●	●	●	●	●		●
Flange Sealing	●	●	●	●	●		●	●	●	●	●			●	●	●	●	●	●
Threadlocking	●	●	●	●	●				●	●	●	●	●	●	●	●	●	●	●
Component Bonding & Sealing	●										●								
Pipe Protection*							●	●											
Gas Leakage Monitoring		●	●						●	●					●	●	●	●	
H_2 Barrier Coatings	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Pipe Protection - Internal Lining, External Protection, External Pipe Repair*

LOCTITE BEYOND THE BOND



LOCTITE BEYOND THE BOND


Power Generation
H_2 Production
H2 Transport / Storage / Distribution
H_2 End Use
Hydrogen
Refuel Station
LEGEND
Thread Sealing
Flange Sealing
Threadlocking
Metal Component Bonding
Pipe Repair and Reinforcement
Gas Leakage Monitoring
H2 Barrier Coatings
LOCTITE
BEYOND THE BOND


Video
Natural gas as feedstock
Hydrogen Generation by steam reforming (Gray or Blue Hydrogen)
Process flow
LEGEND
Thread Sealing
Flange Sealing
Threadlocking
Metal Component Bonding
Pipe Repair and Reinforcement
Gas Leakage Monitoring
H2 Barrier Coatings
LOCTITE
BEYOND THE BOND

Exploring New Hydrogen Storage and Distribution Solutions 4

Case Study & Research for Hydrogen Refueling Station Performance Test Apparatus



Moonbeom Heo
Team Leader, TÜV SÜD KOREA

Education
2009-2011, Master's degree, Chung-ang University, Korea
1999-2008, Bachelor's degree, Chung-ang University, Korea

Professional Career
10/2020 - Present, TUV SUD KOREA Ltd., Team Leader
11/2020 – 10/2020, Hyundai Motor Company, Senior Manager
01/2012 – 11/2020, Hyosung Heavy Industries, Manager

Research Interest
Technical feasibility analysis of hydrogen facilities
Hydrogen charging system design
Rotating body (High Voltage Motor) Inspection/Certification
Wind turbine component, assembly QA / QC

Speech Summary
Although hydrogen refueling stations are expanding, systematic performance verification remains insufficient. Some early stations fail SAE J2601 and metering uncertainty fuels consumer distrust. This study compares global cases, highlighting the need for simplified methods, accurate metering, and standardized procedures to enhance reliability and global alignment.

Company Introduction
TÜV SÜD is a global leader in safety and certification with 26,000+ employees and 600 hydrogen experts in 20+ countries. The company provides end-to-end hydrogen services across the value chain, from green production and storage to mobility, infrastructure, and international standardization

Case Study & Research for Hydrogen Refueling Station Performance Test Apparatus

2025 World Hydrogen Expo (H2 MEET)

Mun-Beom, Heo / Team Leader TÜV SÜD KOREA

Add value.
Inspire trust.

CONTENTS

01 TÜV SÜD Company & Service
02 HRSTA? (HRS Performance Test Apparatus)
03 Domestic and International Standards of HRSTA
04 Case Study and Status of HRSTA
05 Conclusion and Insight

TÜV SÜD at a glance

15,000+ technical experts

150+ years of safety, security & sustainability

1,000+ locations worldwide

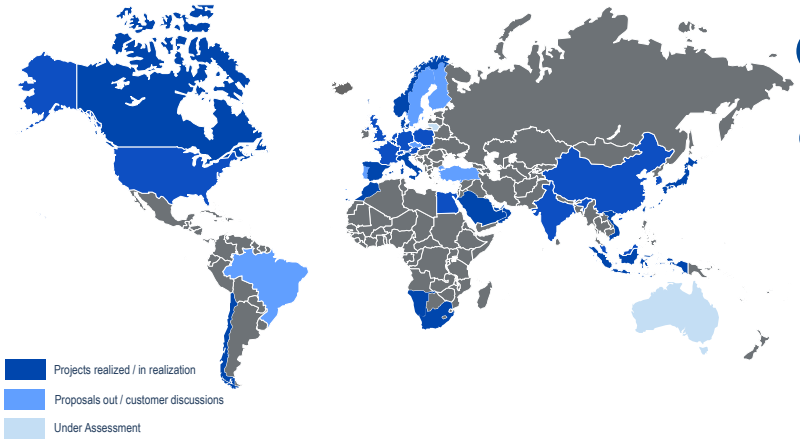
26,000+ TÜV SÜD employees

€2.9 billion in annual revenue

100 % independent & impartial

600+ Hydrogen Experts
Global Footprint in 20+ countries
Pioneers in H2 safety & Green Hydrogen Certification (2011, CertifHy, CMS70)

The TÜV SÜD Hydrogen story – Using our international expert network to help companies safely access the hydrogen market



~ 600 experts with relevant hydrogen know-how and strongly growing

Hydrogen activities in >20 countries from strategy until operation

New services based on market needs (e.g. green/low carbon H2, H2-ready)

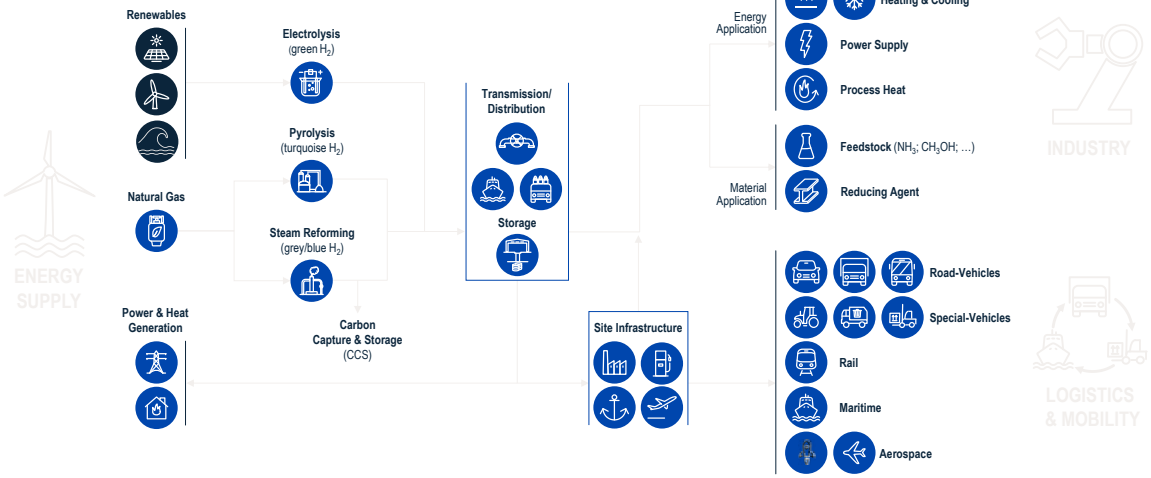
Active memberships in e.g. Hydrogen Council, Hydrogen Europe and Dii

Investor projects: TDD, Trainings, market and fund evaluation

Hydrogen capabilities along the value chain

25.11.2025 4

TÜV SÜD Hydrogen services along the whole H_2-Value Chain



TÜV SÜD Hydrogen services along the whole H_2-Value Chain

Production



- Electrolyzer solutions: from design to operation



- Plant Safety Solutions for hydrogen production (blue, turquoise, pink)
- Carbon Capture & Storage

Transmission



- European Hydrogen Backbone: 50+ projects in the largest pipeline H2 infrastructure in Europe
- Hydrogen readiness for materials and components in critical infrastructures
- H2 strategy and Ecosystem development
- Design review
- Manufacturers & supply chain assessment
- Feasibility assessment
- Construction supervision

Storage & Site infrastructure



- Hydrogen Handling and storage in complex infrastructures
- Salt caverns and site storage
- Hydrogen refuelling stations
- Integrated hydrogen systems for aviation infrastructure
- Gaseous and cryogenic H2 tanks

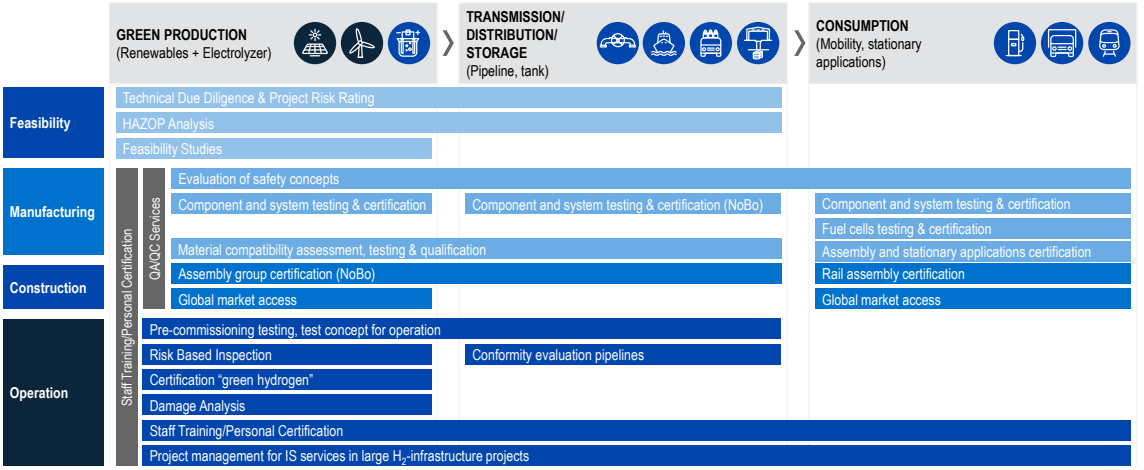


End Use: Industry and mobility



- Safe applications of Hydrogen in hard-to-abate industry (steel, cement, glass, etc…)
- H2 ready for thermal power plants
- Hydrogen use in railway (storage, safety concepts)
- Hydrogen storage systems in passenger cars, light and heavy duty vehicles
- Fuel cells
- Aerospace

Ensuring Safety and Efficiency in hydrogen projects with TÜV SÜD



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TUV SUD Consulting Service

Global hydrogen business and technical support



CONTENTS

01 TÜV SÜD Company & Service
02 HRSTA? (HRS Performance Test Apparatus)
03 Domestic and International Standards of HRSTA
04 Case Study and Status of HRSTA
05 Conclusion and Insight

HRSTA (Hydrogen Refueling Station Test Apparatus)

HRSTA ?

A vehicle simulation test apparatus for verifying the performance and safety of hydrogen refueling stations

HRSTA Key Function

- Fuelling Protocol(SAE J2601) Compliance Test
- Evaluation of HRS system safety and metering accuracy



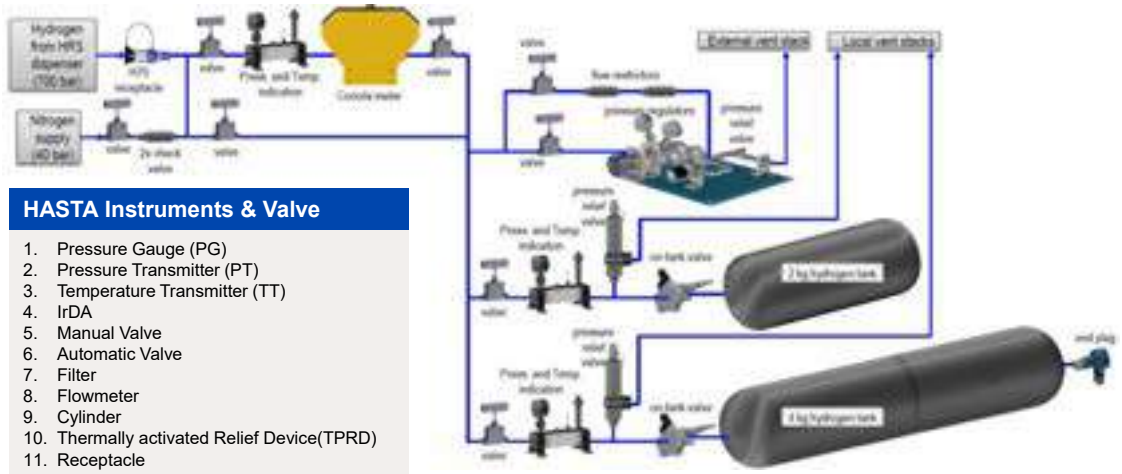
Status & Backgound

- Performance variations occur across HRS
  : Differences in system design and construction methods lead to varying performance
- Lack of international compliance and absence of domestic standards
  : Some early stations do not meet international fueling protocol requirements
- Measurement errors occur
- Growing consumer distrust and concerns regarding gas metering accuracy
- Diverse fueling conditions
  : Increasingly complex conditions due to various mobility applications

Need & Importance

- **Evaluation Criteria** : Unified performance evaluation is needed.
- **Safety Assurance** : Standardize and verify station performance.
- **Consumer Trust** : Accurate metering reduces concerns.
- **Environment Adaptation** : Tools for diverse mobility required.
- **Global Competitiveness** : Ensure compatibility with international standards.

HRSTA System Configuration



HASTA Instruments & Valve

1. Pressure Gauge (PG)
2. Pressure Transmitter (PT)
3. Temperature Transmitter (TT)
4. IrDA
5. Manual Valve
6. Automatic Valve
7. Filter
8. Flowmeter
9. Cylinder
10. Thermally activated Relief Device(TPRD)
11. Receptacle

* Reference : TUV SUD (NEL) HRS light duty FTS

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Relevant Standards & Codes

Domestic(Korea)

Enforcement Rule of the High-Pressure Gas Safety Control Act



KGS Code FP217



International

ISO 19880-1



SAE J2601



Domestic(Korea) Standards & Codes

Enforcement Rule of the High-Pressure Gas Safety Control Act [Effective Date : May 19, 2025]



Article 2 (Definitions of Terms)

The term **"Charging Safety Performance Evaluation Apparatus"** refers to equipment used to conduct safety performance tests and evaluations of hydrogen refueling protocols for hydrogen vehicles. Such protocols regulate the hydrogen refueling process according to the permissible temperature and pressure within the vessel so that hydrogen can be charged safely.

Article 3 (Methods of Confirmation, etc.)

Notwithstanding paragraph (1), a hydrogen refueling facility for which a technical review by the KGS is in progress as of the effective date of this Notice, or which has undergone such technical review prior to the effective date, may have its charging safety performance confirmed by substituting the results of another hydrogen refueling facility equipped with charging equipment and charging logic of the same specification.

* Reference : Enforcement Rule of the High-Pressure Gas Safety Control Act

Domestic(Korea) Standards & Codes

Special Provisions on the Operation of Safety Performance and Measurement Performance Evaluation Apparatus for Hydrogen Vehicle Refueling Stations [Effective Date : July 13, 2023]



Article 4 (Special Provisions on Standards)

An evaluation apparatus that satisfies all of the following standards may be used to charge hydrogen at hydrogen vehicle refueling stations.



Safety Valve





GAS / Flame Detector



Vent Stack



Pressure Gauge

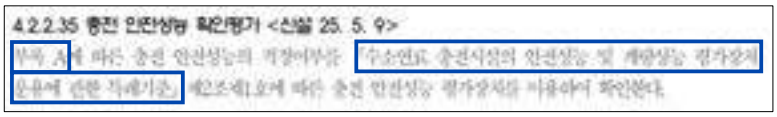
Explosion Proof(KCs)

* Reference : Enforcement Rule of the High-Pressure Gas Safety Control Act

Domestic(Korea) Standards & Codes

KGS FP 217 - Standards for Facilities, Technology, and Inspection of Storage-type Hydrogen Fueling





4.2.2.35 Verification and Evaluation of Charging Safety Performance [Newly Established on May 9, 2025]

The appropriateness of charging safety performance, in accordance with Appendix A, shall be verified using a charging safety performance evaluation apparatus as prescribed in Article 2, subparagraph 1 of the *Special Provisions on the Operation of Safety Performance and Measurement Performance Evaluation Apparatus for Hydrogen Vehicle Refueling Stations*.



* Reference : KGS Code FP 217

International Standards & Codes

ISO 19880-1 : Gaseous hydrogen – Fueling Station, Part 1 : General requirements



Clause 12 (HRS Inspection and Performance Test Procedures)

12.1 General
As part of commissioning prior to opening the station for use by the public,
the hydrogen fuelling station shall be inspected and tested as detailed in 12.2 to 12.6
to ensure compliance with the requirements of this document.
If specific factory acceptance tests are not conducted, or not acceptable,
these tests shall be performed as part of the site acceptance testing (SAT).
The commissioning of the hydrogen fuelling station is not complete
until all inspection and test results demonstrate compliance with requirements as defined above.

12.5 Fuelling safety and performance testing
The fuelling test shall be performed using a hydrogen station test apparatus (HSTA) or equivalent equipment
that can simulate a vehicle. The HSTA shall be capable of testing according to the fuelling protocol in use (e.g., SAE J2601).

Annex J (Basic Design and Guideline of HRSTA)

The communications system may also be designed to send faulty temperature or pressure signals to determine if the dispensing system will adapt and perform safe fill in the event of faults in the communications signal from the vehicle (HSTA).
— Hydrogen storage systems that have at a minimum rated capacity of between 4 kg to 7 kg hydrogen at 70 MPa and 15 °C.
— Ideally, the pressure drop should be within 17 MPa to 19 MPa to be representative of the worst-case conditions being encountered in vehicles currently.

* Reference : ISO 19880-1:2020

Domestic vs. International Standard

For HRSTA Components & Function

* Reference
1) Enforcement Rule of the High-Pressure Gas Safety Control Act
2) ISO 19880-1:2020



Enforcement Regulations of the High Pressure Gas Safety Management Act

VS



ISO 19880-1

HRSTA Components / Function	Domestic	International
Storage Tank	O	O
Receptacle	O	O
Valves (Manual, PRV, etc.)	O	O
TPRD (Thermally activated pressure relief device)	X	O
Pressure Gauge/Sensor	O	O
Temperature Gauge/Sensor	X	O
Vent Stack	O	O
H2 Gas Detector	O	O
H2 Flame Detector	O	X
Filter	X	O
IrDA System (SAE J2799)	X	O
Pressure Drop	X	O
Certificate	O	X

Domestic standards focus on “Safety,”
while international standards cover both “Safety” & **“Performance.”**

Domestic vs. International Standard

For HRSTA Test Contents

* Reference
1) KGS FP 217



KGS Code FP 217

Test Division	Description
Termination of fuelling	Fuelling shall terminate within **5 seconds** after receiving an abort signal.
Communication → Non-communication	During fuelling, the system shall **switch to non-communication mode within 0.5 s** and shall not return to communication mode.
Data error	In case of **abnormal communication**, fuelling shall stop or switch to non-communication mode. - CRC frame errors and data loss beyond SAE J2799 allowance shall be monitored.
Measurement of hydrogen vehicle capacity	**Hydrogen vehicle capacity shall be measurable.** If the measured value and the calcul-ated value are inconsistent, fuelling shall be stopped within 5 seconds.
CHSS temperature	Fuelling shall stop when CHSS temperature goes out of the range **−40 to 85 ℃.**
CHSS pressure	Fuelling shall stop when CHSS pressure goes out of range. This includes cases where the **initial pressure is below 0.5 MPa**, when the initial pressure is set higher than the service pressure, or when the pressure **exceeds 87.5 MPa.**
SOC	Fuelling shall stop if **SOC exceeds 100%.**
Fuel mass (general)	**Before fuelling,** the amount of hydrogen shall be more than **200 g/s**, and the fuelling rate **during operation** shall be more than **60 g/s.**
Fuelling table	**Target pressure and APRR** shall be correctly set and verified.
Non-communication fuelling	In non-communication mode, hydrogen vehicle capacity shall be measurable, or **manual capacity setting shall be available** if measurement is difficult.

These are also same as ISO 19880-1

Domestic vs. International Standard

For HRSTA Test Contents (KGS FP 217 vs ISO 19880-1)

* Reference
1) Enforcement Rule of the High-Pressure Gas Safety Control Act
2) ISO 19880-1:2020



VS



ISO 19880-1

Test item	Description
Measurement of hydrogen vehicle capacity	It shall be verified that the tank volume estimated by the apparatus is within ±15% of the actual value.
Pre-cooling capacity	Verify cooling capacity is sufficient, e.g., during back-to-back fuelling.
High APRR fuelling	Simulate high fuelling rate by lowering ambient temperature or overriding APRR. Check max APRR and mass flow peak. Repeat ≥ 2 times with vessel temperature monitoring.
Low APRR fuelling	Simulate low fuelling rate by raising ambient temperature or over riding APRR. Check min APRR and mass flow control at high pressure. Repeat ≥2 times.
Top-off fuelling	At low initial pressure (~3 MPa), verify target pressure, APRR, and temperature control during final fuelling stage.

→ It is also necessary to refer to the specific evaluation items specified in ISO 19880-1.

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Case Study and Status of HRSTA

* Reference
1) Monthly Hydrogen Economy: "Hy-PAS," a performance evaluation device that enhances the safety of hydrogen charging infrastructure.

Country
: South Korea



Divsision	Description
Equipment	Hy-PAS(Hydrogen station – Performance Assessment System) (2022)
Development	KGS(Korea Gas Safety Corporation) → Developed with reference to Hy-StEP and CSA-HDTA
Features	• Test for SAE J2601 Protocol & HRS Safety • Capable of testing up to 20kg • MFC wass applied at the Vent Stack • All electrical instruments complaint with KCs Explosion Proof
Application	It planned for phased utilization after institutionalization in May 2025

Reference picture







Case Study and Status of HRSTA

Country
: Taiwan



Division	Description
Equipment	HRSTA (Hydrogen Refueling Station Test Apparatus) (2023)
Developer	ITRI (Industrial Technology Research Institute, Taiwan)
Features	• Equipped with 35 MPa receivers for both truck and passenger vehicle applications • Safety evaluation for pressure, explosion, and thermal hazards completed by TÜV SÜD UK
Application	Currently under use : Performance evaluation in progress at Taiwan's first HRS with TÜV SÜD participation

Reference picture

It is recommended that a safety evaluation (Risk assessment, FMEA, etc) be performed on any HSTA prior to use.





Case Study and Status of HRSTA

* Reference
1) Powertech
2) HySTEP

Country
: USA



Division	Description
Equipment	HyStEP (Hydrogen Station Equipment Performance) (2015)
Developer	Led by the U.S. DOE (Department of Energy) : Developed and manufactured by Powertech Labs. Later upgraded in Canada as the CSA-HDTA model (2017).
Features	• Designed and operated in accordance with DOE safety requirements. • In use since the early implementation of fuelling protocols. • Mounted on a mobile trailer, capable of visiting multiple stations to verify protocol per formance and supply conditions.
Application	In active use : Verified 22 hydrogen refueling stations through the California Air Resourc es Board(CARB).

Reference picture

It is recommended that a safety evaluation (Risk assessment, FMEA, etc) be performed on any HSTA prior to use.





Case Study and Status of HRSTA

* Reference
1) TÜV SÜD NEL

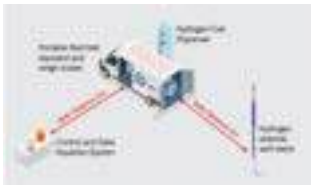
Country
: UK



Division	Description
Equipment	NEL LD HFTS (Light Duty Hydrogen Field Test Standard) (2021)
Developer	MetroHyVe government project (Metrology for Hydrogen Vehicles) : TÜV SÜD NEL (National Engineering Laboratory, UK). → Heavy-Duty version under development.
Features	• Safety assessment conducted by TÜV SÜD NEL in accordance with UK safety regula tions (PSSR, DSEAR, etc.) • Focus Accuracy verification of hydrogen refuelling for passenger car HRSs • Capable of verifying SAE J2601 fuelling protocol (4–6 kg range) • Complies with OIML R139 (International Fuel Measurement Standard)
Application	Actively used in Europe : Serving as a reference infrastructure standard for hydrogen measurement.

Reference picture






Case Study and Status of HRSTA

* Reference
1) HySUT

Country
: JAPAN



Division	Description
Equipment	HySUT Test Truck
Developer	HySUT (Hydrogen Supply/Utilization Technology Association) : the standardization of the hydrogen industry and the establishment of institutional frameworks in Japan
Features	• Designed and manufactured in accordance with HySUT-G 0004/0003 standard • Validates hydrogen refueling station performance through JPEC-S 0003 protocol tests • Verifies dispenser metering accuracy through gravimetric and metering-based calibrat ion • Capable of visiting multiple stations to verify
Application	Extensively used in Japan, with more than 60 successful deployments

Reference picture



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Conclusion and Insight



Institutionalization and Action Plan

Korea institutionalized HRSTA only in May 2025 despite many HRS already in place. Clear action plans are required for existing stations, making HRSTA more critical. Currently only one HRSTA is owned by KGS, so simplification of equipment and government support are essential for wider adoption.

Industry Awareness Improvement

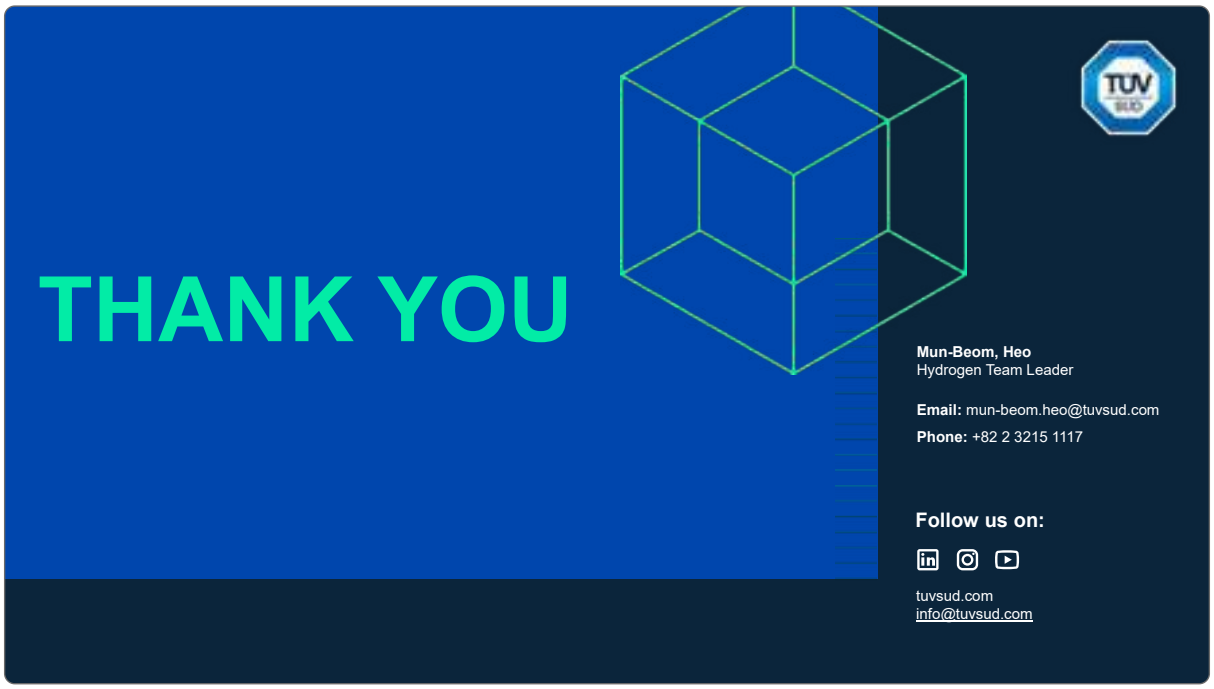
Industry stakeholders must improve awareness: beyond safety (KGS Code), performance assurance should be proven through third-party evaluation or self-declaration, with reference to international standards such as ISO.

Consumer Trust Enhancement

Accurate metering via HRSTA is vital to resolve consumer distrust and enhance public acceptance of hydrogen refueling

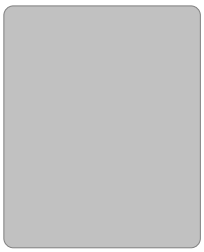
Leadership in International Standards

Future performance evaluation criteria should cover diverse mobility applications, sequential and simultaneous fuelling, enabling Korea to lead and contribute to international standards.

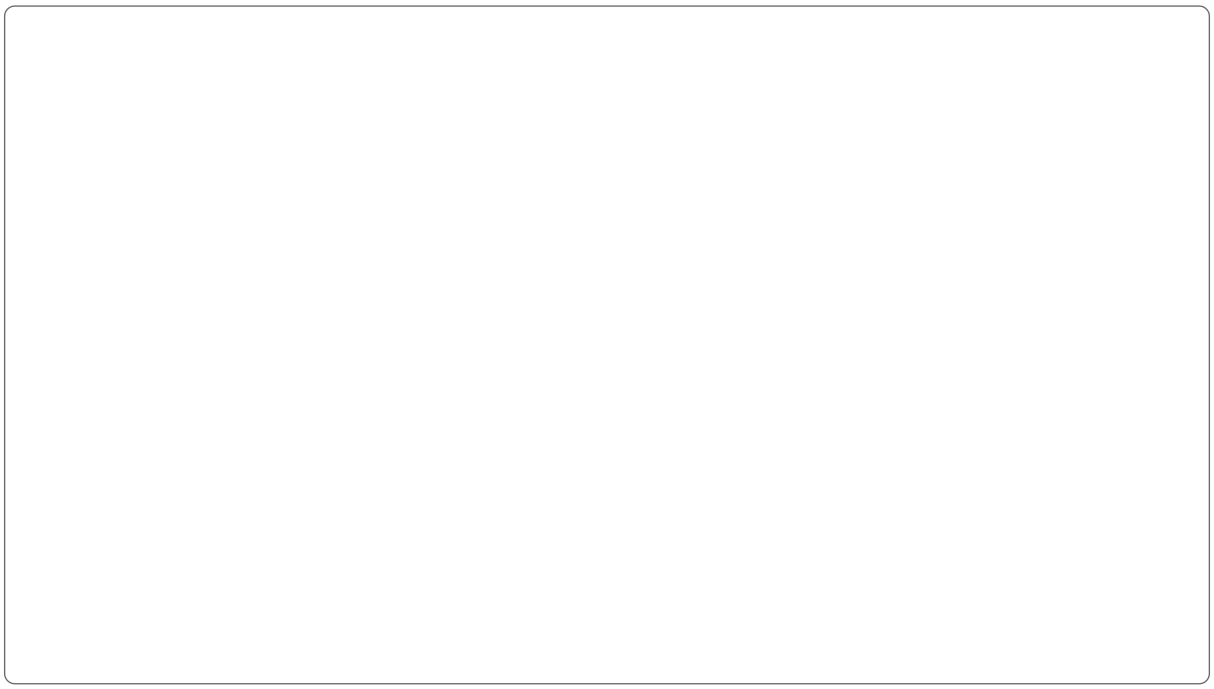

THANK YOU
TUV
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Phone: +82 2 3215 1117
Follow us on:
tuvsud.com
info@tuvsud.com

Exploring New Hydrogen Storage and Distribution Solutions 5

“Industrializing Hydrogen Storage for Global Mobility” How OPmobility is enabling the next generation of zero-emission transport



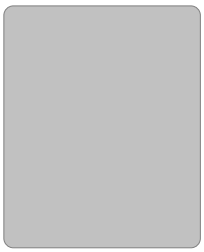
Chanjoo Park
Asia Managing Director, Opmobility





Exploring New Hydrogen Storage and Distribution Solutions 6

TBD



Mikaa Blugeon-Mered

WORLD HYDROGEN EXPO 2025 6th Conference

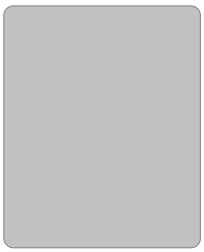
Country Day : Australia Day

WORLD HYDROGEN EXPO 2025 6th Conference

Session I. Opening Function

Session I. Opening Function

Key-note Speech
Australia's cleantech & hydrogen industry – a turning point for Australia?



Nigel Nambhujun
Senior Analyst, Rystad Energy

Education
2015-2016, M.S, Materials Science Engineering, Carnegie Mellon University, Pennsylvania, USA
2018-2022 Ph.D., Chemical Engineering, University of New South Wales, Sydney, Australia

Professional Career
2022-2023, Industry Analyst, AME Research, Australia
2024-Present, Hydrogen Analyst, Rystad Energy, Australia

Research Interest
energy transition (hydrogen, lithium, batteries and electric vehicle)

Speech Summary
Will explore Australia's fast-growing renewable energy sector, examine the current hydrogen market, discuss rising regional competition in green hydrogen, and highlight the export opportunities emerging as global demand continues to grow.

Company Introduction
Global energy research and intelligence delivering data and insights to help clients make informed decisions.

Policies, Market Challenges and Collaboration Opportunities in Clean Tech and Renewables Between Korea and Australia

Presented by Dr Neil Thompson
Adjunct Associate Professor
QUT Energy Transition Centre

World Hydrogen Expo 2025 Australia Country Day
Thursday 4 December 2025

QUT Queensland University of Technology

CRICOS No. 00213J

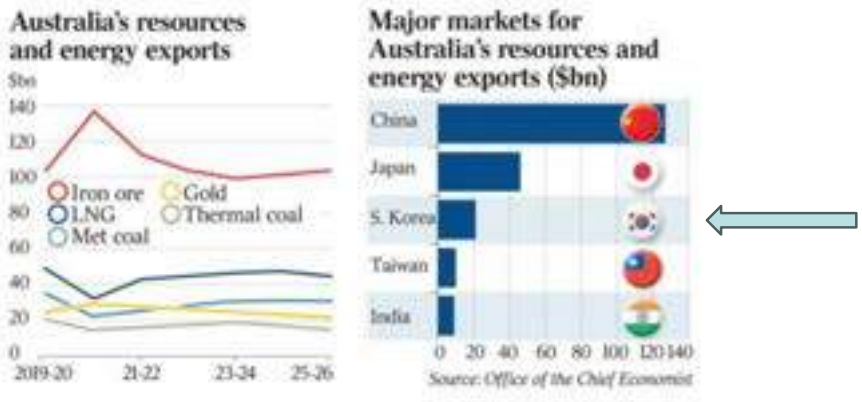
Current State of Australian Energy Trade



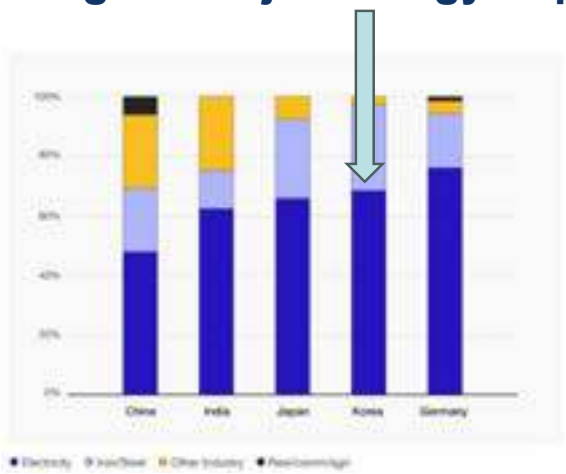
QUT Queensland University of Technology

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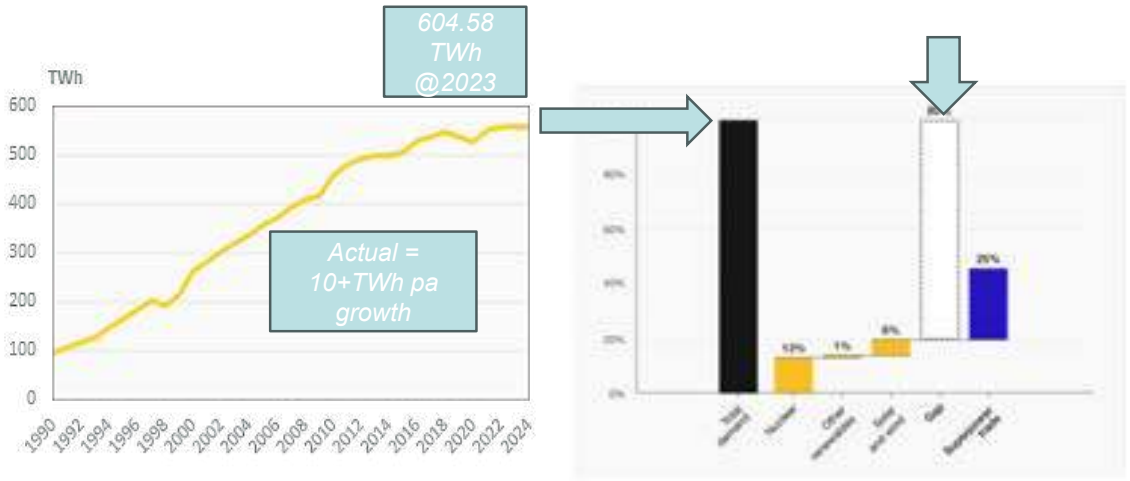
Energy Exports by Market



Coal Usage in Major Energy Export Markets



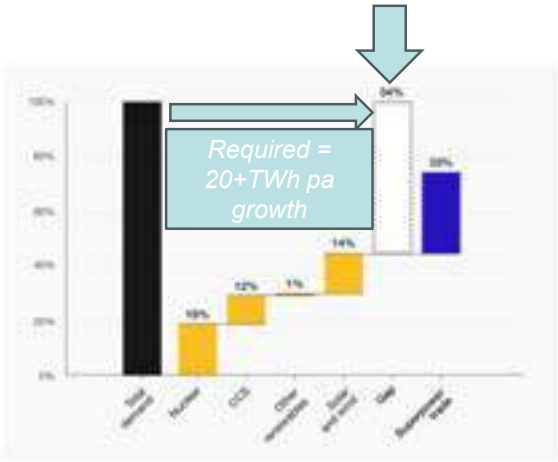
South Korea's Pathway to Net Zero



QUT Queensland University of Technology

elecsee

South Korea's Pathway to Net Zero (cont'd)



QUT Queensland University of Technology

elecsee

Korea's Energy Gap = Australia's Opportunity

8 KEY AUSTRALIAN "SUPERPOWER" EXPORT INDUSTRIES

	Iron	Aluminium	Silicon & polysilicon	Ammonia & urea	Methanol (industrial)	Shipping	Aviation	Road freight	Total
Potential market share	40%	30%	25%	25%	25%	25%	25%	15%	
Export revenue, contemporary market size	$386 billion	$67 billion	$11 billion	$29 billion	$15 billion	$43 billion	$80 billion	$54 billion	**$683 billion**
Export revenue, 2060 market size	$386 billion	$89 billion	$36 billion	$90 billion	$29 billion	$43 billion	$158 billion	$156 billion	**$987 billion**

Korea = 16.52Mt @2038

Korean SP exports @ A$40b+ pa by 2060

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CRICOS No. 00213J

Australia's "Clean Tech" Gap = Korea's Opportunity

South Korea Exports to Australia	Value	Year
Mineral fuels, oils, distillation products	$8.74B	2024
Vehicles other than railway, tramway	$3.47B	2024



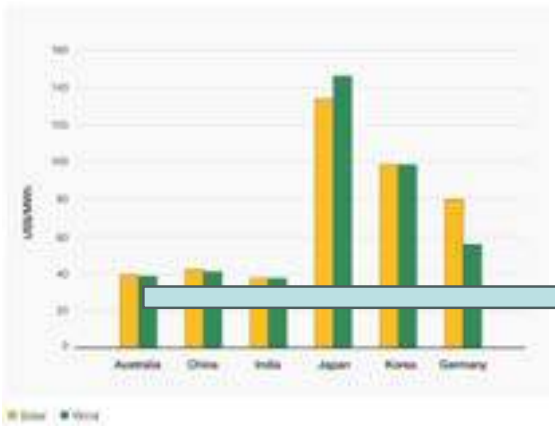
A$17b funded



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Collaboration Opportunities in Renewables





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South Australia's Hydrogen Action Plan





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Exemplar South Australian Hydrogen Projects





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Market Challenges



***Domestic* Scale -** Pragmatic Projects

Large Renewable Generation Projects (**Solar, Wind, Hydro**)

Large Scale - Hydrogen Projects Using Clean Energy

Export of Green Hydrogen /Methanol / SAF / Ammonia to Markets

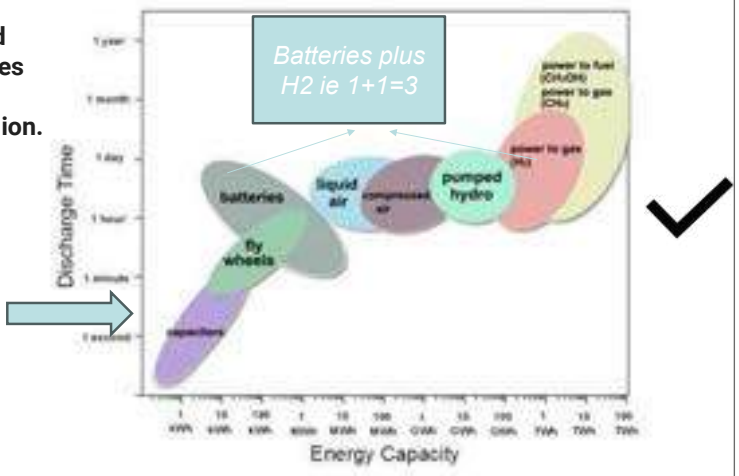
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Market Challenges (cont'd)

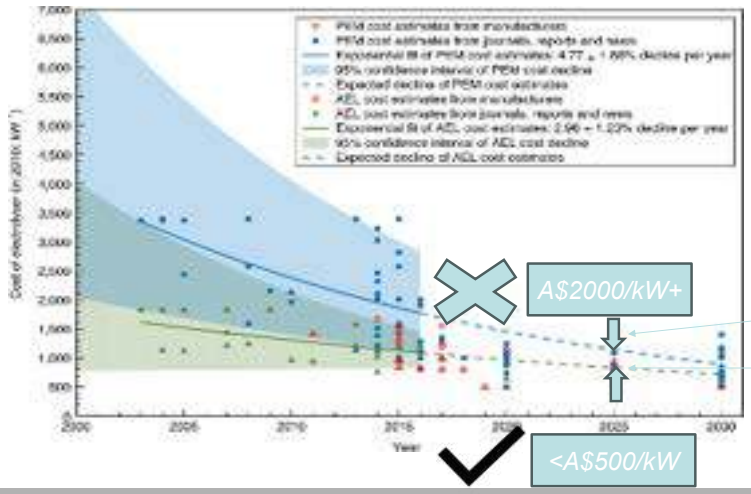
The Snowy 2.0 project has experienced significant cost blowouts, with estimates now approaching $30 billion, far exceeding the original budget of $2 billion.





Queensland University of Technology

Market Challenges (cont'd)



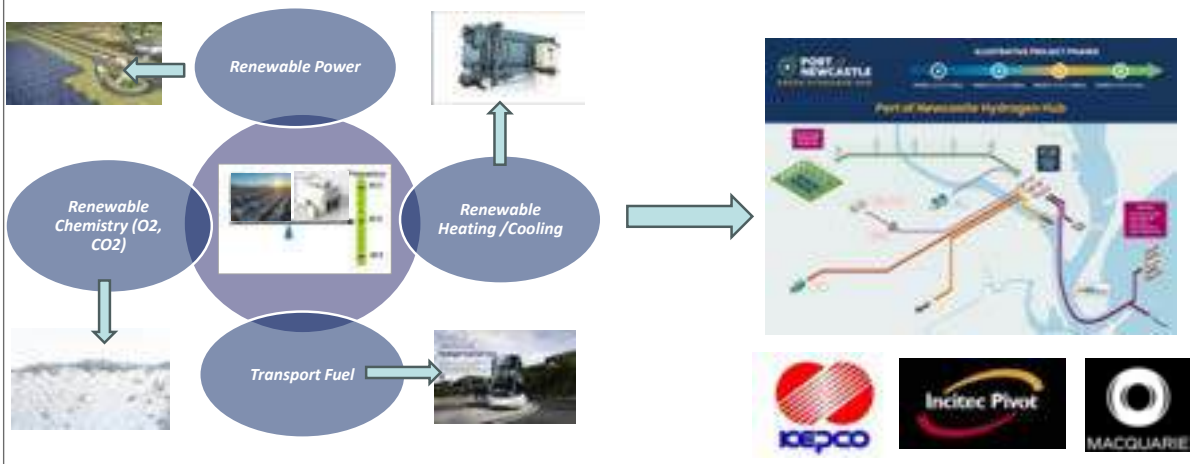






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Market Challenges (cont'd)



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Policies





Carbon trading market stalls after COP28 failure

Is the WTO terminally ill? Threats to the international trading system

CPI rises 1.3% in the September 2025 quarter

Shovel-ready renewables projects grind to a halt

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감사합니다 Thank you







Government of South Australia

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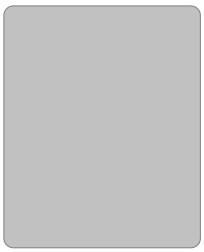
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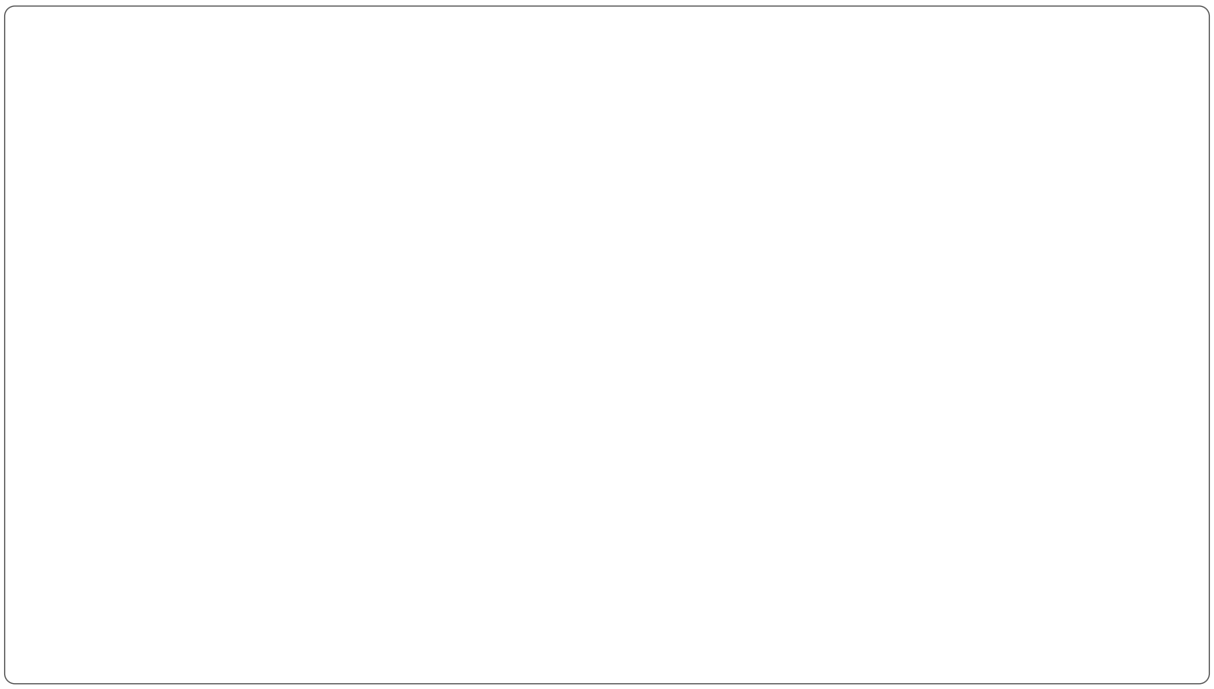
Session II. NSW State Government

Session II. NSW State Government

Accelerate the clean fuel transition of carbon-intensive industry: Direct injection dual-fuel technology



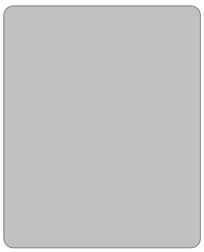
Dongchan Kim
Engineering Lead, Decarice



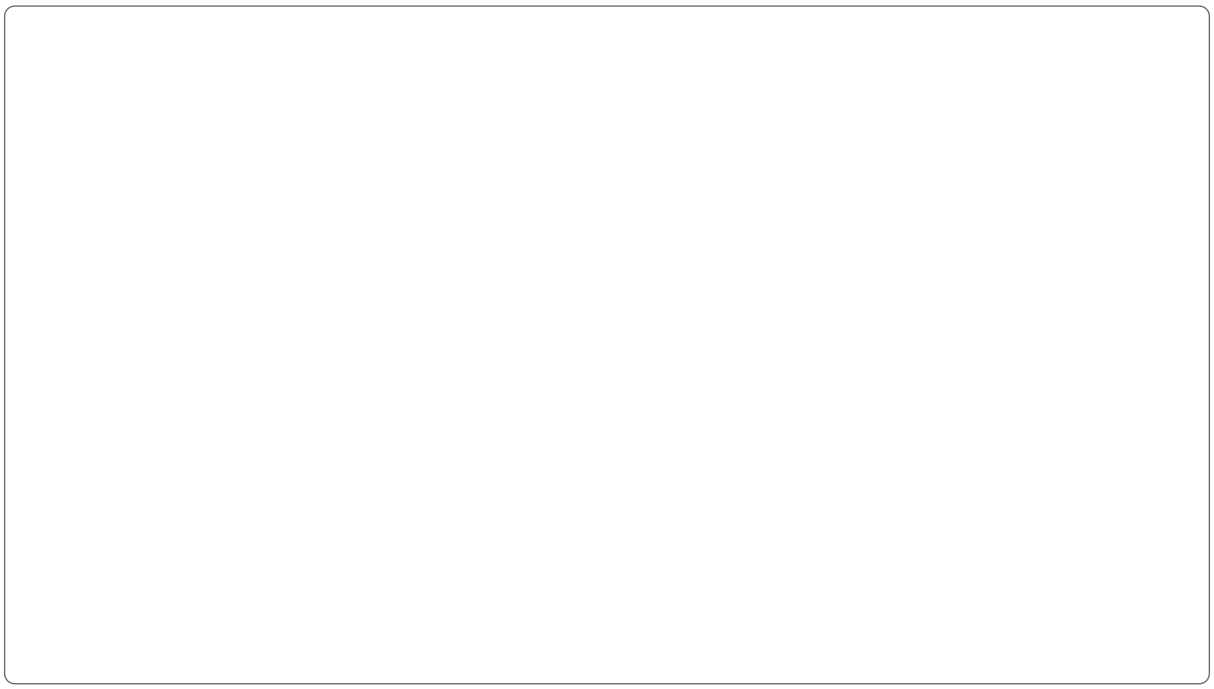


Session II. NSW State Government

Port of Newcastle: Australia's most advanced hydrogen export project



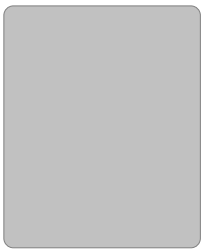
Sheena Martin
Senior Manager Government Relations, Port of New Castle



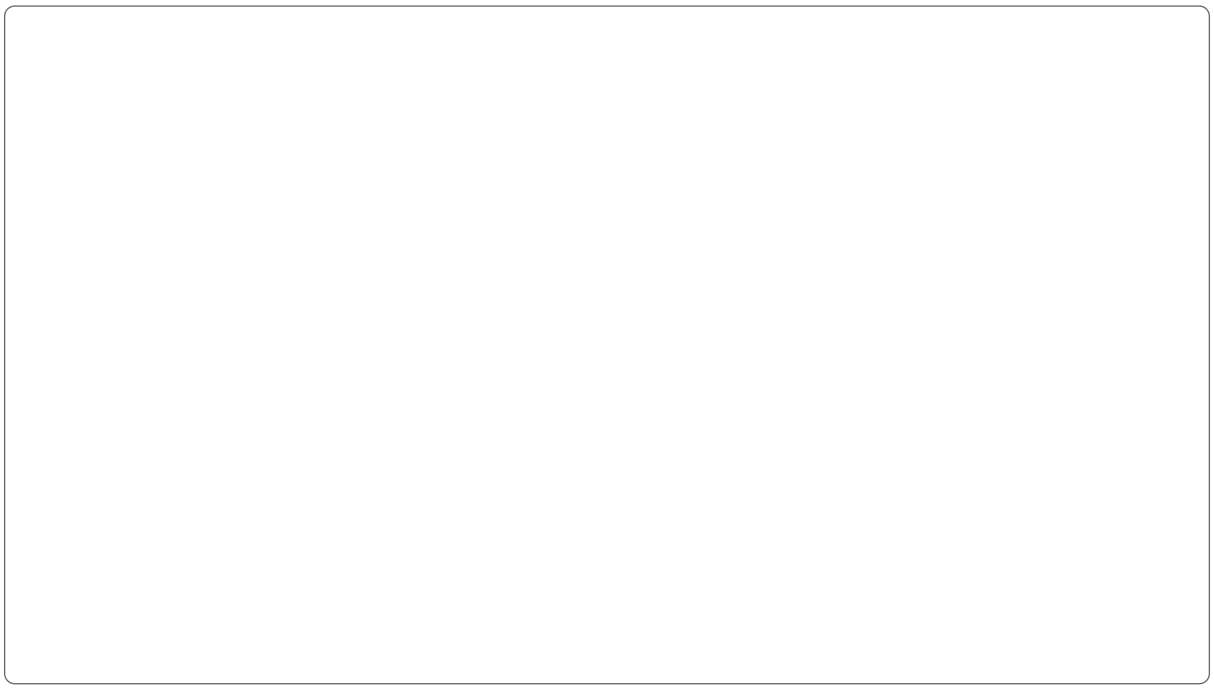


Session II. NSW State Government

"Beating Diesel: How Rux Energy's Advanced Metal Organic Framework (MOF) Storage Materials will slashthe cost of Hydrogen"



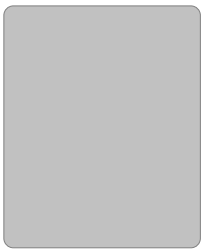
Jehan Kanga
Founder and CEO, Rux Energy





Session II. NSW State Government

How Fugu is Pairing Hydrogen and DAC to Produce Green Methanol At Scale



Luke Marshall
CEO & Co-Founder, Fugu

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Session III.
SA State Government

Session III. SA State Government

Green Hydrogen and Regional Decarbonisation: Helios Project at Port Augusta to Support Local Superpower Industries



Kyu Hong Lee
Chief Strategy Officer, Elecseed

Education
[Mar. 2002 – Aug. 2004] M.A., Political Science, Sungkyunkwan University, Seoul
[Aug. 2002 – Feb. 2003] Exchange Student, Korea National Defense University, Seoul
[Mar. 1994 – Feb. 1998] B.A., Political Science, Sungkyunkwan University, Seoul

Professional Career
[Aug. 2017 – Present] Chief Strategy Officer, Elecseed Group
[2021 – Present] Executive Committee Member, Korean Federation of Environmental Movements (Seongnam)
[Mar. 2022 – Present] General Auditor, Seongnam Citizen's Solar Farm Coop.
[Feb. 2012 – Present] Chief Executive Officer, Orange Project Group Co., Ltd.
[Dec. 2002 – Nov. 2003] Researcher, Project Funded by the Korea Research Foundation
[Jun. 2002 – Sep. 2002] Researcher, The National Assembly of Korea Funding Project
[Jul. 1998 – Jun. 2001] Captain, Chief Intelligence Officer, K-COIC, KOREA Air Force

Research Interest
Green Hydrogen Production
Interface between Renewable Energy and Green Hydrogen Production
Hydrogen Transportation
Hydrogen Usage and Application

Speech Summary
While many commercial-scale green hydrogen projects have recently been paused or cancelled, the demand for decarbonisation across regional industries continues to grow. In Australia, mining and agriculture account for the majority of national exports, meaning that decarbonising these sectors carries significant global impact.
By anchoring green hydrogen projects within export corridors and regional industrial hubs, and ensuring they can scale over time, early commercial viability can be secured while simultaneously preparing for future large-scale export opportunities.
Elecseed is pursuing this strategy by co-developing green hydrogen projects in Australia together with Korea's state-owned power generation companies, the country's future large-volume off-takers of green hydrogen.

Company Introduction
Elecseed is a renewable energy developer and consultancy with offices in Seoul and Brisbane, providing integrated solutions across solar, wind, hydrogen and battery storage. The company focuses on innovation, technical excellence, funding and project development to support the transition in how energy is generated, managed and consumed.
As a Korean owned business with a strong presence in Australia, Elecseed acts as a bridge between the two nations by connecting investment, technology, skills and research. Working with partners across the Asia-Pacific region, Elecseed originates and delivers renewable energy projects that contribute to decarbonisation, energy security and long term sustainable growth.


elecseed
WORLD HYDROGEN EXPO 2025
Project Helios Decarbonisation in USG SA
December 2025
Kyu Hong Lee
Driving future energy


Speaker
elecseed
Kyu Hong Lee
Chief Strategy Officer
Elecseed (Brisbane and Seoul)
Kyuhong.lee@elecseed.io

I. PROJECT OVERVIEW

1. OPPORTUNITY : SA INDUSTRY

elecseed Driving Future Energy

■ Global Hub for Critical Minerals

- ✓ Copper: The foundation of electrification. Olympic Dam (world's 4th largest Cu deposit) and Prominent Hill.
- ✓ Uranium: Holds 80% of Australia's total reserves, supporting low-carbon nuclear energy.
- ✓ Others: Cobalt, Graphite, and Iron Ore, crucial for batteries and renewable technology manufacturing.

■ SA is actively pursuing sustainability

- ✓ Hydrogen Integration: Strong potential for Green Hydrogen adoption to fuel remote mine-site operations (haulage, processing), reducing reliance on diesel & LPG.
- ✓ Energy Resilience: Mines are increasingly utilising Renewable Energy and Battery Energy Storage Systems (BESS) to power operations and secure supply.



I. PROJECT OVERVIEW

2. Project Summary

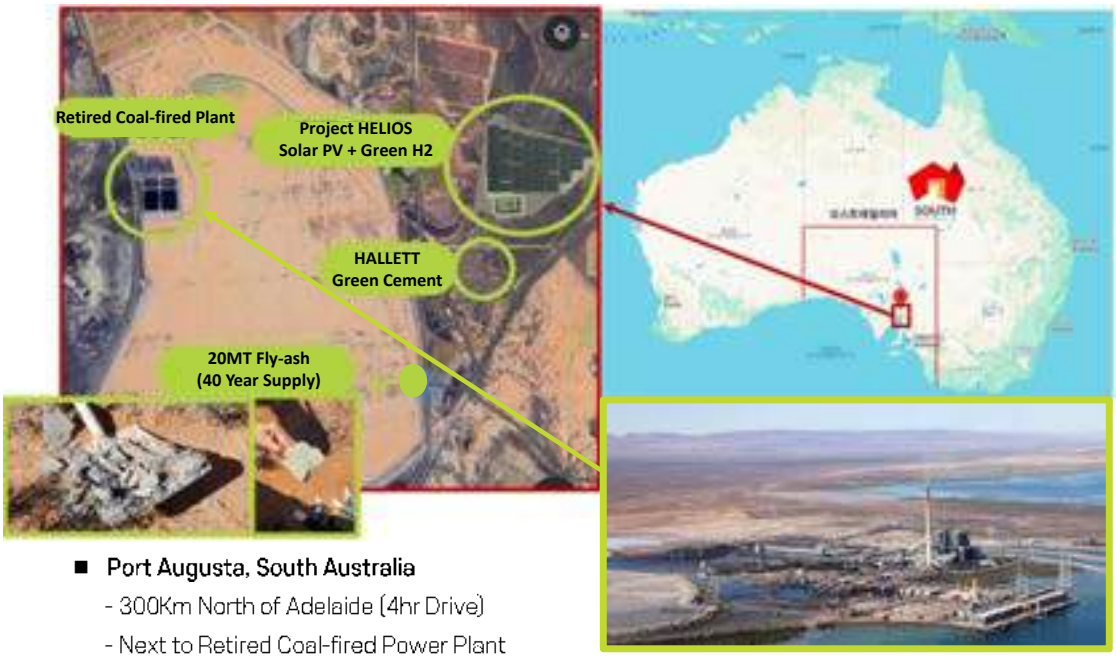
elecseed Driving Future Energy

PROJECT	Project HELIOS (Green Hydrogen Project at Port Augusta, SA)
LOCATION	Port Augusta, SA (Former Coal-fired Plant Site, Partial use of 276HA)
DEVELOPER	Elecseed Group (Off-taker : Local Superpower Industries incl. Hallett)
CAPEX / REVENUE	(CAPEX) A$45m, (Revenue) A$178.5m for 35 years
KEY FACILITIES	- H2 Production : Solar PV – 5.6MWpdc / PEM Electrolyser - 5MW - Storage & Transportation : Compressed Tank / Pipeline to Cement Facility
TIMELINE (Indicative Only)	- Cement Facility : Operational from Dec 2026. (Hallett, under Construction) - Off-take by Local Industry : EOI will be announced in 2026 - FS (Pre-FEED) : June 2023 ~ June 2024 by Elecseed - Construction : Jan 2027 ~ June 2028 (Elecseed, KHNP) - Operation (Life Cycle) : 35 Years by KHNP
FEED PERIOD	- July 2025 ~ August 2026
FUTURE OPPORTUNITIES	- GH2 supply to H2 Applications in the region (FCET, FC Generator, HRS) - HRS between Mining Area and Ports / Fuel Cell Trucks - Scale-up for Export to Overseas

I. PROJECT OVERVIEW

3. SITE LOCATION

elecseed Driving Future Energy



- Port Augusta, South Australia
  - 300Km North of Adelaide (4hr Drive)
  - Next to Retired Coal-fired Power Plant

I. PROJECT OVERVIEW

3. SITE LOCATION

elecseed Driving Future Energy

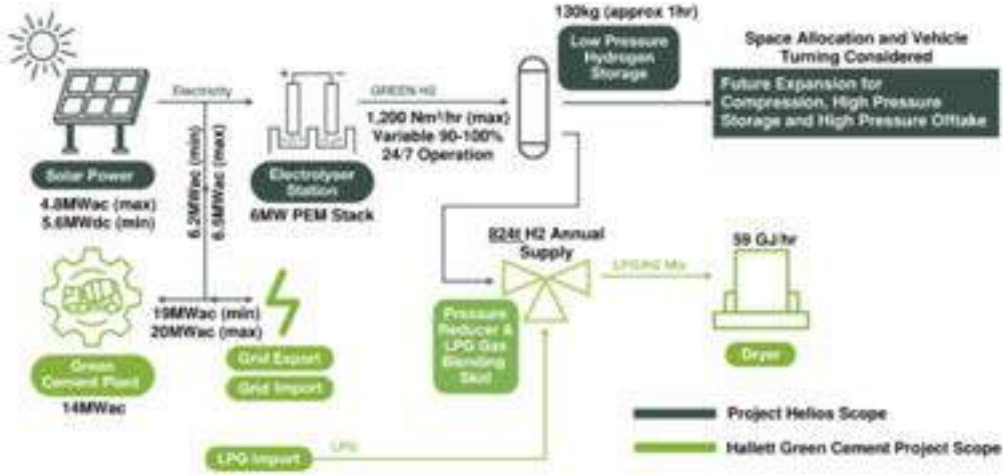


- Hallett Green Cement Transformation Project
  - GCTP under construction
  - FFD Energy Minister Bowen Site Visit (July 2024)

I. PROJECT OVERVIEW

4. KEY FACILITIES – Green Cement & HELIOS

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- ✓ Green Power : Solar PV 5.6MWpdc / Green PPA
- ✓ PV Structure : Deployable Tracker by 5B (SA Manufacturer)
- ✓ GH2 Production : PEM Electrolyser 5~6MW (approx. 850T p.a.)
- ✓ Storage : 130kg (Low Pressure, 1Hr Production)
- ✓ Transportation : Pipeline to Green Cement Facility and Tube Trailer to Regional Industries
- ✓ Support Facility : Admin Office, Car Park and Site Infrastructure

I. PROJECT OVERVIEW

4. KEY FACILITIES

elecseed Driving Future Energy



■ Bird view from Office Entrance

I. PROJECT OVERVIEW

4. KEY FACILITIES

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■ Bird view of the Project Helios in the morning

I. PROJECT OVERVIEW

4. KEY FACILITIES

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■ Bird view of the Project Helios in the afternoon

I. PROJECT OVERVIEW
4. KEY FACILITIES

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■ Bird view of the Project Helios

I. PROJECT OVERVIEW
4. KEY FACILITIES

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■ Bird view of Green Hydrogen Facility from the office entrance

I. PROJECT OVERVIEW
4. KEY FACILITIES

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■ Bird view of Green Hydrogen Facility from the carpark entrance

I. PROJECT OVERVIEW
4. KEY FACILITIES

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■ Bird view of pipelines in the rear of Green Hydrogen Facility

I. PROJECT OVERVIEW

4. KEY FACILITIES

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■ Side view of Green Hydrogen Facility

I. PROJECT OVERVIEW

4. KEY FACILITIES

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■ Cooling and Storage of Green Hydrogen Facility

I. PROJECT OVERVIEW

4. KEY FACILITIES

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■ Solar PV and 5B Deployable Structure

II. GOVERNMENT SUPPORT

1. OFF-TAKER & GOVERNMENTS

elecseed Driving Future Energy

■ Project Promotion at H2 MEET 2023 / 2024

- ✓ Joint promotion in the SA Booth at AUSTRADE
- ✓ ogether with MR. Mark Pickard (Iallett Group Owner, 2023) / MR. Craig Cresp (GM of Por. Augusta, 2024)
- ✓ Project Speech on Australian Country Day
- ✓ Meetings with Korean Green Hydrogen Related Companies (Fuel Cell Power Plants, Scalable in Por. Augusta)







II. GOVERNMENT SUPPORT

1. OFF-TAKER & GOVERNMENTS

elecseed Driving Future Energy

■ Korea Hydro and Nuclear Power Visit 2024

✓ SA Gov. Hallett and Elecseed Visited to KHNP HQs at Gyeongju

✓ KHNP are supposed to be a Strategic Investor and O&M Provider to Project HELIOS





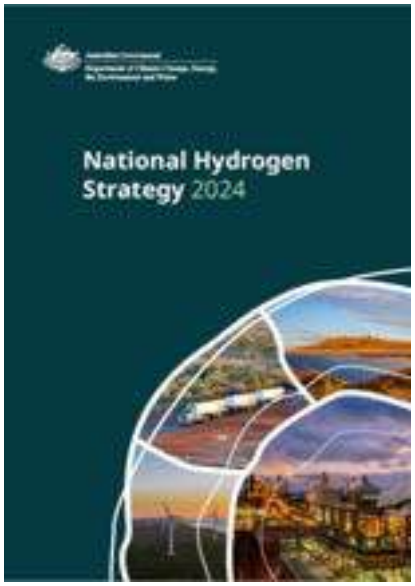


II. GOVERNMENT SUPPORT

2. FED GOVERNMENT

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■ National Hydrogen Strategy 2024 (The Fed. Dept of Climate Change Energy the Environment and Water)





✓ The Australian Federal Government (DCCEEW) published National Hydrogen Strategy 2024

✓ Helios is included as one of South Australian key hydrogen projects

II. GOVERNMENT SUPPORT

3. SA GOVERNMENT

elecseed Driving Future Energy

■ World Hydrogen Summit 2025, Rotterdam





PORT AUGUSTA
Hallett Group, Elecseed and KHNP – Hydrogen Powered Green Cement
Vast Solar Methanol Consortium, Concentrated Solar Thermal – Lime Plant – Green Methanol

■ Australian Week, OSAKA EXPO 2025, Japan





II. GOVERNMENT SUPPORT

4. KOREAN GOVERNMENT

elecseed Driving Future Energy

■ Ministry of Climate, Energy and Environment – KEITI Overseas Environment Project Grant



- ✓ Korean Government Grant : A$1.35 mil
- ✓ Elecseed & KHNP Contribution : A$0.9 mil
- ✓ Feasibility Report for Final Investment Decision (FID) will be produced and delivered by June 2026



Australia Climate Change Energy Minister Chris Bowen and Korean Climate Energy and Environment Minister Kim met at COP30 in Brazil to discuss a possible cooperation on Green Hydrogen and Clean Tech.

III. FUTURE OPPORTUNITIES

1. REGIONAL EXPANSION

elecseed Driving Future Energy

■ **Opportunities in Upper Spencer Gulf**

- Minerals : Iron ore, Copper, Uranium, Magnetite
- Companies : SIMEC, BHP, OZ Minerals
- Mines
  - Whyalla : Iron Ore (10MT p.a)
  - Prominent Hill : Copper (100kT p.a)
  - Olympic Dam : Copper (200kT p.a), Uranium (4kT p.a)





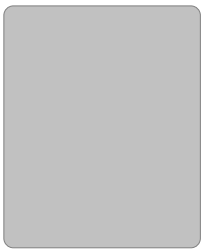
■ **H2 Applications and Future Demands**

- FCET/FCEV and HRS (Mineral Transportation)
- FC Power Plants / FC Machinery
- Synthetic Fuel Production
- By-product O2 : Waste Water Facility



Session III. SA State Government

Policies, Market Challenges and Collaboration Opportunities in Clean Tech and Renewables between Korea and Australia



Neil Thompson

Industry Adjunct Professor, Queensland University of Technology

Education

- PhD in clean technology systems integration (ISD, SolaDrive, HydroDrive, BioDrive)
- Master's Degree in Business Administration (International Business Major)
- Bachelor in Electrical Power Systems and Computer Engineering (ADEE with Distinction)

Professional Career

- MD, ITM Linde JV APAC
- National Sustainability Manager, VDM Group
- GM, Silver Asset Services, Devine Property Group
- APAC Business Manager Renewables, Yuasa Corporation
- APAC Business Manager Radiation Processing Systems, Iwasaki Electric Group

Research Interest

- Deployment of AI control in electricity grid for reduced kWh and network charges
- Infrastructure sensors in digital grid transmission towers for predictive maintenance
- Integration of battery, fuel cell and biogas in combined power and transport systems
- Development of low-cost, recyclable lithium-ion batteries
- Scale-up of gasifiers using plastic waste, ag waste, MSW for low carbon liquid fuels

Speech Summary

The Australian-Korean bilateral trade and investment relationship stands on the cusp of a new era of accelerated growth to 2050 with the provision of value-added Australian renewable energy and energy transition materials to Korea in return for supply of clean tech building blocks such as batteries, electrolysers, fuel cells and advanced finished goods such as EV and FCEV cars, buses, trucks and trains as well as inbound Korean investment into Australian renewables and "Superpower" projects that can effectively quadruple Australian-Korean bilateral trade by mid-century.

Company Introduction

QUT's academic staff consult in industry and work on industry projects which often involve students. Industry representatives and professionals contribute to our course development, adding a practical perspective to theoretical education. Staff and students have access to the latest teaching technology.

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Session IV.
WA State Government

Session IV. WA State Government

The Cardinia CCS Project: A Carbon Storage Solution for the Hard-To-Abate Industries



Peter Hoiles
General Manager, InCapture

Education
2008-2012, PhD, Earth Sciences, The University of Melbourne, Melbourne, Australia
2006, BSc (Hons), Earth Sciences, James Cook University, Cairns, Australia
2001-2005, BSc, Earth Sciences, The University of Melbourne, Melbourne, Australia

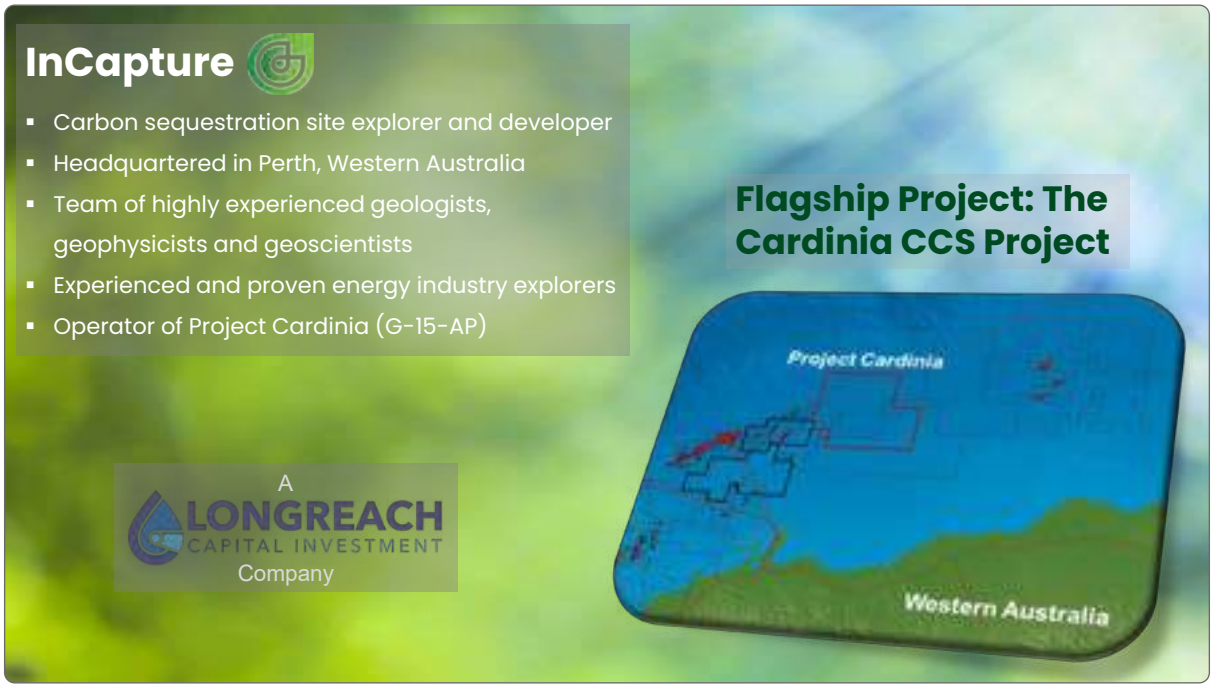
Professional Career
2024-2025, General Manager, InCapture, Perth, Australia
2021-2024, Business Development Manager, InCapture, Perth, Australia
2019-2021, Senior Geoscientist, Discover Geoscience, Perth, Australia
2015-2019, Senior Geophysicist, DownUnder GeoSolutions, Perth, Australia
2012-2015, Geophysicist, DownUnder GeoSolutions, Perth, Australia
2006-2008, Engineering Geologist, Golder Associates, Cairns, Melbourne, Australia

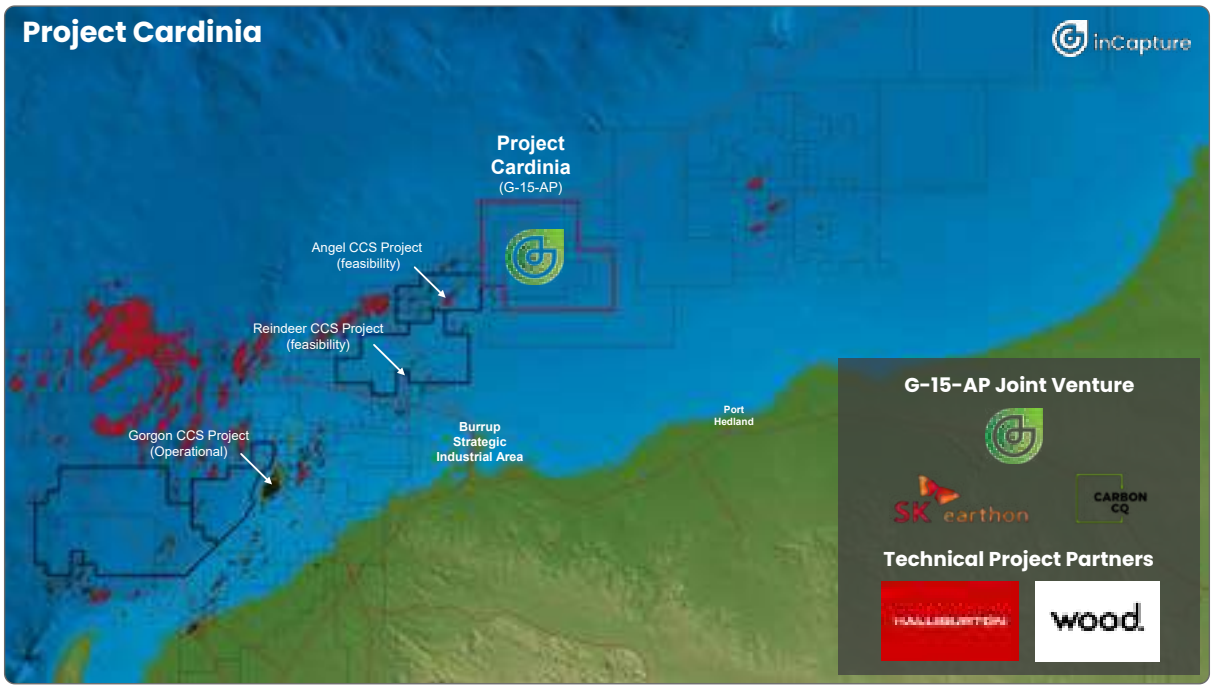
Research Interest
Carbon capture and storage, low carbon solutions, value chain facilitation, emitter engagement.

Speech Summary
The Cardinia CCS Project aims to offer geological carbon dioxide storage solutions to the hard-to-abate sectors from South Korea, Japan and Australia. Located on the North West Shelf of Australia, the Cardinia CCS Project is situated next to the Burrup Strategic Industrial Area and is near to a future industrial and green energy corridor. Together with joint venture partners SK earthon and Carbon CQ, InCapture is working with technical program partner Halliburton to rapidly carry out a technical work program designed to move through key regulatory milestones to work towards an accelerated operational timeframe.

Company Introduction
InCapture Pty Ltd (InCapture) is a privately owned company based in Western Australia and is part of the Longreach Capital Investment group. InCapture is a carbon storage site explorer and developer, with the Cardinia CCS Project as its flagship project.


inCapture
THE CARDINIA CCS PROJECT
A Carbon Storage Solution For The
Hard-to-abate Industries


InCapture
Carbon sequestration site explorer and developer
Headquartered in Perth, Western Australia
Team of highly experienced geologists, geophysicists and geoscientists
Experienced and proven energy industry explorers
Operator of Project Cardinia (G-15-AP)
A
LONGREACH
CAPITAL INVESTMENT
Company
Flagship Project: The Cardinia CCS Project
Project Cardinia
Western Australia



Project Cardinia Highlights

- First mover advantage on one of Australia's first green CCS projects.
- Burrup Peninsula location – prime future industrial and green energy corridor.
- Rapid assessment program with potential early 2030s operational timeframe.
- Global-scale storage sites with the potential for 5+ million tonnes CO_2 per annum and considerable upside.
- Second year of a three-year exploration program, rapidly moving towards the next major regulatory milestone



One of Australia's first potential carbon sequestration sites that does not promote, rely, nor prolong oil and gas projects



Located in a prime future industrial and green energy corridor with access to the South-East Asian region emissions sources



Hub Concept Development Design Concept

inCapture



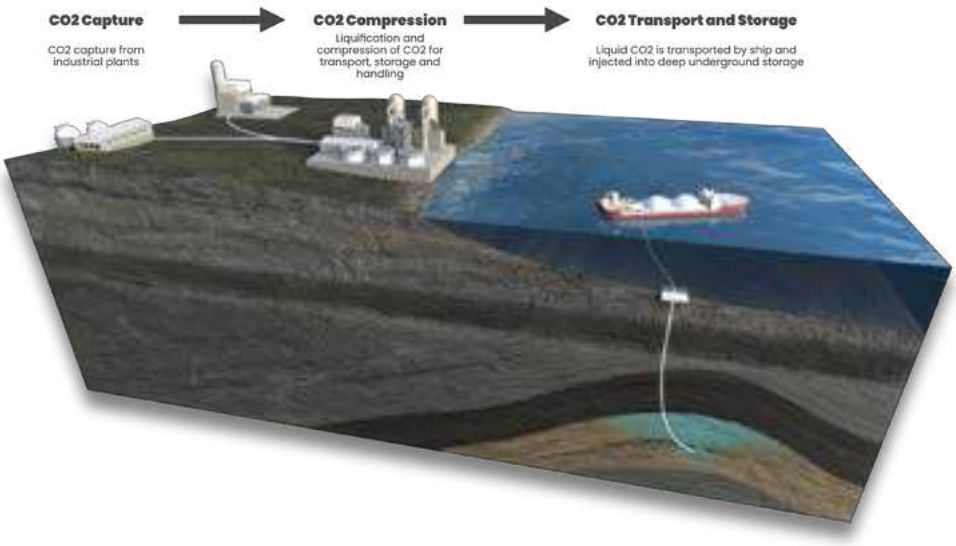
Project Overview Schematic with Pipeline Concept

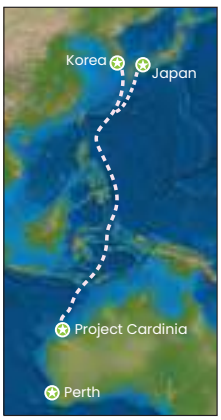


Schematic of Onshore facilities for the Hub Concept with CO_2 Import Terminal

Liquid CO_2 Carrier Shipping Option

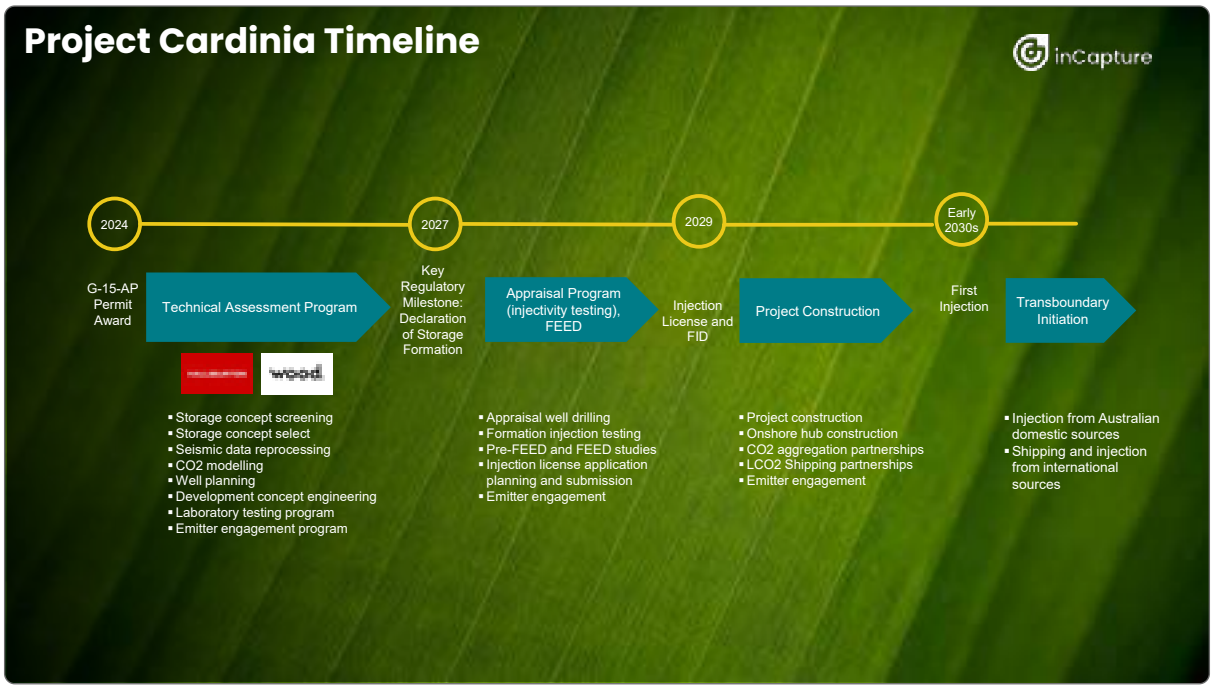
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Cross Border Transportation

High Level Concept

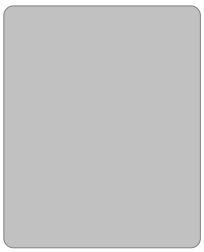

Project Cardinia Timeline
inCapture
2024
2027
2029
Early 2030s
G-15-AP Permit Award
Technical Assessment Program
Key Regulatory Milestone: Declaration of Storage Formation
Appraisal Program (injectivity testing), FEED
Injection License and FID
Project Construction
First Injection
Transboundary Initiation
wood.
▪ Storage concept screening
▪ Storage concept select
▪ Seismic data reprocessing
▪ CO2 modelling
▪ Well planning
▪ Development concept engineering
▪ Laboratory testing program
▪ Emitter engagement program
▪ Appraisal well drilling
▪ Formation injection testing
▪ Pre-FEED and FEED studies
▪ Injection license application planning and submission
▪ Emitter engagement
▪ Project construction
▪ Onshore hub construction
▪ CO2 aggregation partnerships
▪ LCO2 Shipping partnerships
▪ Emitter engagement
▪ Injection from Australian domestic sources
▪ Shipping and injection from international sources


The Opportunity
▪ Access to a dedicated carbon storage site for Australian, Korean and Japanese emitters
▪ Be part of one of Australia's first green CCS projects
▪ Located in proximity to the Burrup Strategic Industrial Area
▪ Located in proximity to one of Australia's future industrial and green energy growth corridors
▪ Become part of the CCS value chain:
▪ CO2 Aggregation
▪ LCO2 Shipping
▪ Onshore Hubs & Storage
▪ Engineering and construction
Contact: info@incapture.com.au
SK earthon
CARBON CQ

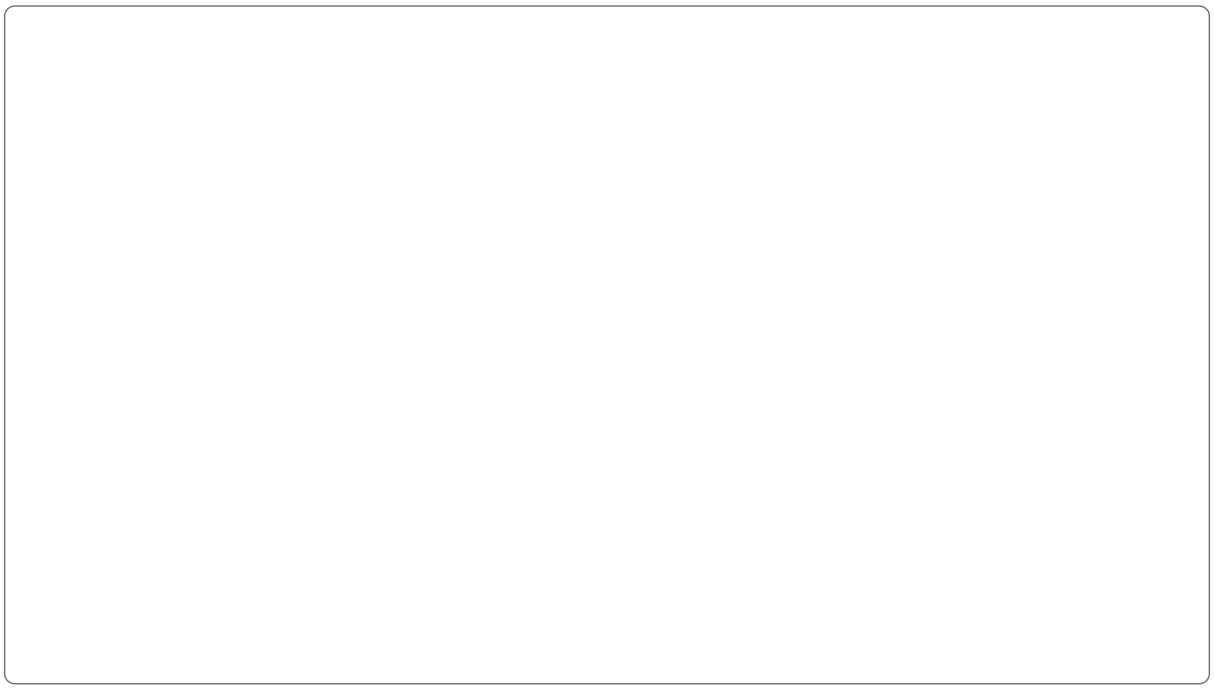
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Change the future of decarbonization, without changing your engines



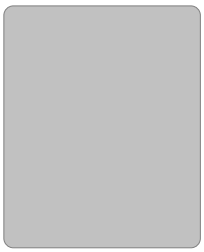
Mark Burke
Group Corporate Development Manager,
Hy-Boost Technology



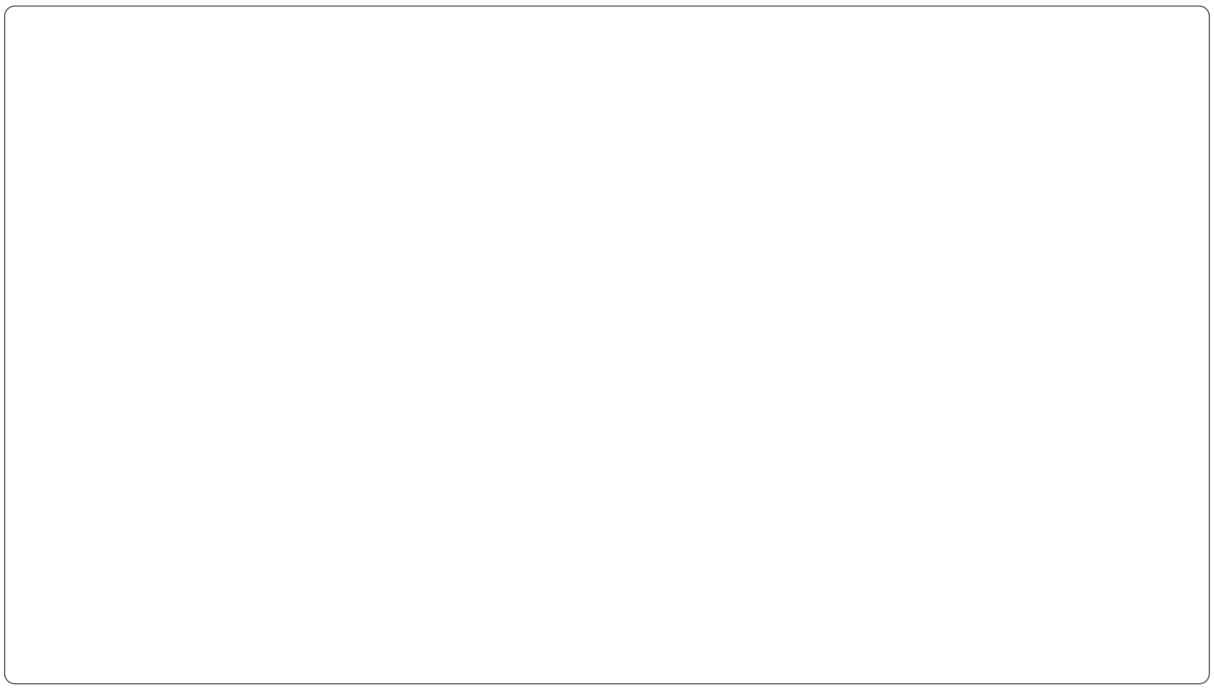


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Australian Natural Hydrogen Exploration



Krista Davies
Chief Operating Officer, Prominence Energy



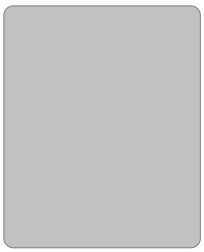


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Country Day : Canada Day

WORLD HYDROGEN EXPO 2025 6th
Conference

Canada's Hydrogen Roadmap: Building an Economically Prosperous, Low-Carbon Future



Nicolas Hilario
Vice-President, Operations,
Canadian Hydrogen Association

Canada's Hydrogen Roadmap: *Building an Economically Prosperous, Low-Carbon Future*

Seoul, Korea

December 2025

David Billedeau
President and CEO, CHA

Canadian Hydrogen Association | Association Canadienne de l'Hydrogène

Hydrogen Ontario

Canada's Hydrogen Journey

ESTABLISHING PIONERRING LEADERSHIP

1905 – 1970s

Beginnings

1905 – A.T. Stuart presented the opportunity for electrolysis of water in Niagara Falls.

1913 - 1948 – "Stuart Cell" and The Electrolyser Corporation.

1973-79 – The oil crisis led to renewed interest in hydrogen. Investments were made in hydrogen research to reduce dependence on imported oil, and the Canadian Hydrogen Association was established

1980s- 2010s

Strategic Developments

1983 – Ballard Power Systems is founded.

1987 – Hydrogen National Mission for Canada is published.

2016 – Hydrogenics partnered with Alstom to develop hydrogen-powered trains.

2020s

Accelerating towards a hydrogen economy

2020 – Canada's "Hydrogen Strategy for Canada" is released.

2022-2025 – Numerous projects were announced, including the development of hydrogen hubs in AB, SK and ON, and increased. investments in electrolyzers and fuel cells.

The Canadian H2 Value Proposition

Leading energy exporter	Top-10 H2 producer at 3 million tons per year	100+ years of expertise in electrolyzer technology & products
40+ years of expertise in hydrogen fuel cell technologies	Hydrogen production expertise (electrolysis, biomass gasification, pyrolysis, reforming)	CAD $500MM sector revenues
Diverse industrial ecosystem spanning the entire value chain	4,000+ highly skilled professionals	Every province in Canada has strong competitive advantages



Canadian Project Developments since 2020



Provinces with H2 Hubs



Our Mission



The CHA: By the numbers

50+
Years of history

190+
Members nationwide

3
Regional affiliates

60+
International trade missions

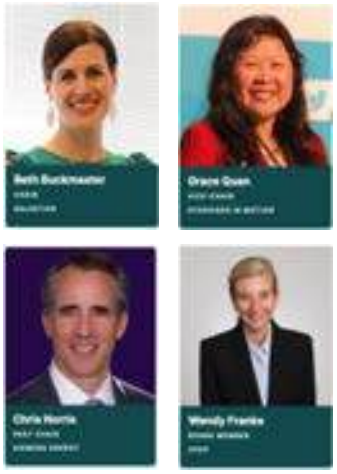
$17MM
Project funding secured in the last decade

40+
Partner organizations

Our Team



Management Team



Executive Leadership



Regional Affiliates

As a national association, the CHA works collectively with our network of unique affiliates to tackle regional advocacy and advance hydrogen projects and policy in each province.

HYDROGEN BC | **HYDROGEN ALBERTA** | **HYDROGEN ONTARIO**

Each affiliate works to maximize the opportunity for companies and provinces to participate in the economic and environmental opportunities afforded by the deployment of hydrogen and hydrogen technologies.

Meet the CHA in 2025-26

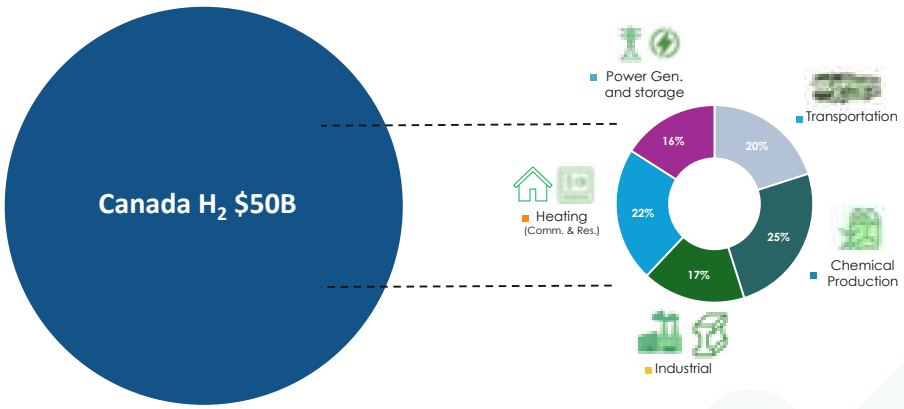
- March 17-19, 2026 – **TOKYO** – H2&FC EXPO (World Smart Energy Week)
- April 21-23, 2026 – **EDMONTON** – Canadian Hydrogen Convention
- May 17-29, 2026 – **ROTTERDAM –** World Hydrogen Summit





www.canadah2.ca

Canadian H2 market by 2050



12

Canada's Hydrogen Strategy (NRCAN, 2020)

Vision:

- Position Canada as a **top 3 global producer** of clean hydrogen by 2050.
- Build a net-zero emissions future through **hydrogen as a key pillar of decarbonization.**

Core Objectives:

- **Scale up production:** Leverage Canada's abundant renewable and low-carbon energy resources.
- **Develop domestic markets:** Support transportation, industry, power generation, and heating.
- **Enable exports:** Build infrastructure for Atlantic and Pacific hydrogen trade.
- **Foster innovation:** Advance R&D in hydrogen technologies and applications.

2030–2050 Roadmap:

- **By 2030:** Kickstart hydrogen hubs, build enabling infrastructure, scale initial markets.
- **By 2050:** Hydrogen could meet up to 30% of Canada's end-use energy demand and cut up to 190 Mt CO_2e annually.

Strategic Enablers:

- Investment tax credits, clean fuel regulations, and federal funding programs (e.g., Clean Fuels Fund, Canada Growth Fund).
- Collaboration with provinces, Indigenous communities, and international partners.



Canadian Federal Government Support

Regulatory measures	Funding programs	Investment Tax Credits
• Clean Fuel Regulations (CFR)	• Clean Fuels Fund (CFF)	• Clean Hydrogen Investment Tax Credit (CH ITC)
• Carbon Pollution Pricing	• Strategic Innovation Fund/Net Zero-Accelerator (SIF-NZA)	• Clean Electricity Investment Tax Credit
• Methane Regulation	• Canada Growth Fund (CGF)	• Clean Technology Investment Tax Credit
	• Canada Infrastructure Bank (CIB)	• Clean Technology Manufacturing Investment Tax Credit
	• Zero Emission Vehicle Infrastructure Program (ZEVIP)	• The Investment Tax Credit for Carbon Capture, Utilization and Storage (CCUS ITC)

Hydrogen Applications – State of Affairs & Key Projects

Transportation

- Alberta Zero Emissions Truck Electrification Collaboration (AZETEC): demonstration of 2 heavy-duty, class 8 fuel cell electric trucks
- 100 Toyota Mirai's at Edmonton airport
- HTEC liquid hydrogen production (in development)
- GTAA: ground transportation / refueling

Transit

- Winnipeg Transit: 8 fuel cell buses purchased in 2024. Deployment of 33 zero-emission buses by 2027.
- City of Mississauga: 10 fuel cell bus pilot
- Cordia iLint: Alstom hydrogen train pilot from Montmorency Falls to Baie-Saint Paul

Production/Storage/Blending/ Biofuels

- Production Projects in Nanaimo (Parkland) and Prince George (early stage)
- Atura Power Niagara Project
- HONE hydrogen generator system
- Triple Point: salt dome hydrogen / compressed air storage project near Stephenville, NL
- Enbridge Markham, ON: H2 blending and CHP
- Varennes, QC: biorefinery and hydrogen electrolysis project

Heavy Industry

- CCS from (carbon intensive) hydrogen production at existing facilities in AB. New developments could achieve capture rates up to 98% when paired with autothermal reforming, e.g. Shell's Scotford Upgrader, Nutrien's Redwater Sturgeon refinery & fertilizer plant, Linde & ATCO (in development)
- ArcelorMittal, QC & ON: Hydrogen ready DRI plant & electric arc furnace

15

Core Federal Policy Priorities

Focus: Enabling Canada's Clean Hydrogen Economy

- Integrate Hydrogen and Its Derivatives Within Canada's Economic, Industrial, and Export Strategies
- Strengthen Investment Tax Credits for Clean Hydrogen, Clean Technology, and Carbon Capture, Utilization, and Storage
- Drive Investment and Rapid Deployment in Canada's Hydrogen Economy
- Build Out Hydrogen Infrastructure for Transportation, Power, Marine, and Derivative Fuels
- Ensure Long-Term Market Stability

Outlook for Domestic Hydrogen Deployment

Opportunities:

- **Strong domestic resource base:** abundant renewable electricity and natural gas with CCUS.
- **Growing provincial initiatives:** hydrogen hubs in Alberta, Ontario, B.C. gaining traction.
- **Potential to strengthen North American energy security if cross-border alignment improves.**

Challenges:

- **Unstable policy environment**: shifting federal and provincial priorities.
- **Cross-border trade disruptions**: tariffs, Buy America provisions, and regulatory misalignment with the U.S.
- **Financing challenges**: high risk due to uncertain revenue streams and policy timelines.



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Outlook for Atlantic Export

Opportunities:

- **Current strong demand:** EU urgently diversifying away from Russian energy.
- **Supportive EU policy frameworks (e.g., REPowerEU hydrogen import targets).**
- **First-mover advantage:** Canada can establish itself as a reliable long-term supplier.

Challenges:

- **Demand uncertainty:** EU may reduce imports from Canada if relations with Russia normalize.
- **High capital requirements for transatlantic export infrastructure.**
- **Volatile policy signals:** shifts in EU's hydrogen certification and trade rules.



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Outlook for Pacific Export

Opportunities:

- **Japan, South Korea, and Taiwan:** stable, technology-friendly partners with ambitious hydrogen roadmaps.
- **Potential for multilateral Indo-Pacific clean energy partnerships.**
- **Diversification of export markets** reduces dependence on any single trade partner.

Challenges:

- **Strained Canada–China relations:** tariffs, trade barriers, and limited trust.
- **Regional instability:** tensions in the Indo-Pacific increase risk for long-term contracts.
- **Competitive markets:** Australia, Middle East, and U.S. are also pursuing Pacific hydrogen exports.



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Canada–Korea Potential Areas of Collaboration

Policy & Standards

- Joint development of hydrogen safety, certification, and regulatory frameworks.
- Knowledge exchange on national hydrogen strategies and policy roadmaps.

Technology & Innovation

- Collaboration on electrolyzers, fuel cells, and hydrogen storage R&D.
- Joint demonstration projects (e.g., hydrogen-powered transit, port operations).

Trade & Investment

- Korean investment in Canadian hydrogen production hubs.
- Canadian hydrogen exports to Korea for industrial decarbonization and power generation.

Academic & Workforce Development

- University partnerships for hydrogen research and training programs.
- Exchange programs to develop a skilled hydrogen workforce in both countries.

Closing Thoughts

Canada's Path Forward in Hydrogen & Low-Carbon Energy

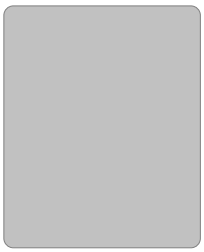
- Canada possesses **abundant resources** and technological expertise to lead in the global hydrogen transition.
- Domestic deployment faces **uncertainty**, but offers **transformative opportunities** for energy security and decarbonization.
- Atlantic and Pacific export pathways reflect both promise and unpredictability shaped by geopolitics.
- Strategic partnerships — including with Korea — can strengthen innovation, investment, and market access.

Key Message:

➢ Canada's hydrogen and low-carbon ecosystem is not just a national project — it is a global roadmap built on collaboration, resilience, and shared opportunity.

Thank you.

Hydrogen Opportunities from Alberta in the AI Era: New Potential for Korea–Canada Cooperation.



Victor Lee
Counsellor, Alberta Government Representative in Korea

Hydrogen Opportunities from Alberta in the AI Era:
Potential for Korea–Canada Cooperation



Victor Lee
Alberta Government Representative in Korea / Counsellor
알버타 주정부 대표 / 참사관
주한캐나다대사관



Alberta's International Presence





Alberta Korea Office
Canadian Embassy in Korea
(Established in 1988)



Our Mandate

- Trade Promotion
- Investment Attraction
- Talent Attraction
- R&D Collaboration
- Advocacy

Alberta
Canada

Economic Development Activities

For Alberta stakeholders

- Introduce commercial and R&D opportunities in Korea
- Support trade missions from AB to Korea
- Introduce & facilitate targeted B2B matchmaking



For Korean stakeholders

- Introduce commercial and R&D opportunities in AB
- Support buyers/investors missions from Korea to AB
- Introduce & facilitate targeted B2B matchmaking

알버타, 캐나다?











Alberta

Canada's economic engine
























Drumheller: Dinosaur capital of the world

Alberta & Korea



Energy Security

- Heavy Oil
- LNG
- Hydrogen
- CCUS
- Critical Minerals



Food Security

- Beef
- Pork
- Grains
- Functional beverages
- Pet food



Innovation Partnerships

- Leverage 50+ years of Alberta-Gangwon Sister-Province relationship
- R&D partnerships in various fields



Creative Industry

- Attracting Korean films/movies
- Sports exchange
- Tourism
- Cultural exchanges

Hydrogen Opportunities (Trade, Investment, R&D)













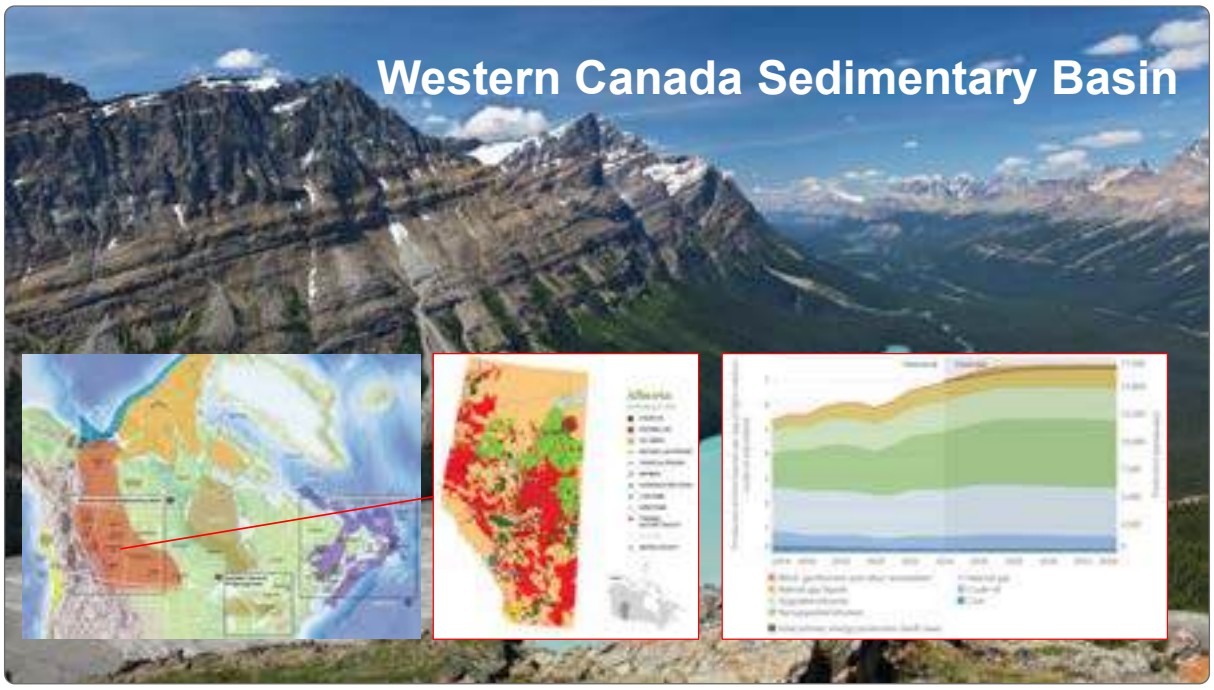
The Division of Powers in Canada

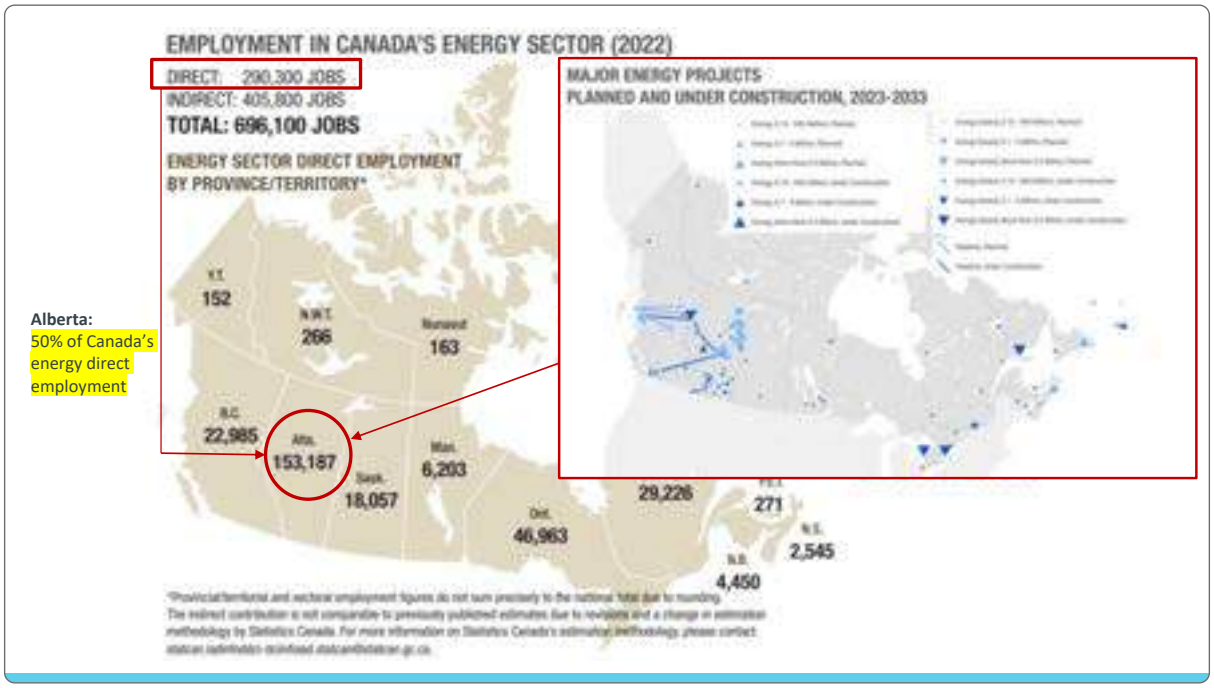


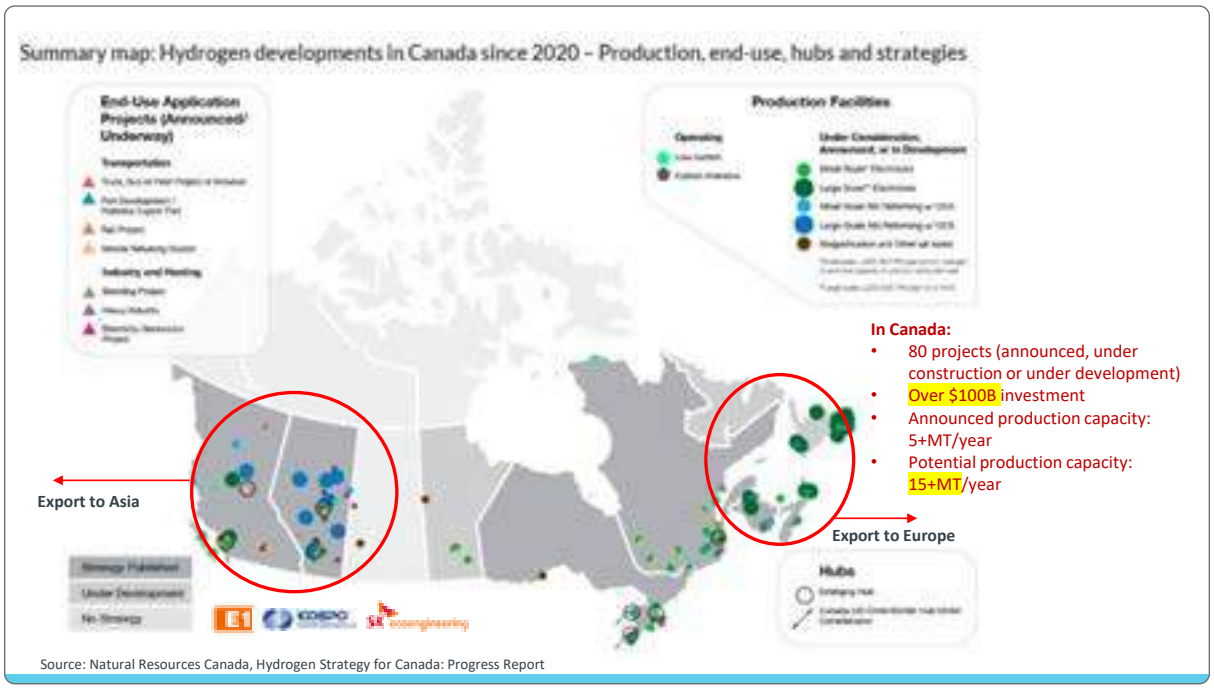




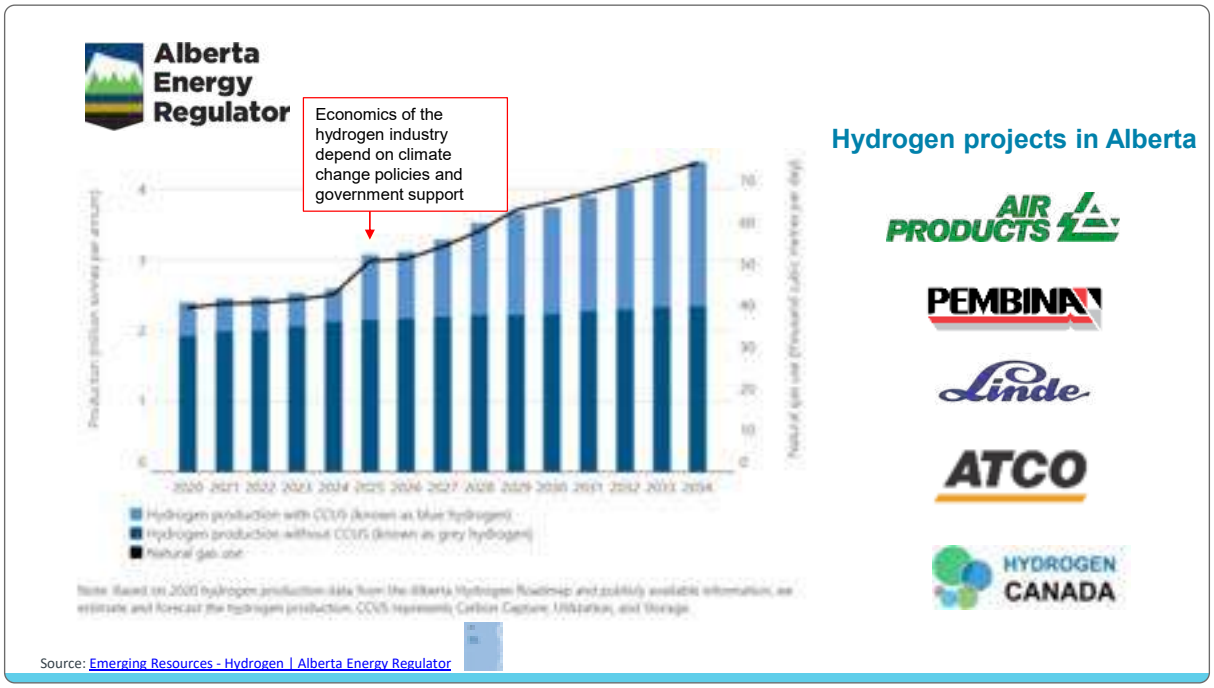
Province	Federal
Healthcare Education Provision of Social Services Natural Resources	National Defense Foreign Affairs International Trade (ex. FTAs)
Environment (depending) Agriculture (shared)	


Western Canada Sedimentary Basin

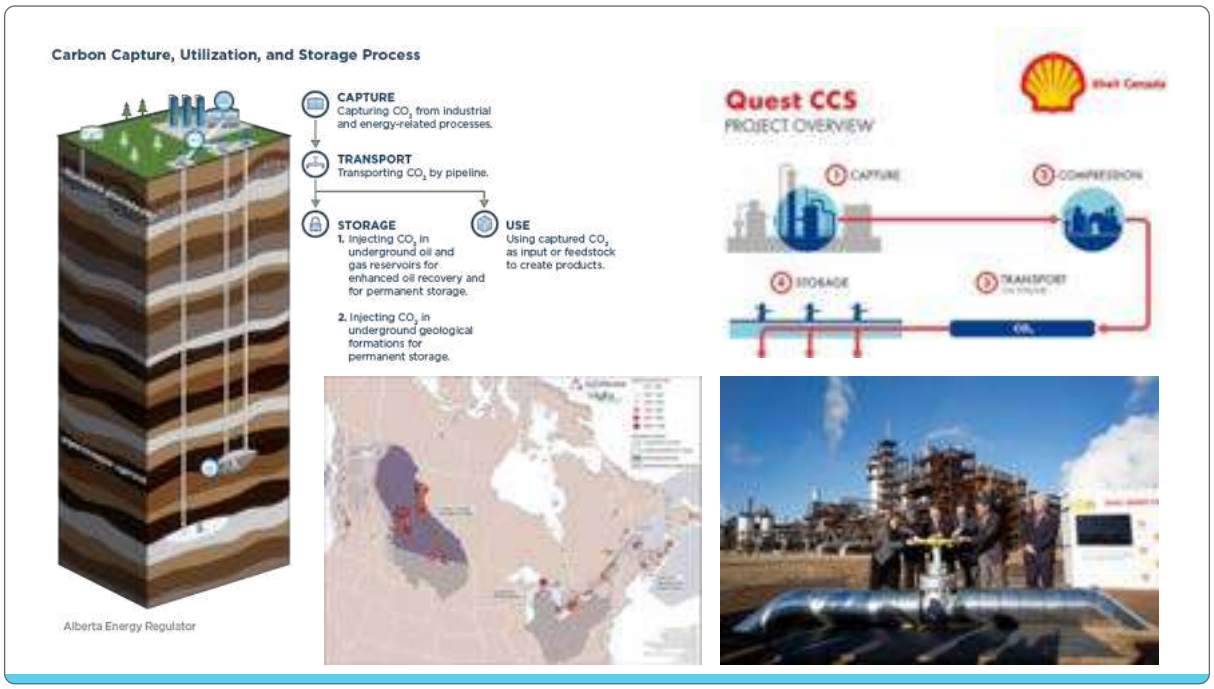

EMPLOYMENT IN CANADA'S ENERGY SECTOR (2022)
DIRECT: 290,300 JOBS
INDIRECT: 405,800 JOBS
TOTAL: 696,100 JOBS
ENERGY SECTOR DIRECT EMPLOYMENT BY PROVINCE/TERRITORY*
MAJOR ENERGY PROJECTS PLANNED AND UNDER CONSTRUCTION, 2023-2033
Alberta:
50% of Canada's energy direct employment
Y.T. 152
N.W.T. 266
Nunavut 163
B.C. 22,985
Alta. 153,187
Sask. 18,057
Man. 6,203
Ont. 46,963
Que. 29,226
P.E.I. 271
N.S. 2,545
N.B. 4,450



Source: Natural Resources Canada, Hydrogen Strategy for Canada: Progress Report



Source: Emerging Resources - Hydrogen | Alberta Energy Regulator


Carbon Capture, Utilization, and Storage Process
CAPTURE
Capturing CO_2 from industrial and energy-related processes.
TRANSPORT
Transporting CO_2 by pipeline.
STORAGE
1. Injecting CO_2 in underground oil and gas reservoirs for enhanced oil recovery and for permanent storage.
2. Injecting CO_2 in underground geological formations for permanent storage.
USE
Using captured CO_2 as input or feedstock to create products.
Alberta Energy Regulator
Quest CCS
PROJECT OVERVIEW
CAPTURE
COMPRESSION
STORAGE
TRANSPORT


Edmonton Global
Day 1 Highlights from the Canadian Hydrogen Convention
What a start! Day 1 was packed with energy, global collaboration, and big announcements driving Canada's hydrogen economy forward. Here's what stood out:
The University of Alberta unveiled its Centre for Hydrogen Innovation, Workforce Development, and Outreach—supporting the next generation of hydrogen talent.
We witnessed the launch of the Canadian Hydrogen Safety Centre (CHySC) - a critical step in developing a safe and skilled hydrogen workforce.
Alberta's hydrogen hubs—Edmonton Region Hydrogen HUB, Calgary Region Hydrogen Hub and Hydrogen Alberta—came together to highlight the power of collaboration.
The Edmonton Global Stage featured powerful conversations, thought-provoking questions, and international perspectives.
Delegations and panelists joined us from Japan, the Netherlands, the UK, and more.
And the trade show floor was buzzing with innovation and connection.
We're just getting started—more insights, more collaboration, and more momentum still to come.
Canadian Hydrogen Convention
Expo & Conference: April 21-22, 2026 | Site Tours: April 23, 2026
Edmonton Convention Centre - Edmonton, Canada

Efficient Sea Transport, but Potential Challenges with Ammonia via Rail



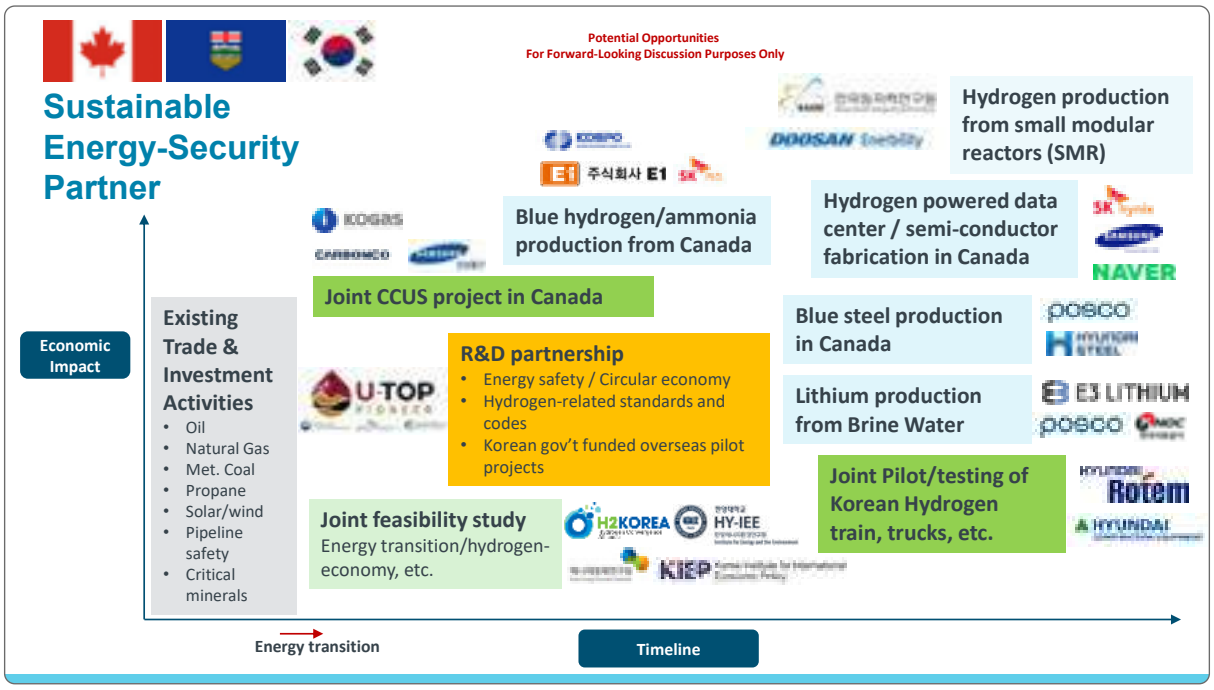


Hydrogen production





1. **Hydrogen Production & Export**
   - Scalable production, transport, and export solutions
2. **AI-Ready Clean Power**
   - Develop hydrogen-based power options for data centres and AI facilities
3. **Pilot Testing & Certification**
   - Provide advanced testing, safety validation, and technology demonstration environments
4. **Industrial Decarbonization**
   - Apply hydrogen in refineries, manufacturing, steel, transport, and petrochemicals
5. **Digital Twins & Smart Hydrogen Systems**
   - Develop AI, modelling, and big-data tools to optimize hydrogen production, storage, and infrastructure safety



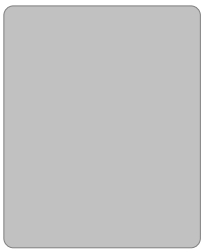


Alberta Government Office in Korea
알버타주정부 한국대표부

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T: 02-3783-6141

WORLD HYDROGEN EXPO 2025 6th Conference

Introduction to AVL Fuel Cell Canada



Nam Gi Kim
Mechanical Engineer, AVL Fuel Cell Canada

AVL Fuel Cell Canada

Overview

AVL Fuel Cell Canada Public

Introduction

AVL

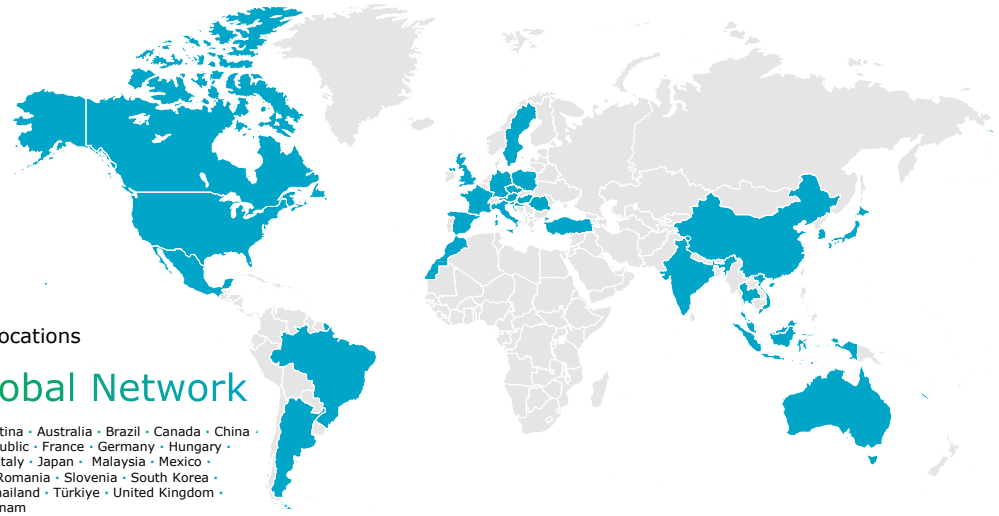


AVL is the world's largest independent company for development, simulation and testing in the automotive industry, and in other sectors

AVL Fuel Cell Canada



AVL Fuel Cell Canada (AVL FCC) is AVL's global center of excellence for PEM fuel cell & electrolyzer stacks



Worldwide Locations

Our Global Network

Austria, HQ | Argentina · Australia · Brazil · Canada · China · Croatia · Czech Republic · France · Germany · Hungary · India · Indonesia · Italy · Japan · Malaysia · Mexico · Morocco · Poland · Romania · Slovenia · South Korea · Spain · Sweden · Thailand · Türkiye · United Kingdom · United States · Vietnam

AVL at a Glance

1948
Founded

29
Countries Represented

12,200
Employees Worldwide

11 %
Of Turnover Invested in Inhouse R&D

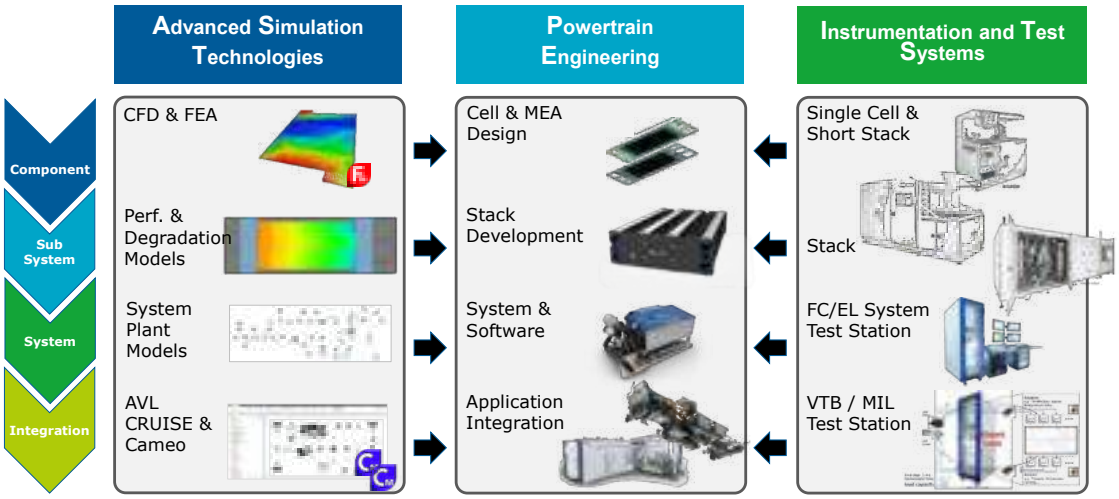
75+
Years of Experience

50+
Global Tech and Engineering Centers

67 %
Engineers and Scientists

2,300
Granted Patents in Force

Three AVL Divisions with Cross-functional Expertise



Introduction to AVL Fuel Cell Canada (AVL FCC)

Established 2018 in Burnaby, BC, Canada

~50 people; core team stack engineers & scientists with **20+ years of stack experience**

Focus: designing, engineering, prototyping, and testing custom **fuel cell & electrolyzer** stacks

Access to resources and capabilities of global AVL (e.g., plant & production engineering)



From Stack Components to Complete Vehicle



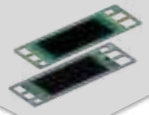
Development of FC & EL components	Development of FC & EL stacks	Stack system integration	System & Application integration

AVL Fuel Cell Canada in Vancouver | Global AVL

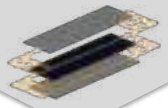
Offering of AVL Fuel Cell Canada

Design of Fuel Cell Stacks

Design of Bipolar Plates
Carbon or metal plate designs including seal



Design of Membrane Electrode Assemblies
Electrodes, membranes, CCMs, GDLs & PTLs



Design of Stack Hardware
End plates, compression systems, bus bars, CVP etc.



Design of Electrolyzer Stacks



Fuel Cell and Electrolyzer Stacks

Solutions for customer/application-specific requirements

… plus a broad range of stack-related services



AVL Fuel Cell Canada R&D Infrastructure

State-of-the-art R&D infrastructure in Burnaby, BC
- 450 m² hydrogen-safe lab for sub-scale to full-size stack testing
- 370 m² prototyping components & stacks, material characterization and QC

Nine Greenlight test systems readily available
- 4 x G60 for sub-scale testing
- 1 x G200, 3 x G500, 1 x G900 for short and full-size stack testing

Optional services available on demand
- Pre-test consultation, prototyping, post-processing, failure analysis
- Broad range of R&D services: requirements engineering, design, simulation, benchmarking

Wide range of equipment available
- Climatic chamber
- Leak test cart
- Cell Voltage Monitoring (CVM) systems
- Electrochemical Impedance Spectroscopy (EIS) systems
- Exhaust measurement (H_2, CO_2) systems
- Segmented cell current mapping tool



Greenlight Innovation G60
Sub-scale, small active area (1-5 cell)



Greenlight Innovation G200 & G500
Short stack, full active area (5-30 cells)
with freeze start-up capability



Greenlight Innovation G900
Full stack, full active area (<450 cells)
with freeze start-up capability



Project Landscape



Bipolar plate innovations



MEA innovations



Stack hardware innovations

Component-level R&D projects



AVL Gen-0
Industrial stack (>100 kW)

AVL AES-1
High-performance stack (>6 kW/l)





AVL Gen-1
High-power stack (~330 kW)

AVL EL stack
PEM electrolyzer stack design



AVL stack platforms



150 kW stack for commercial vehicle OEM
Customer project



100 kW stack for marine OEM
Customer project, SOP 2023



Air-cooled stack for drones
Customer project



Multi-MW PEMEL stack
Customer project

Only selected customer projects shown

Customer stack projects

AVL Gen 1: State of the Art Reference FC Stack Design

More Power in a Single Row
200 kW at rated power, 330 kW peak power

Best in Class Efficiency
Low TCO with 56% efficiency at rated power

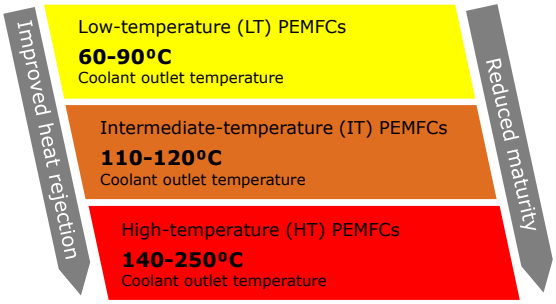
Robust and Durable Design
-30°C freeze-start certified, 25000+ h lifetime

Power Density and Packaging
Modular design for volume-efficient applications



New Fuel Cell Technologies

- Increased operating temperatures solve heat rejection limitations
- AVL is currently benchmarking IT & HT PEM MEAs



AVL is a development partner for IT and HT-PEMFCs.


Heat rejection results in drag


Limited airstream, large radiators

Lightweight Stack Development with Red Bull Advanced Technologies

AVL Gen 1 Stack
Stainless steel compression hardware
100 kg 3.1 kW/kg



Goal:
- Low cost
- Manufacturable at volume

AVL Gen 1 Stack
Carbon fiber compression hardware
<68 kg >4.6 kW/kg



Goal:
- Lightweight!

State-of-the-art PEM fuel cell performance

Target applications: Automotive, motorsport and aviation

Next lightweighting planned for unit cell body: **>7kW/kg**

AVL and Red Bull are partnered to revolutionize gravimetric power density

PEM Electrolyzer

- AVL in-house reference design
  - Design point: 500kW cell row
- Available for Scale-up
  - Licensing Opportunity



Key Dates (all 2024):
- ✓ Project Kick-Off – 19-Jan-2024
- ✓ Architecture Freeze – 16-Feb-2024
- ✓ Concept Release – June-2024
- ✓ Design Release – July-2024
- ✓ Build Complete – Nov-2024
- ✓ **Test Results – 20-Dec-2024**

KPI	US DOE 2026**	AVL AEE-1 (Targets)	Cummins	Schaeffler	Siemens
Efficiency (%LHV)	>67	71	60	58	
Efficiency (kWh/kgH_2)	<49	47	55	57	
Operation Mode	Diff	Diff	Diff	Diff	Diff
Operating P (bara)	30	30	30	10	35

** Adjusted to 30 bar diff

Scalable Electrolyzer Stack Platforms

State of The Art Performance

- Differential pressure operation
- 5 – 120% operating range
- Recombination catalyst to control 50% LFL
- 70% LHV, 47 kWh/kg H_2 (35+ bar, 80 °C)
- Scalable to multi-MW solutions

LFL … Lower Flammable Limit

AEE – 1
Baseline Design: 50 kW

- 50 – 500 kW
- Active Area: 300 cm²
- Rod & spring compression



AEE – 2
Baseline Design: 2500 kW

- 500 – 3000 kW
- Active Area: 2000+cm²
- Springless compression



AEM Development Activities

Supply Chain Definition

Benchmarking component suppliers

Building component performance database

Applying stack expertise to component design

Focus:

- Next generations MEAs and CCMs

Stack Development

State-of-the-art AEM technology

AVL reference stack will offer a foundation for customer stack projects

Focus:

- Maturing AEM stack lifetime and efficiency
- Shunt current optimization

Testing Services

Subscale + short stack testing services

Performance benchmarking

Focus:

- ASTs for lifetime durability
- Optimizing operating conditions / system requirements

AEM Stack Focus

AEM electrolyzers will play a key role for low-cost hydrogen production

- Design target for full stack:
  - 250 cell, 500 kW, 225 kg H_2/day
  - 500 cm^2 active area (lab prototype)
  - Performance targets based on existing supplier data





KPIs:	**IRENA 2020***	**AVL AEM-1** (Targets)
Efficiency (%LHV)	>60	63
Efficiency (kWh/kgH2)	<55.8	53.2
Operation Mode	Diff	Diff
Operating P (bara)	<35	30

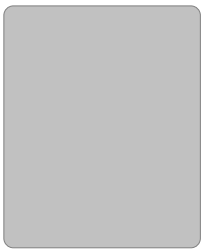
**IRENA (2020) Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5ºC Climate Goal International Renewable Energy Agency, Abu Dhabi*

Thank you

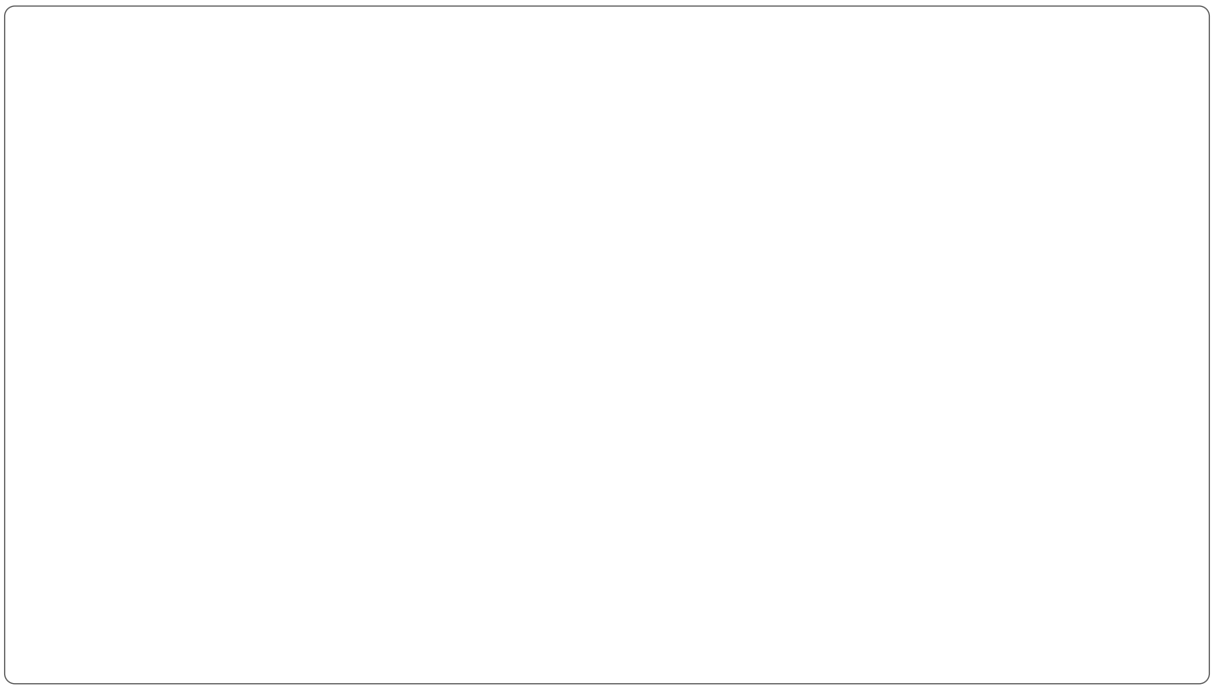
www.avl.com

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Infrastructure Independent Energy with H2M's Innovative Hydrogen Storage Material



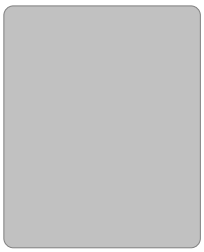
Grace Quan
President and CEO, Hydrogen In Motion Inc. (H2M)



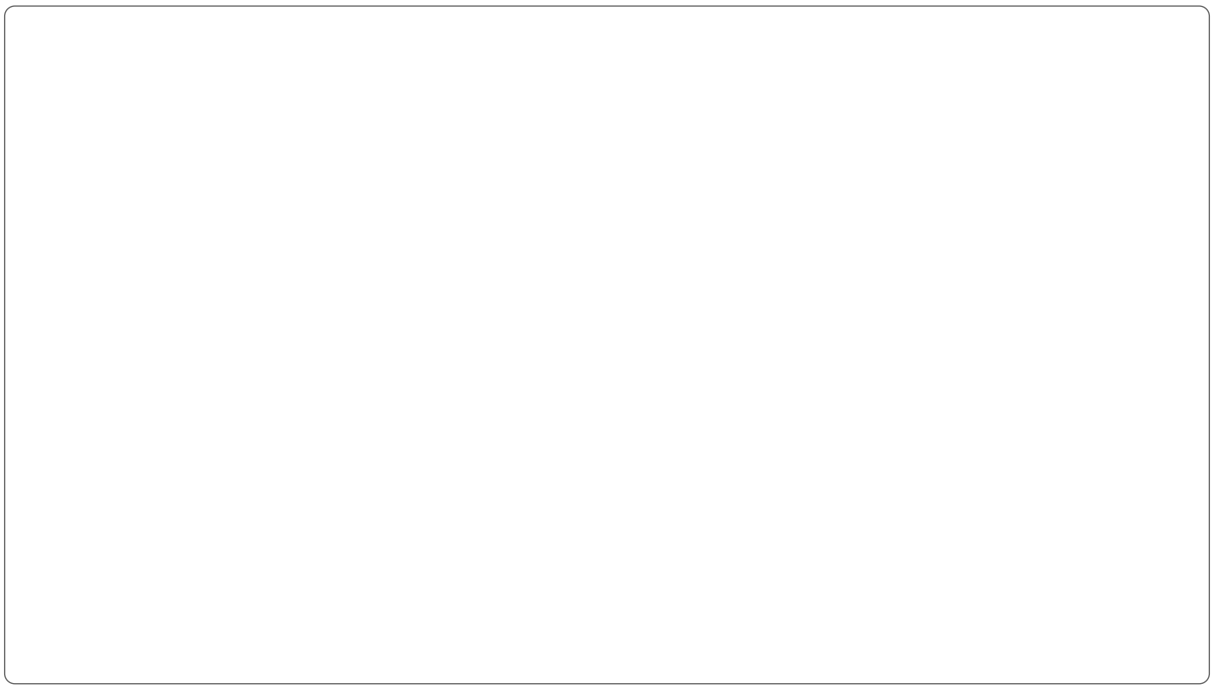


WORLD HYDROGEN EXPO 2025 6th Conference

Advanced Fast-Cycle Rotary Valve PSA for High-Purity Hydrogen Purification

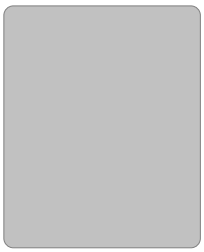


John Li
Director-PSA Sales, Ivys Adsorption





Powertech Labs Introduction



Tanja Smutny

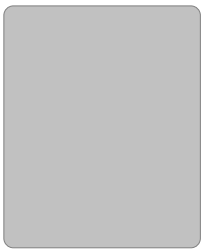
Engineering Team Lead, "Hydrogen Industry Technology and Testing Group , Powertech Labs"

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Country Day : UK Day

WORLD HYDROGEN EXPO 2025 6th
Conference

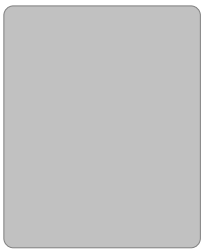
Gas Detection Solutions in the Hydrogen Industry



Jarod Lim
Area Sales Manager, Crowcon Detection Instruments

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Innovative Sealing Solutions Enabling Safe and Reliable Hydrogen Applications

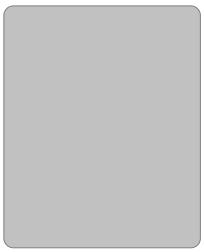


Alesssandro Cavalli

New Energy Business Development Manager,
Flexitallic UK Ltd.

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Role of Dual Fuel Hydrogen in the transition to Net Zero - Dual Fuel Hydrogen Combustion



Paul Turner
Technical Director, ULEMCO Ltd.


ULEMCo
ULTRA LOW EMISSION
Hydrogen Solutions Engineered for your needs
December 2025


Delivering achievable zero-carbon hydrogen fuel innovations for road, off-road and hard to decarbonise applications

Company history

2014
ULEMCo Founded by Amanda Lyne, commercialising hydrogen dual fuel technology



2017
Low Emission Freight Trial, evidencing CO2 and emission savings on 11 vehicles



2021
Developed worlds first H2 powered Ambulance with FCRX



2024
Consortium partner in Element 1 Project that was awarded £4.9m, converted four excavators to hydrogen dual fuel



2024
Developed and showcased worlds first hydrogen Medium Aircraft Tow Tug (MATT) with HYICE



2025
Official launch of mobile hydrogen refueling bowser HyTANKa



2017
Moved to current Headquarters in Liverpool, UK



2020
First fleet wide conversion of 20 gritters for Glasgow City Council



2023
Worlds first hydrogen dual fuel piling rig demonstration



2024
Closed £5m funding round for hydrogen transport technologies



2025
Featured in PwC's UK Net Zero Future50 Innovators list



ISO 9001 Certified

ULEMCo's place in the hydrogen value chain



Hydrogen Production — Hydrogen Storage & Distribution — Hydrogen Demand



Mobile Refuelling

Transport, Mobility, Construction, Rail, Marine

Globally leading skills in hydrogen transport solutions

ULEMCo



- Performance & requirements knowledge
- Standards and regulatory compliance
- Economic model of replacement cost and total lifetime costs
- H_2 supply chain knowledge
- Patented engine and H2 safety technology
- Track record of delivering different solutions across a range of heavy energy demand & use sectors

ULEMCo's Hydrogen Solutions to reduce GHG emissions

ULEMCo



H2ICED Hydrogen Dual Fuel

Hydrogen dual-fuel technology
UPGRADE existing or new diesel vehicles or machines to ULTRA-LOW emissions
Diesel usage typically reduced annually between 30-50% PER UPGRADE
Typical daily H_2 use per vehicle between 5-15kg
The COST EFFECTIVE route to saving real-world GHG now



FCRX Fuel Cell Range Extension

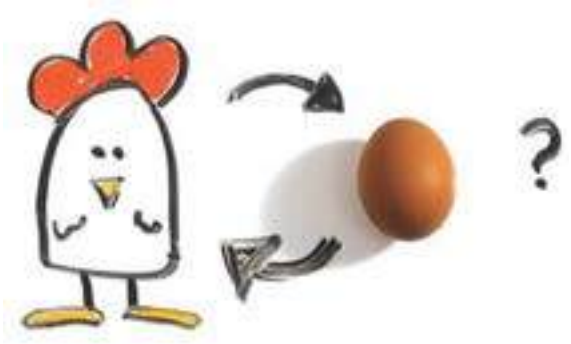
"Plug & Play" fuel cell range extension power module
UPGRADE electric vehicles to use hydrogen fuel for EXTRA ENERGY & FLEXIBILITY
Zero emission (except water)
Typical H_2 use per vehicle of up to 15kg per day
Improve PRODUCTIVITY & ASSET UTLITISATION of battery electric vehicles

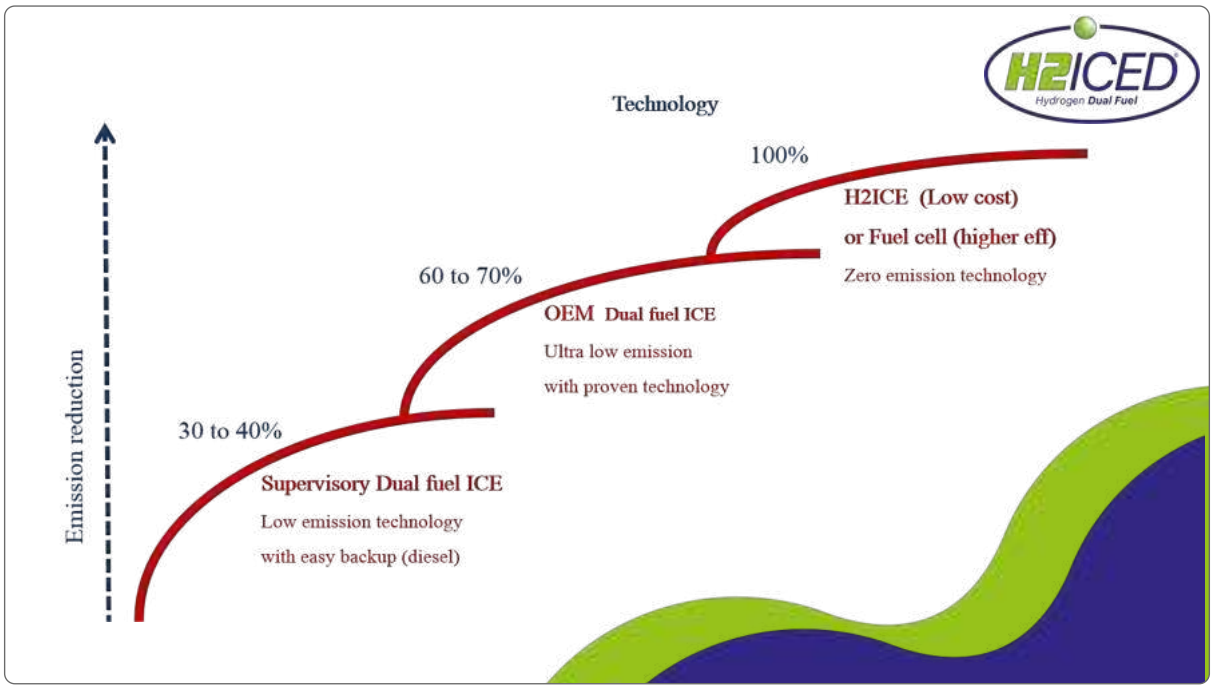


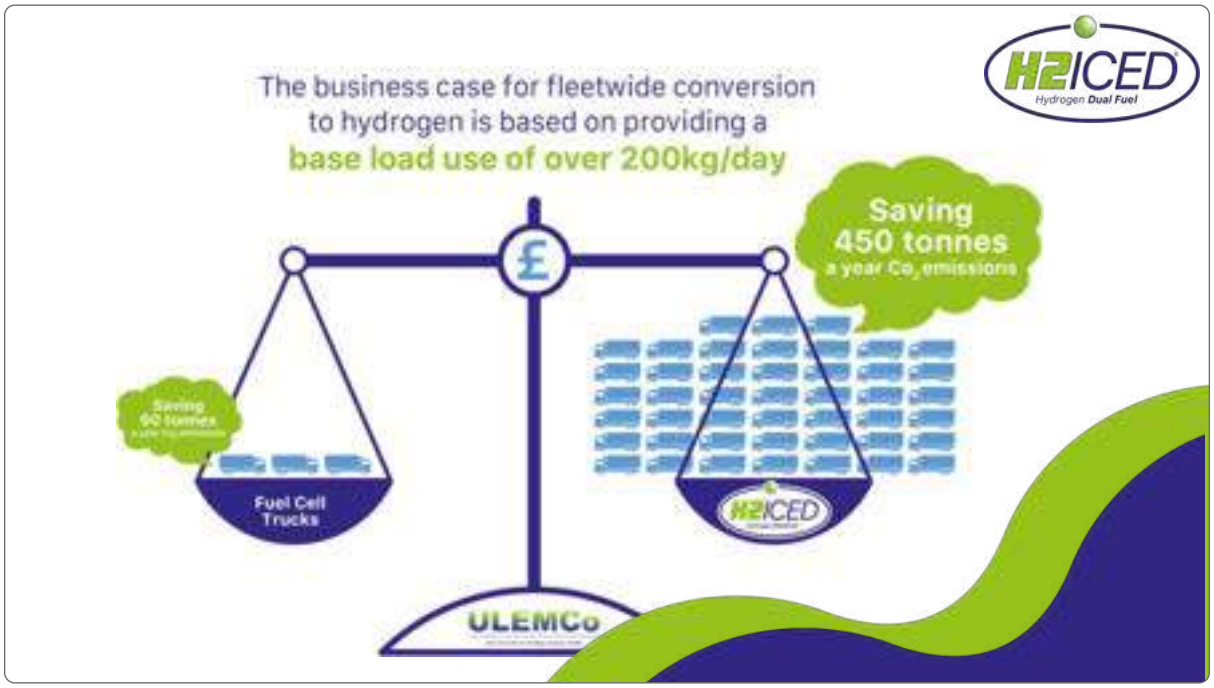
HYICE Zero Emission H2 Combustion

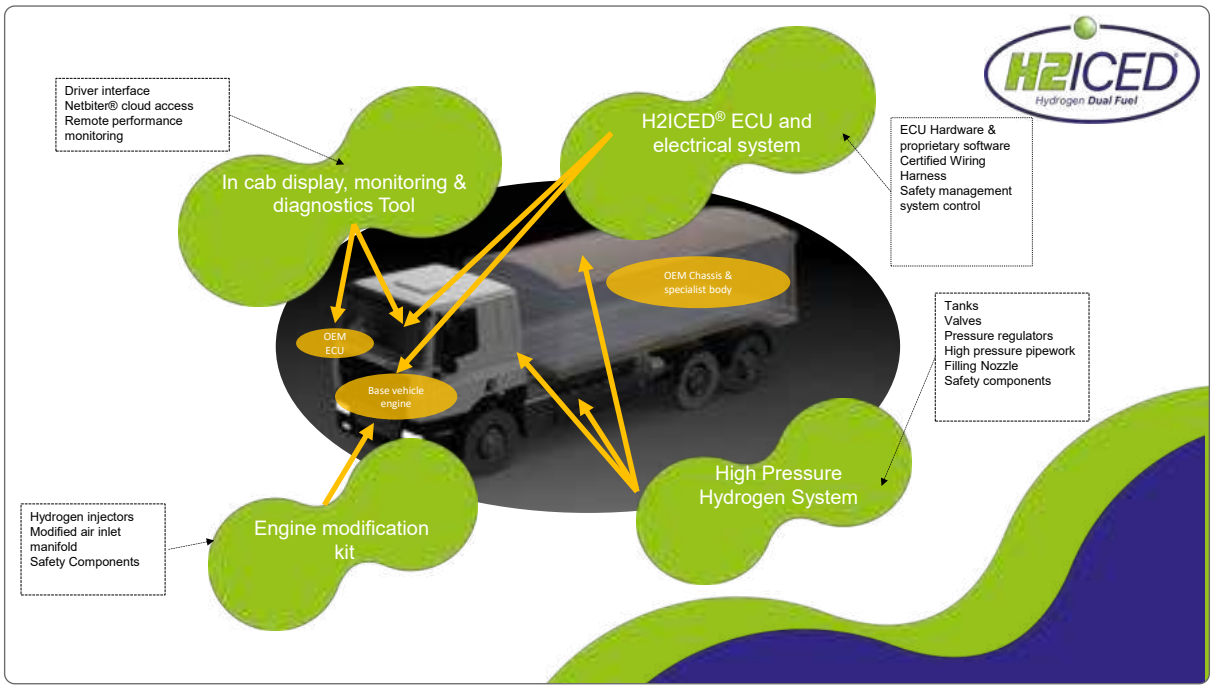
Hybrid Hydrogen ICE powertrain
UPCYCLE & REPOWER specialist vehicles and equipment by SWAPPING DRIVETRAINS
Zero carbon and ultra-low emission
Typical H_2 use 30-40kg a day
Extend VALUABLE ASSET LIFE whilst saving embedded carbon & reducing GHG emissions

ULEMCo and The Hydrogen Tansition




H2ICED
Hydrogen Dual Fuel
Technology
Emission reduction
30 to 40%
Supervisory Dual fuel ICE
Low emission technology
with easy backup (diesel)
60 to 70%
OEM Dual fuel ICE
Ultra low emission
with proven technology
100%
H2ICE (Low cost)
or Fuel cell (higher eff)
Zero emission technology


H2ICED
Hydrogen Dual Fuel
The business case for fleetwide conversion
to hydrogen is based on providing a
base load use of over 200kg/day
£
Saving
450 tonnes
a year Co2 emissions
Fuel Cell
Trucks
H2ICED
ULEMCo


H2ICED
Hydrogen Dual Fuel
Driver interface
Netbiter® cloud access
Remote performance monitoring
In cab display, monitoring & diagnostics Tool
H2ICED® ECU and electrical system
ECU Hardware & proprietary software
Certified Wiring Harness
Safety management system control
OEM Chassis & specialist body
OEM ECU
Base vehicle engine
Tanks
Valves
Pressure regulators
High pressure pipework
Filling Nozzle
Safety components
High Pressure Hydrogen System
Hydrogen injectors
Modified air inlet manifold
Safety Components
Engine modification kit


South Derbyshire District Council


6997
DAF


DAF


storengy
Powered by
green hydrogen


DAF




plantforce



ULEMCo

Mobile Hydrogen refuelling


HyTANKa
ULEMCo
DAF


MOTIVE

ULEMCo

FCRX™ Fuel Cell Range Extension

HYICE™ Zero Emission H2 Combustion

Zero emission solutions




ULEMCo
ROYAL AIR FORCE


SV66 VMH




Emergency Ambulance
NHS
ZERO
EMISSION
HYDROGEN
FUEL CELL
ELECTRIC
AMBULANCE
HYDROGEN
FUEL CELL
ELECTRIC
AMBULANCE



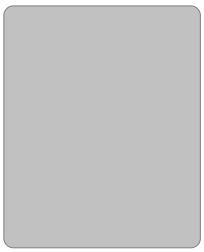
ULEMCo
ULTRA LOW EMISSION

Hydrogen – Tomorrow's Fuel TODAY!

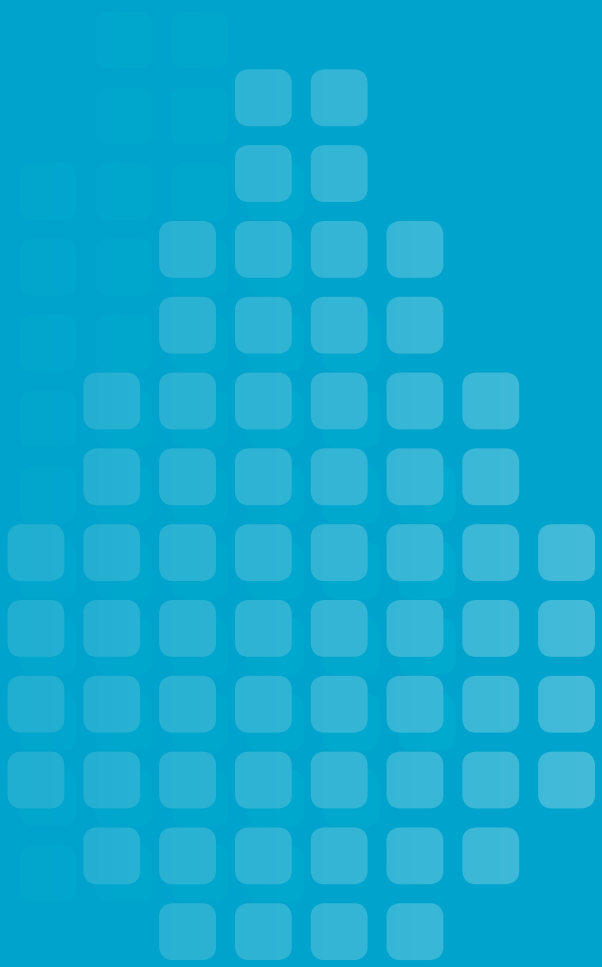
Contact us: Amanda Lyne | **Email:** alyne@ulemco.com | **www.ulemco.com**

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Creating a viable market for green hydrogen and ammonia



Youngsun Om
Business Development Analyst, Yamna



6th WORLD HYDROGEN EXPO 2025

Conference