BRIN
BADAN RISET
DAN INOVASI NASIONAL

CTCN
UN Climate Technology Centre & Network

UN environment programme

H_2 INDONESIA
Hydrogen Economy

GREEN HYDROGEN PRODUCTION AND FUEL CELL RD&D

INDONESIA'S RESEARCH, INNOVATION AND FUTURE COLLABORATION OPPORTUNITIES

CTCN LEARNING VISIT 2026

Collaboration with KIST, KRICT and KIER

Seoul & Daejeon, Republic of Korea

14 – 16 July 2026

RESEARCH
INNOVATION
DEMONSTRATION
COLLABORATION
HYDROGEN ECONOMY

Dr. Eng. Deni Shidqi Khaerudini
Research Professor
Research Center for Energy Conversion Technology
National Research and Innovation Agency (BRIN)
Indonesia

KEY THEMES

- Green Hydrogen Production
- Fuel Cell Technologies
- Hydrogen Storage
- Pilot Demonstration
- Future Joint RD&D
- ASEAN Collaboration

Advancing Hydrogen Innovation Through International Collaboration and Sustainable Energy Solutions

Dr. Eng. DENI SHIDOI KHAERUDINI, M.Eng.

RESEARCH PROFESSOR | HYDROGEN STRATEGIST | FUEL CELL EXPERT
ENERGY TRANSITION ADVISOR

Over 18 years of research, innovation, and leadership in hydrogen technology, fuel cells, advanced materials, and low-carbon energy systems. Driving technology development, strategic studies, and national programs toward a sustainable energy future.

220+ PUBLICATIONS | **1,700+** CITATIONS | **24** PATENTS | NATIONAL & INTERNATIONAL LEADERSHIP ROLES

deni.shidoi.khaerudini@brin.go.id | Indonesia | R&D | Innovation | Collaboration | Impact

EXECUTIVE SUMMARY

Leading expert in hydrogen, fuel cells, and advanced energy systems with extensive experience in R&D, technology assessment, and strategic implementation. Proven track record in managing multi-disciplinary projects, building research ecosystems, and delivering practical solutions for industry, government, and national energy transition initiatives.

- Expert in hydrogen production, storage, transportation, and utilization
- Specialist in fuel cell technologies and hybrid microgrid systems
- Strong background in advanced materials and energy storage
- Extensive leadership in national R&D programs and industrial collaborations
- Committed to innovation, sustainability, and low-carbon transformation

FLAGSHIP PROJECTS

1. **Optimization and Development of Mini Electrolyzer Reactor**
   Design, manufacturing, commissioning, and process optimization for hydrogen production.
2. **Fuel Cell Implementation in Hybrid Microgrid Systems**
   Technology selection, system integration, risk and operational assessment.
3. **Technology and Feasibility Study of Fuel Cell in Hybrid Microgrids**
   Comprehensive study on technical feasibility, risk mapping, and implementation roadmap.
4. **Low Emission Hydrogen Production with High-Temperature Electrolyzer (SOEC)**
   Integration study with small modular nuclear power for clean hydrogen production.
5. **Solid Hydrogen Storage Materials Development**
   Carbon-based sorbent materials and engineering design for safe storage systems.
6. **Advanced Materials for Energy Storage and SOFC Applications**
   Development of carbon materials, anode materials, and rare earth-based dlectrolytes.

CORE EXPERTISE

Hydrogen Technologies
Production (electrolysis), storage, transport, and infrastructure

Hybrid Microgrid & Energy Systems
System design, modeling, and implementation

Fuel Cell Systems
SOFC, PEMFC, system integration and performance optimization

Advanced Materials & Nanotechnology
Carbon materials, rare earth oxides, and functional materials

Energy Storage Materials
Advanced materials for batteries and hydrogen storage systems

Techno-Economic & Feasibility Studies
Technology assessment, risk analysis, and business model development

LEADERSHIP & PROFESSIONAL ROLES

- Research Professor and Principal Investigator in Hydrogen and Advanced Energy Systems
- Trusted Advisor for Government, SOEs, and Industry in Energy Transition and Technology Strategy
- Leader of Multi-disciplinary Teams in National and International R&D Programs
- Active Collaborator with Universities, Research Institutions, and Global Partners
- Contributing Expert for National Roadmap on Hydrogen Economy and Low-Carbon Development

VALUE TO DECISION MAKERS

STRATEGIC INSIGHT
Evidence-based analysis for policy and technology decision-making.

TECHNOLOGY LEADERSHIP
Driving innovation and adoption of proven, scalable, and future-ready technologies.

RISK MANAGEMENT
Comprehensive assessment to reduce technical, financial, and operational risks.

SUSTAINABLE IMPACT
Creating long-term value through clean energy solutions and environmental responsibility.

NATIONAL & GLOBAL VALUE
Supporting energy security, economic growth, and global competitiveness.

"Delivering Innovation.
Enabling Clean Energy.
Empowering the Future."

INDONESIA

DIVERSITY IN CULTURE, BEAUTY IN NATURE

A nation of thousands of islands, rich in culture and traditions, blessed with breathtaking destinations.
Indonesia: Timeless Culture, Endless Wonders.

wonderful indonesia

THE ESSENCE OF INDONESIA

- **17,000+** Islands
- **1.91 Million km²** Total Area
- **278+ Million** Population (2024)
- **700+** Ethnic Groups
- **720+** Local Languages
- **10** UNESCO World Heritage Sites

CULTURAL RICHNESS

TRADITIONS
Deep-rooted traditions, customs, and local wisdom passed down through generations.

ARTS & CRAFTS
Exquisite handicrafts, batik, weaving, and art forms that reflect Indonesia's identity.

MUSIC & DANCE
Vibrant performances that express the soul of our diverse cultures.

ARCHITECTURE
Unique traditional houses and historical buildings across the archipelago.

HERITAGE
From ancient temples to colonial landmarks, a living testament of history.

CULINARY
A rich and diverse cuisine, full of spices and unforgettable flavors.

TOP DESTINATIONS

BALI
Island of Gods

YOGYAKARTA
The Heart of Javanese Culture

RAJA AMPAT
The Last Paradise

LABUAN BAJO
Gateway to Komodo

LOMBOK
Natural Beauty and Serenity

DANAU TOBA
The Majestic Volcanic Lake

OUR CULTURE, OUR PRIDE

Diversity is our strength, culture is our identity, and hospitality is our nature.

HOSPITALITY
Warm and friendly people always welcome you.

SAFETY
A safe and comfortable destination for every traveler.

SUSTAINABILITY
Preserving nature and culture for future generations.

EXPERIENCES
Unforgettable journeys that enrich your life.

ACCESSIBILITY
Better connections to explore the beauty of Indonesia.

Explore Indonesia,
Discover the Wonders

BRIN ORGANIZATIONAL STRUCTURE

BRIN
BADAN RISET DAN INOVASI NASIONAL

Driving Research and Innovation for Indonesia's Future

PRESIDENT
OF THE REPUBLIC OF INDONESIA

GOVERNING BOARD
- Chair: Member of the BRIN Governing Board
- Vice Chair: Minister & Head of Agencies
- Secretary: Professional and/or academic expert in the field of research
- Members: 6 professional and/or academic experts in the field of research

CHAIRMAN OF BRIN

VICE CHAIRMAN OF BRIN

MAIN INSPECTORATE
3 INSPECTORATES

MAIN SECRETARIAT
5 BUREAUS

DEPUTY
Policy Development Deputy
1 Deputy
4 Directorates

DEPUTY
Research and Innovation Deputy
1 Deputy
3 Directorates

DEPUTY
Human Capital and Resources Deputy
1 Deputy
3 Directorates

DEPUTY
Research and Innovation Infrastructure Deputy
1 Deputy
5 Directorates

DEPUTY
Research and Innovation Facilities Deputy
1 Deputy
5 Directorates

DEPUTY
Research and Innovation Utilization Deputy
1 Deputy
4 Directorates

DEPUTY
Regional Research and Innovation Deputy
1 Deputy
3 Directorates

DATA AND INFORMATION CENTER (PUSDATIN)
Data and Information Center

TECHNOLOGY SERVICES CENTER (PUSYANTEK)
Technology Services Center

BRIN POLYTECHNIC (POLITEK BRIN)
Polytechnic of BRIN

NON-STRUCTURAL SECRETARIAT

RESEARCH ORGANIZATIONS
- RO for Nuclear Energy
- RO for Governance, Economy, and Community Welfare
- RO for Energy and Manufacturing
- RO for Nanotechnology and Materials
- RO for Electronics and Informatics
- RO for Aeronautics and Space
- RO for Earth Sciences and Maritime
- RO for Life Sciences and Environment
- RO for Agriculture and Food Security
- RO for Health
- RO for Archaeology, Language, and Literature
- RO for Social Sciences and Humanities

Internal services + office infrastructure

External services + research infrastructure

Technical implementation of research (RO = Research Organization) + PR (Research Center)

ROs still under K/L (being integrated)

ORGANIZATION

Research Center for Energy Conversion Technology

BRIN
BADAN RISET DAN INOVASI NASIONAL

Tata Sutardi, S.T., M.T., Ph.D.
Head of Research Center
for Energy Conversion Technology

02

2. Research Group of Energy Conservation Technology in Building
Coordinator:
Dr. Ir. Cahyadi, M.Kom.

04

4. Research Group of Process Optimization in Energy Conversion and Gas Emission Management
Coordinator:
Taopik Hidayat, S.T., M.T.

06

6. Research Group of Analysis and Optimization of Energy Generation Systems
Coordinator:
Dr. Ir. Agus Nurrohim, M.Eng.

08

8. Research Group of Solar Energy for Photovoltaic
Coordinator:
Dr. Ing. Drs. Oo Abdul Rosyid, M.Sc.

10

10. Research Group of Sustainable Prime Mover
Coordinator:
Dr. Muchammad Taufiq Suryantoro,

12

12. Research Group of Electro Mechanical System for Power Generation
Coordinator:
Dr. M.Kasin

14

14. Research Group of Electrochemical Energy Conversion Technology
Coordinator:
Dr. Oka Ajasa

01

1. Research Group of Thermal and Solid Fuel Combustion
Coordinator:
Dr.Ir. Hariana,

03

3. Research Group of Geothermal Energy Resources
Coordinator:
Dipl. Ing. Suyanto

05

5. Research Group of Thermodynamics in Thermal and Refrigeration
Coordinator:
Dr. Hariyotejo Pujowidodo, S.T., M.T

07

7. Research Group of Solar Thermal and Hydro Power
Coordinator:
Dr. Ahmad Rajani

09

9. Research Group of Wind Energy
Coordinator:
Prof. Ir. Amiral Azis, M.Sc.

11

11. Research Group of Energy Conversion Technology for Industrial Decarbonization
Coordinator:
Hanafi Prida Putra

13

13. Research Group of Energy Conversion for Gasification Products
Coordinator:
Nina Konitat

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DAN INOVASI NASIONAL

SCOPE OF RESEARCH

RESEARCH CENTER FOR ENERGY CONVERSION TECHNOLOGY

Driving innovation across the energy value chain for a low-carbon and sustainable future.

01 ENERGY SYSTEM OPTIMIZATION

Research on planning, analysis and optimization of energy systems through energy modeling from the supply side to user side.

02 THERMODYNAMICS OF ENERGY CONVERSION SYSTEM

Thermodynamic technology of energy conversion systems: thermal generation, air conditioning systems, heat exchange systems and cooling systems.

03 LOW EMISSION COMBUSTION TECHNOLOGY

Implementation of energy-saving and low-emission technology research on fossil energy conversion.

04 RENEWABLE ENERGY TECHNOLOGY

Technology for renewable energy application includes solar energy, hydropower, geothermal energy, hydrogen, biomass, and other alternative energies.

05 PRIME MOVER TECHNOLOGY

Research in the field of prime mover technology with fossil energy and other alternative energies that are efficient, reliable, and low in emissions.

06 SMART ELECTRICITY

Electrical technology research that supports new and renewable energy, namely smart grid systems, energy monitoring systems, improving the quality of the electricity network, electric vehicle charging systems, storage systems and fuel cells.

07 ENERGY CONSERVATION TECHNOLOGY

Energy management, energy-saving technology and energy audits in the power generation, household, transportation, building and industrial sectors, as well as waste heat recovery and cogeneration.

INNOVATIVE RESEARCH
Pioneering technologies for a sustainable energy future

LOW CARBON SOLUTIONS
Supporting Indonesia's commitment to a net-zero emissions future

CROSS-SECTOR IMPACT
Delivering real impact across industry and society

NATIONAL EXCELLENCE
Strengthening national capability through world-class research

TOGETHER FOR A SUSTAINABLE INDONESIA
Research and innovation for energy security, environmental sustainability, and economic growth

RESEARCH ACTIVITIES

Driving Innovation in Energy Conversion Technologies

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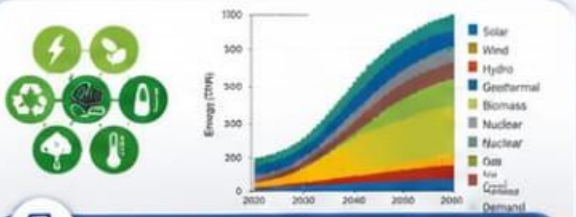


Energy System Optimization and Analysis

Solar Thermal & Floating PV

Pico and Micro Hydro

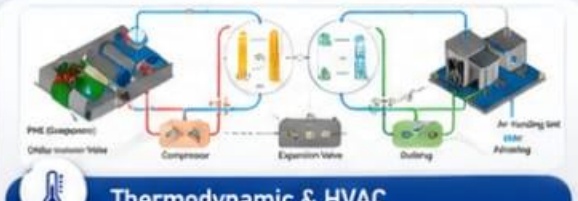
Geothermal

Biomass and Coal Combustion

Gasification Technology

Onshore and Offshore Wind Turbine

Energy Conservation



Thermodynamic & HVAC

Binary Cycle Power Gen

Biofuel Filtration & Conditioning System

Hydrogen and Fuel Cells

Gas Emission Concern

INNOVATIVE RESEARCH
Developing advanced technologies for sustainable energy conversion.

IMPACTFUL SOLUTIONS
Addressing national challenges through science and innovation.

COLLABORATIVE APPROACH
Working together with industries, academia, and communities.

SUSTAINABLE FUTURE
Contributing to net-zero emissions and energy security.

Research Center for
Energy Conversion Technology

BRIN HYDROGEN & FUEL CELL RD&D PORTFOLIO

Integrated Research Across the Hydrogen Value Chain

BRIN develops end-to-end hydrogen and fuel cell technologies to accelerate Indonesia's clean energy transition through innovation, pilot-scale demonstration, and strategic collaboration.

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H_2 INDONESIA
Hydrogen Economy

OUR RD&D FOCUS AREAS

1. HYDROGEN PRODUCTION

- SOEC-based low-emission hydrogen production
- Water electrolysis catalysts and electrode development
- Hydrogen hydrolysis reactor optimization
- Techno-economic and feasibility assessment

2. HYDROGEN STORAGE

- Metal hydride materials (AB_5, Mg-based, etc.)
- Sorbent-based storage (activated carbon, MOF, zeolite, etc.)
- Sodium-based solid hydrogen storage
- System integration and safety evaluation

3. FUEL CELLS

- PEMFC for mobility and backup power
- SOFC for stationary power and industrial use
- High-temperature fuel cells and components
- Durability, performance testing, and system optimization

4. SYSTEM INTEGRATION

- Hybrid microgrid with fuel cells
- Small islands and remote communtties
- Renewable energy integration
- Energy management and optimization

SELECTED MAJOR RD&D PROJECTS

PROJECT TITLE	PARTNER / SPONSOR
SOEC-Based Low-Emission Hydrogen Production	Pertamina NRE
Fuel Cell Hybrid Microgrid Implementation	PLN Enjiniring
Advanced Hydrogen Storage System	BRIN – LPDP
Hydrogen Hydrolysis Reactor Development	PLN (Puslitbang)
Electrolysis Catalyst Development	Ministry of Research & Technology

STRONG TRACK RECORD

- **220+** Publications
- **1,700+** Citations
- **24** Patents
- Contributor to National Hydrogen Standards (SNI)
- Strong Collaboration with Industry, Government, Universities, and International Research Institutions

BRIN: Connecting Indonesia to the World, Building the Hydrogen Future Together

SUSTAINABLE | INNOVATIVE | COLLABORATIVE | IMPACTFUL

RD&D ACHIEVEMENTS AND FUNDING SOURCES

Proven Track Record in Innovation, Collaboration, and Impact

BRIN delivers high-impact research outputs, leads national initiatives, and secures competitive funding to advance Indonesia's hydrogen and fuel cell ecosystem.

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RESEARCH IMPACT & OUTPUT

220+ Publications (Scopus Indexed)

1,700+ Citations (Scopus)

24 Patents (Granted)

Contributor to National Hydrogen Standards (SNI) TC 206 & TC 207 (Hydrogen Technology)

Active Collaboration with 20+ national and international institutions

Key Strengths

- Multidisciplinary R&D Leadership
- From Materials to System Integration
- Pilot-Scale Demonstration Capability
- Techno-Economic & Feasibility Expertise
- Policy, Standardization & Ecosystem Development

NATIONAL & REGIONAL ROLES AND LEADERSHIP

Deputy
Indonesian Fuel Cell and Hydrogen Energy (IFHE)
Advancing national hydrogen & fuel cell development

ASEAN SCMST Focal Point
Representing Indonesia in ASEAN Committee on Science, Technology & Innovation

SNI Technical Committee Member
Active in TC 206 & TC 207 for Hydrogen Technology Standardization

Advisor & Reviewer
National R&D Programs, Technology Assessment, and Policy Formulation

International Engagement
Workshops, Invited Talks and Knowledge Sharing in ASEAN & Global Platforms

MAJOR FUNDING SOURCES & GRANT SCHEMES

FUNDING SOURCE	SCOPE / FOCUS AREA	TYPE
BRIN	Strategic National Research on Hydrogen & Fuel Cells	Government (National)
lpdp	Hydrogen Storage Materials (Metal Hydride & Sorbent)	Government (Competitive Grant)
PLN Enjiniring	Fuel Cell Systems, Hybrid Microgrid, Hydrogen Technologies	State-Owned Enterprise (SOE)
PLN PUSLITBANG	Hydrogen Storage System Development	State-Owned Enterprise (SOE)
PERTAMINA NRE	SOEC-Based Low-Emission Hydrogen Production	State-Owned Enterprise (SOE)
Ministry of Research & Technology	Electrolysis Catalyst Development	Government (National Grant)

STRATEGIC PARTNERS

AIST Japan	Noritake Japan	HUBEI UNIVERSITY China	CHINESE ACADEMY OF SCIENCES China	ENTEC NSTDA Thailand	ASEAN Initiatives
HIROSAKI UNIVERSITY Japan	THE UNIVERSITY OF TOKYO Japan	SWINBURNE UNIVERSITY OF TECHNOLOGY Sarawak Campus Malaysia	UTM UNIVERSITI TEKNOLOGI MALAYSIA Malaysia	Universiti Kebangsaan Malaysia Malaysia	Institut Teknologi Bandung Indonesia
					The Sirindhorn International TGGS Thai-German Graduate School of Engineering Thailand

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INDONESIA HYDROGEN INITIATIVES

Building a National Ecosystem for a Clean and Competitive Hydrogen Economy

Indonesia is advancing hydrogen as a key pillar of energy transition through roadmap, pilot projects, industrial engagement, and research & innovation.

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NATIONAL DRIVERS & POLICIES

National Hydrogen & Ammonia Roadmap
Government roadmap to accelerate the development of hydrogen and ammonia ecosystem in Indonesia.

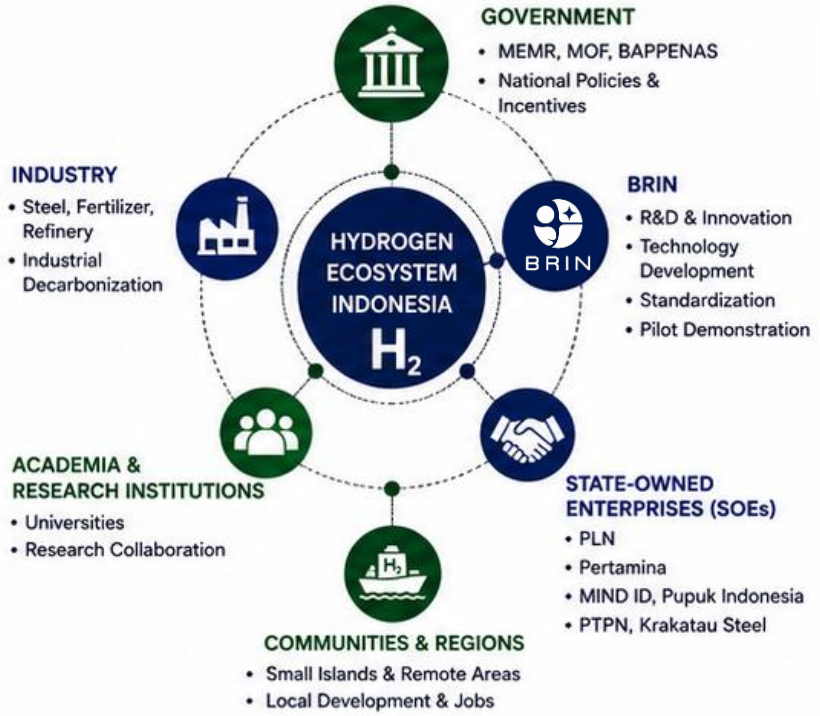
Net Zero Emission 2060
Indonesia's commitment to achieve net zero emission by 2060 or earlier.

Energy Transition Agenda
Diversifying energy mix, enhancing energy security, and reducing carbon intensity.

Regulatory & Standardization
Development of SNI for Hydrogen Technology and alignment with international standards.

Public–Private Collaboration
Strengthening collaboration across government, SOEs, industry, academia, and communities.

KEY STAKEHOLDERS & ECOSYSTEM



GOVERNMENT
- MEMR, MOF, BAPPENAS
- National Policies & Incentives

INDUSTRY
- Steel, Fertilizer, Refinery
- Industrial Decarbonization

BRIN
- R&D & Innovation
- Technology Development
- Standardization
- Pilot Demonstration

ACADEMIA & RESEARCH INSTITUTIONS
- Universities
- Research Collaboration

STATE-OWNED ENTERPRISES (SOEs)
- PLN
- Pertamina
- MIND ID, Pupuk Indonesia
- PTPN, Krakatau Steel

COMMUNITIES & REGIONS
- Small Islands & Remote Areas
- Local Development & Jobs

PRIORITY APPLICATION AREAS

- Industrial Feedstock & Raw Materials
- Power Generation & Backup Power
- Transportation (Heavy Duty)
- Aviation & Maritime (Future Fuel)
- Residential & Commercial Energy
- Energy Storage & Grid Balancing

BRIN CONTRIBUTION

- Developing critical hydrogen technologies (production, storage, fuel cells).
- Leading feasibility studies and techno-economic assessments.
- Implementing pilot projects with strategic partners.
- Supporting policy formulation and standardization.
- Building national capabilities and human resources.

NATIONAL TARGETS

Hydrogen Production ~ 0.5 – 1.0 Million Ton/Year by 2030	Green Hydrogen Share in Energy Mix 2 – 5% by 2030	CO_2 Reduction Potential ~ 10 – 25 Million Ton/Year by 2030	New Green Jobs > 50,000 Jobs by 2030	Investment Opportunity USD 20 – 60 Billion by 2030	Energy Security & Sustainable Growth

BRIN: Connecting Indonesia to the World, Building the Hydrogen Future Together

SUSTAINABLE | INNOVATIVE | COLLABORATIVE | IMPACTFUL

ASEAN & INTERNATIONAL COLLABORATION

Working Together for a Regional Hydrogen Future

BRIN actively collaborates with regional and global partners to advance hydrogen and fuel cell technologies through joint research, capacity building, and knowledge sharing.

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H_2 INDONESIA
Hydrogen Economy

EXISTING COLLABORATION NETWORK

ASEAN
- ASEAN SCMST Focal Point
- ASEAN COSTI
- ASEAN Hydrogen Discussions
- Regional capacity building and policy dialogue

JAPAN
- AIST (Japan)
- Hirosaki University
- Noritake Co., Ltd.
- Advanced materials, fuel cells, and hydrogen technologies

THAILAND
- ENTEC – NSTDA
- MHESI
- Training & capacity building
- Technology and innovation collaboration

CHINA
- Chinese Academy of Sciences
- Hubei University
- Xi'an Jiaotong University
- Joint research on hydrogen materials and systems

REPUBLIC OF KOREA
- ASEAN–ROK Cooperation funds and programs
- Hydrogen technology cooperation opportunities
- Future joint RD&D initiatives

GLOBAL PARTNERS
- Universities & Research Institutes
- International Conferences & Workshops
- Technology Transfer and Knowledge Sharing

FOCUS AREAS OF COLLABORATION

JOINT RD&D
Co-develop advanced hydrogen production, storage materials, fuel cells, and systems.

PILOT DEMONSTRATION
Implement pilot projects for real-world applications and technology validation.

CAPACITY BUILDING
Training, workshops, and exchange programs to strengthen human resources.

POLICY & STANDARDIZATION
Collaborate on hydrogen standards, regulations, and best practices.

REGIONAL VALUE CHAIN DEVELOPMENT
Build a resilient hydrogen ecosystem across ASEAN and beyond.

OUR VISION
A strong and inclusive hydrogen ecosystem in ASEAN through collaborative innovation, shared knowledge, and sustainable partnerships.

COLLABORATION IMPACT

Accelerate Innovation
Access to complementary expertise and cutting-edge technologies.

Strengthen ASEAN Hydrogen Ecosystem
Promote regional integration, knowledge sharing, and joint initiatives.

Enhance Competitiveness
Position ASEAN as a global hub for hydrogen technologies.

Support Net Zero Goals
Contribute to decarbonization and sustainable energy transition.

Create Socio-Economic Value
Generate green jobs, investment, and long-term economic growth.

Together, we can unlock the full potential of hydrogen for a clean, secure, and prosperous future.

ENGAGEMENT PLATFORMS

- International Conferences & Symposia
- Research & Academic Partnerships
- Policy Dialogues & Roundtables
- Joint Labs & Demonstration Facilities
- Innovation Challenges & Grants

"Collaboration today, sustainable hydrogen future for ASEAN tomorrow."

BRIN: Connecting Indonesia to the World, Building the Hydrogen Future Together

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INDONESIA'S GREEN HYDROGEN POTENTIAL

A Clean Energy Superpower in the Heart of Maritime Southeast Asia

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INDONESIA COUNTRY PROFILE

Total Area	1.91 million km²
Population (2024)	~280 million
GDP (Nominal, 2024)	~USD 1.37 trillion
Energy Demand (2023)	~1.2 EJ
Primary Energy Supply (2023)	~1.4 EJ
Energy Mix (2023)	Coal 41% Oil 29% Natural Gas 17% Renewables 13%
GHG Emissions (2022)	~716 $MtCO_2e$
Net Zero Target	2060
National Strategies	NZE 2060, RUEN, RUPTL 2025–2034, RHAN

ABUNDANT RENEWABLE ENERGY RESOURCES

Solar Energy Potential	> 3,200 GWp
Hydropower Potential	~95 GW
Geothermal Potential	~23 GW
Wind Energy Potential	~155 GW
Bioenergy Potential	~32 GW
Ocean Energy Potential	~60 GW

Excellent renewable resource endowment across the archipelago enables cost-competitive green hydrogen production.

HYDROGEN PRODUCTION POTENTIAL ACROSS INDONESIA (BY ENERGY SOURCE)

WHY INDONESIA?

- Abundant renewable energy resources with high capacity factors
- Strategic maritime location for global hydrogen & ammonia trade
- Strong industrial base and growing domestic demand
- Government commitment and supportive policies
- Large land availability and diverse project opportunities

TOTAL ECONOMICALLY BANKABLE POTENTIAL (EBT)

- Current Status (Installed): 0.3% (13.6 GW)
- Solar Energy: 3,294 GW (Majority in Nusa Tenggara & Kalimantan)
- Hydropower: 95 GW (Focus in North Kalimantan & Papua)
- Geothermal: 23 GW (Along the Pacific Ring of Fire)
- Wind Energy: 155 GW (Coastal & Island Regions)

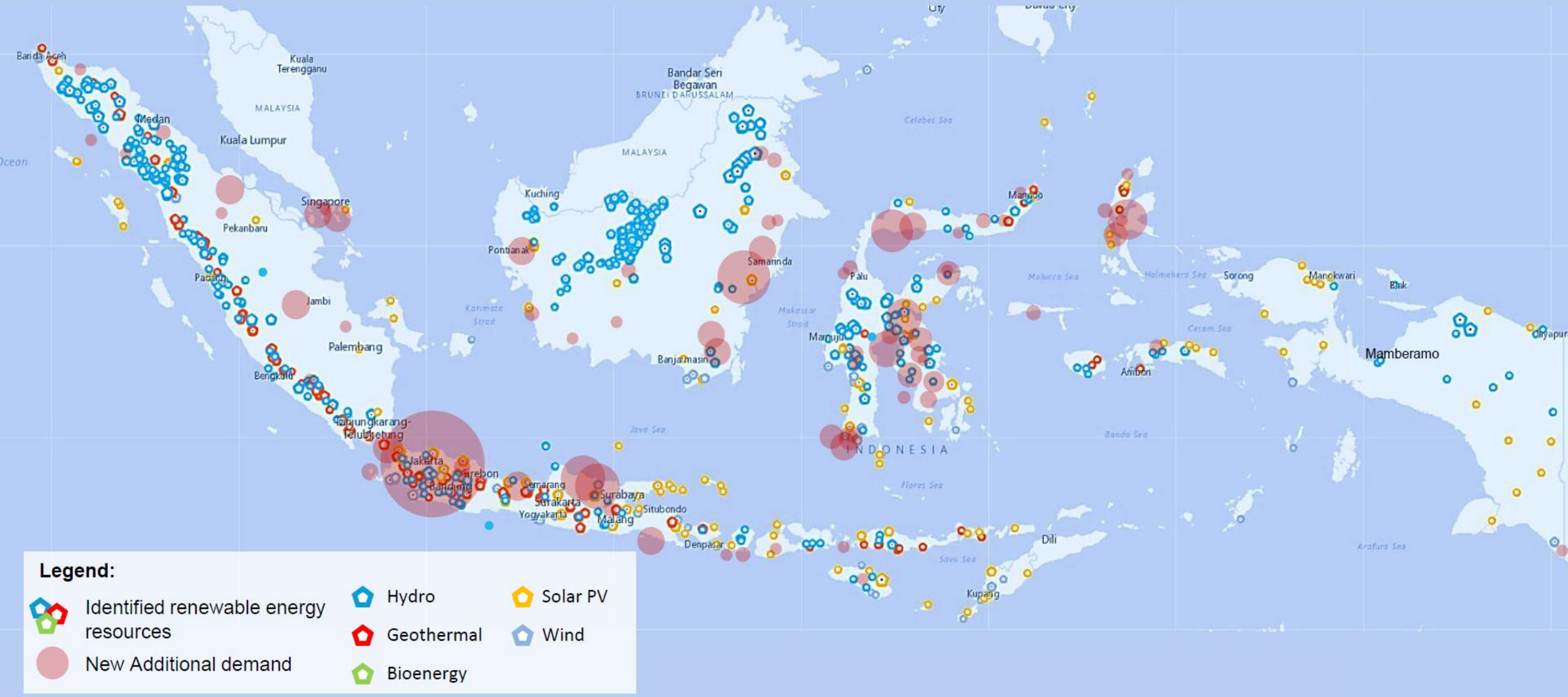
**Estimated total technically feasible potential for green hydrogen production based on renewable energy availability and electrolyzer technology assumptions.*

CONCLUSION: Indonesia's vast renewable energy resources position it as a key global player in the green hydrogen economy and a future clean energy hub.

Energy Security | Decarbonization | Economic Growth | Job Creation | Global Leadership

Source: MEMR, IEA, IRENA, BPS, DEN, 2023 – 2024

There is a mismatch between the location of potential new and renewable energy (NRE) sources and the epicenter of demand



WHY HYDROGEN?

The Smart Choice for a Clean Energy Future

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H_2 INDONESIA
Hydrogen Economy

TOWARDS NET ZERO EMISSIONS

WOOD (BIOMASS)

10 carbon atoms
to produce
1 hydrogen atom

COAL (BATUBARA)

2 carbon atoms
to produce
1 hydrogen atom

PETROLEUM (OIL)

1 carbon atom
to produce
2 hydrogen atoms

NATURAL GAS (CNG)

1 carbon atom
to produce
4 hydrogen atoms

HYDROGEN (H_2)

0 carbon atoms
to produce
2 hydrogen atoms

COMPARISON OF CARBON-TO-HYDROGEN ATOMIC RATIO

- CO_2 — High CO_2 **Emissions**
- High Fossil Fuel **Dependency**
- Energy Transition **Enabler**
- Cleaner Energy **Lower Emissions**
- H_2 — Zero Carbon Emissions **Future Energy**

Hydrogen delivers the highest energy per unit of carbon, enabling a cleaner, more sustainable, and future-ready energy system.

INDONESIA ROADMAP TOWARDS NET ZERO EMISSION (NZE) 2060

	2021–2025	2026–2030	2031–2035	2036–2040	2041–2050	2051–2060
Target: GHG Emission Reduction	**2025** GHG Emission Reduction **231.2 million tons** CO_2	**2030** GHG Emission Reduction **327.9 million tons** CO_2	**2035** GHG Emission Reduction **388 million tons** CO_2	**2040** GHG Emission Reduction **629.4 million tons** CO_2	**2050** GHG Emission Reduction **1,043.8 million tons** CO_2	**2060** GHG Emission Reduction **1,798 million tons** CO_2
KEY INITIATIVES **SUPPLY-SIDE MEASURES**	• Development of rooftop solar PV • Acceleration of waste to energy • Development of small-scale PLTBm • *Co-firing* for coal-fired power plants • Addition of PLTA (aligned with RUPTL 2021–2030)	• Addition of new power plants after 2030 from EBT • *Pumped storage* starts in 2025	• Green hydrogen from EBT starts in 2031 • *Battery Energy Storage System* (BESS) remains in operation until 2034 • Installed capacity of PLTP increases to 11 GW in 2035	• Use of nuclear power for electricity starts in 2039 • Development of *Variable Renewable Energy* (VRE) with high share, supported by PLTB *onshore* and PLTB *offshore* starting in 2037	• Green hydrogen for substituting natural gas in fossil power plants starts in 2041 • Primary energy from EBT higher than from fossil fuels	• Emission reduction in the electricity sector will achieve net zero and in the industrial and transportation sectors by 129 million tons CO_2e • Use of hydrogen gas for electricity generation
DEMAND-SIDE MEASURES	• Industrial coal boiler 8.1 million tons • *Dimethyl ether* using LPG for households • Deployment of 300,000 electric cars and 1.3 million electric motorcycles • Conversion of 5.2 million motorcycles to electric • Mandatory biodiesel blending 30% in 2025	• Industrial coal boiler 18.1 million tons • 2 million electric cars and 13 million electric motorcycles • Conversion of 10.2 million motorcycles • Biofuel in industrial and transportation sectors reaches 40% • Energy and equipment management for 11 million households	• Industrial coal boiler 28.2 million tons • 9.3 million electric cars and 51 million electric motorcycles • Conversion of 15.2 million motorcycles • Biofuel usage increases to 40% • Implementation of Energy Management and SKEM	• CCS for cement and steel sectors starts in 2036 • Low-carbon fuel for shipping • Industrial coal boiler 37.9 million tons • 23 million electric cars and 101 million electric motorcycles • Conversion of 20.2 million motorcycles • Biofuel in industrial and transportation sectors reaches 40%	• Industrial coal boiler 46.6 million tons • 50.2 million electric cars and 163 million electric motorcycles • Conversion of 22.7 million motorcycles • Biofuel in industrial and transportation sectors reaches 40%	• CCS in industry 13 million tons CO_2 • Industrial coal boiler 54.3 million tons • 175 million electric cars and 65 million electric motorcycles • Conversion of 22.7 million motorcycles • Projection of electricity demand 1,942 TWh and electricity consumption intensity 5.862 kWh/capita

Support the national energy transition

Reduce carbon emissions and air pollution

Ensure energy security and affordability

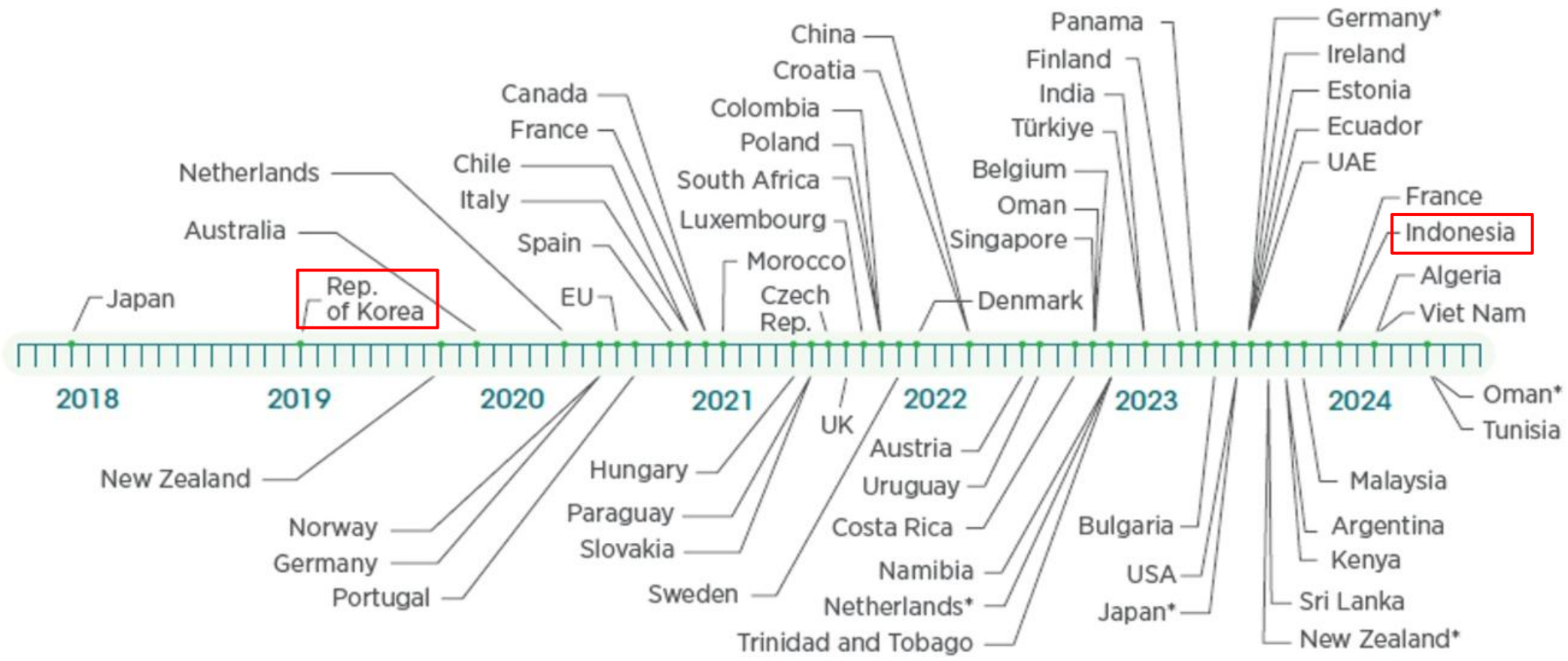
Drive green investment and economic growth

Innovation and education on hydrogen technology

Strategic collaboration for a sustainable future

TOWARDS NET ZERO EMISSION 2060

TIMELINE OF HYDROGEN STRATEGIES AND ROADMAPS (as of May 2024)



Global momentum
More countries are adopting hydrogen strategies every year.

Shared goal
Accelerating the transition towards a sustainable hydrogen economy.

Collaborative future
International cooperation is key to building a resilient and inclusive hydrogen value chain.

Cleaner tomorrow
Hydrogen is a catalyst for a low-carbon, secure, and prosperous future.

Note: Updates are indicated with an asterisk; EU = European Union; Rep. of Korea = Republic of Korea; Czech Rep. = Czech Republic; UAE = United Arab Emirates; USA = United States of America.

Source: IRENA (2024): *Green hydrogen strategy A guide to design*

INDONESIA'S HYDROGEN STRATEGY

Building the Foundation Today, Leading the Transition Tomorrow

BRIN
BADAN RISET
DAN INOVASI NASIONAL

SOLIDIFYING THE FOUNDATION: COMPLETED MILESTONES

STRATEGIC ANCHOR

National Strategy Published (Dec 2023).

GOVERNANCE

Hydrogen Technical Committee (27-11) Established.
Scope: Mirroring international standards (ISO/TC 197 & IEC/TC 105).

STANDARDIZATION

3 Critical SNI (National Standards) issued in 2024.

- SNI ISO 14687:2019 (Fuel quality & product specs)
- SNI ISO 19880-1:2020 (Refuelling station safety & general requirements)
- SNI ISO/TR 15916:2015 (Basic considerations for hydrogen system safety)

Strong standards, robust governance, and a clear strategic anchor lay the groundwork for Indonesia's hydrogen future.

THE MASTER PLAN: NATIONAL HYDROGEN STRATEGY

LAUNCHED DECEMBER 15, 2023

CURRENT CONDITION

Baseline mapping of infrastructure and resources.

GOALS

Concrete milestones for the Net Zero 2060 mandate.

DIRECTION

Strategic pathways for domestic and international integration.

This overarching strategy serves as the True North for domestic hydrogen development and international investment, laying the groundwork for all derivative regulations.

- Energy Security & Sovereignty
- Decarbonization & Climate Action
- Economic Growth & Green Industry
- Job Creation & Social Benefit
- Global Leadership & Energy Diplomacy

INDONESIA HYDROGEN ROADMAP

A Comprehensive Strategy for a Clean, Competitive, and Sustainable Future

BRIN BADAN RISET DAN INOVASI NASIONAL

H_2 INDONESIA Hydrogen Economy

01 The Current Energy Landscape in Indonesia

02 Hydrogen Potential in Indonesia

03 Policy and Regulatory Framework

04 Research and Innovation

05 Hydrogen Adoption Scenario

06 Infrastructure Development

07 International Collaboration & Hydrogen Supply Chain Development

08 Hydrogen Implementation and Utilization Plan

The roadmap provides a strategic direction for hydrogen development in Indonesia, covering policy, technology, infrastructure, and market adoption.

- Supports national energy security and resilience
- Enables low-carbon economic growth
- Creates jobs and strengthens industries
- Positions Indonesia as a regional hydrogen leader

Strategic roadmap for Indonesia's hydrogen future

Integrated policy, technology, and market approach

Driving innovation and industrial competitiveness

Strengthening partnerships and global collaboration

Advancing toward a net-zero emission future

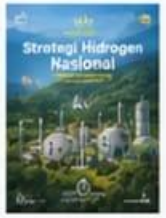
POLICIES PREPARED BY MEMR

Strengthening the Policy Framework for Indonesia's Hydrogen Ecosystem

BRIN BADAN RISET DAN INOVASI NASIONAL

H_2 INDONESIA Hydrogen Economy

COMPLETE / PUBLISHED



1 HYDROGEN

- The document
and goals of hy
- The National Hy
on December 15
https://bit.ly/St

2 HYDROGEN TECHNICAL COMI

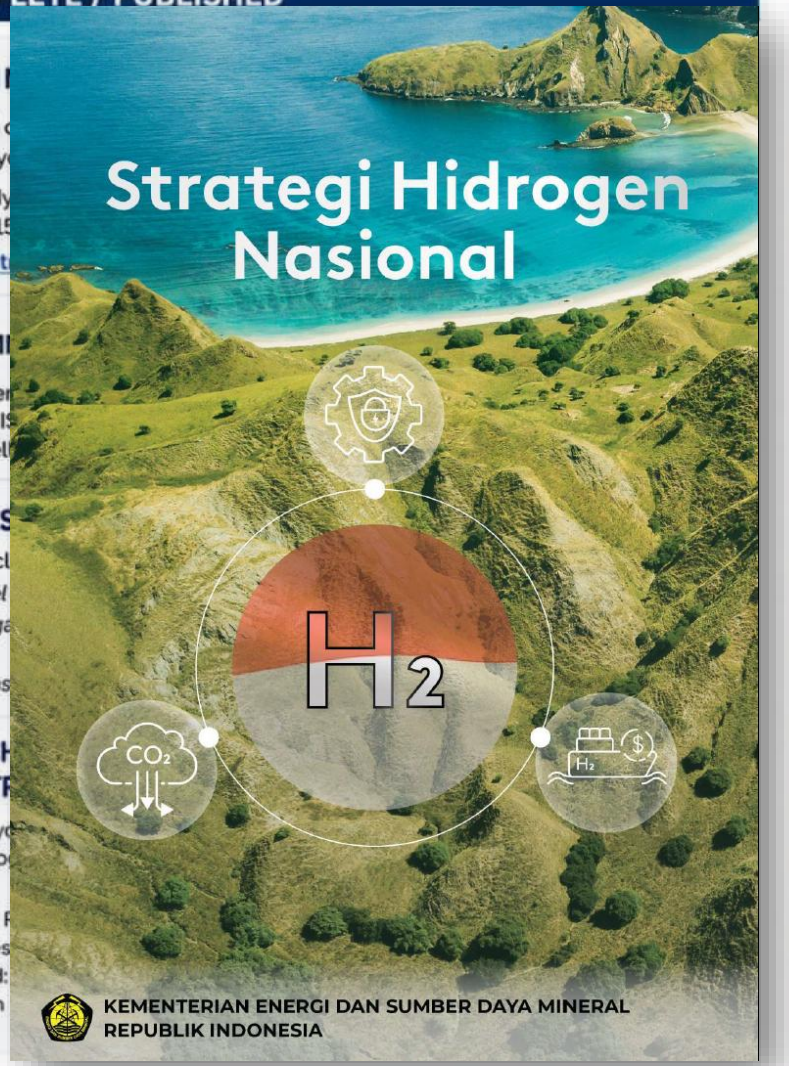
Technical Committee 27-11 Hydrogen
established with a scope: Mirroring IS
Technologies & IEC/TC 105 Fuel Cell

3 STANDAR NASIONAL INDONES

3 SNIs have been issued in 2024, incl
- ✓ **SNI ISO 14687:2019**, *Hydrogen fuel*
- ✓ **SNI ISO 19880-1:2020**, *Hydrogen ga*
Part 1: General requirements
- ✓ **SNI ISO/TR 15916:2015**, *Basic cons*

4 GREEN HYDROGEN SUPPLY CH
STUDY (UPSTREAM-DOWNSTR

- Detailed study and guidelines for hyd
sector for the preparation of a hydro
- Overview of study results:
  - Potential Green H2 Source: PLN
  - Potential Green H2 Storage: pres
  - Potential H2 distribution method:
  - Potential utilization: at Hydrogen



ON PROGRESS

AMMONIA
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OUR COMMITMENT

- Ensuring safety, reliability, and sustainability
- Strengthening standards and regulations for a competitive ecosystem
- Collaborating across stakeholders for national energy independence
- Supporting net-zero emission and clean energy transition

INDONESIA'S HYDROGEN NATIONAL STRATEGY

BRIN BADAN RISET DAN INOVASI NASIONAL

H_2 INDONESIA Hydrogen Economy

OUR VISION

To establish a hydrogen economy that contributes to the energy transition and plays an essential role in **decarbonizing the global energy system.**

Indonesia will reduce dependence on fossil fuels to ensure sovereignty and security of energy

Indonesia will pursue its decarbonization target by developing the domestic hydrogen market

Indonesia will export hydrogen and its derivatives to the global market by taking advantage of its uniqueness as a maritime country

OUTCOME

- NZE target achieved
- High NRE penetration
- High foreign investment in green industry
- Creation of green jobs
- Universal energy access meets SDG 7 criteria
- Exports of low-carbon hydrogen and ammonia increased

LOW CARBON HYDROGEN AND AMMONIA DEVELOPMENT FOCUSED IN FOUR SECTORS IN INDONESIA

1 Industrial

- As a gradual substitution for high carbon (existing) hydrogen. Low-carbon hydrogen and ammonia produced from NRE sources supports the decarbonization of the industrial sector, and increases industrial competitiveness when a carbon tax is implemented.
- Reducing emissions for industries that require high temperatures (cement and steel)

2 Transportation

- Starting in 2030, **low-carbon hydrogen** will be used in the transportation sector for **long-distance vehicles** such as trucks, heavy transport and shipping.
- Hydrogen vehicles as a diversification of electric vehicles such as batteries

3 Electricity

- Low carbon hydrogen/ammonia cofiring in fossil fuel plants. This option can be considered in the 2030-2050 period, when there are high EBT penetration and curtailment, EBT prices are already cheap, carbon prices are quite high
- Storage options for off grid generation
- Storage technology options to overcome curtailment of NRE generators

4 As an export commodity

Hydrogen and ammonia have the potential trading on regional and international markets, taking into account: Indonesia's strategic position as a maritime country, the potential for monetization of NRE sources for power generation with low demand, and the high interest of market players in capturing opportunities for trading low-carbon hydrogen and ammonia.

Energy Security & Sovereignty | Economic Growth & Competitiveness | Decarbonization & Climate Leadership | Innovation & Technology Advancement

Large number of renewable energy potency may serve rapid growth demand hydrogen and ammonia

BRIN BADAN RISET DAN INOVASI NASIONAL

H_2 INDONESIA Hydrogen Economy

The projected growth in hydrogen and ammonia demand is driven by accelerating adoption across key sectors, supported by abundant renewable energy potential and ongoing technological advancements.

Hydrogen

PROJECTION (Ton/Year)		2025	2030	2035	2040	2045	2050	2055	2060
Overall H_2 DEMAND*		39.391	874.239	1.194.068	1.827.750	3.185.523	5.393.337	10.106.161	11.770.041
DEMAND SECTORS	Industry	38.541	850.613	1.126.644	1.646.365	2.836.681	4.690.489	5.576.621	6.522.148
	Transportation	-	438	3.690	31.081	73.199	273.012	515.619	985.230
	Power Plant	850	20.285	56.146	136.251	253.343	403.973	3.977.140	4.221.429
	City Gas	-	2.903	7.588	14.053	22.300	25.863	36.781	41.234
Overall H_2 SUPPLY		199.492	1.099.506	2.339.059	3.892.468	6.169.964	9.297.504	14.930.052	17.513.658

KEY TAKEAWAYS

- Hydrogen demand grows nearly **300x** from 2025 to 2060.
- Strongest growth comes from industry and power generation sectors.
- Hydrogen supply increases steadily to meet the rising demand.
- Hydrogen is key to achieving a low-carbon and sustainable energy future.

Ammonia

PROJECTION (Ton/Year)		2025	2030	2035	2040	2045	2050	2055	2060
Overall NH_3 DEMAND		27.772	1.324.961	2.084.729	4.089.985	5.670.132	7.128.445	8.980.480	9.629.191
DEMAND SECTORS	Fertilizer	-	1.232.387	1.807.008	3.534.294	4.743.797	5.738.792	5.738.792	5.738.792
	Power Plant (co-firing)	27.772	92.574	277.721	555.441	925.735	1.388.603	3.240.073	3.888.088
	Transportation	-	-	-	250	600	1.050	1.615	2.311
Overall NH_3 SUPPLY		-	1.773.321	2.618.368	5.180.304	7.181.560	9.957.843	13.571.968	13.571.968

KEY TAKEAWAYS

- Ammonia demand grows more than **340x** from 2025 to 2060.
- Fertilizer remains the largest demand driver, followed by power generation.
- Ammonia supply keeps up with demand to support long-term energy security.
- Ammonia plays a vital role in food security and clean energy transition.

POWERING GROWTH, FUELLING THE FUTURE

Abundant Renewable Potential
Indonesia's rich renewable energy resources enable large-scale clean hydrogen and ammonia production.

Growing Market Demand
Rapid demand growth across multiple sectors opens vast opportunities for innovation and investment.

Sustainable Solutions
Hydrogen and ammonia support decarbonization, energy security, and a sustainable future for Indonesia and beyond.

Collaborative Path Forward
Strong collaboration among industry, research institutions, and government is key to realizing the full potential of clean energy.

> "Clean Energy Today Stronger Tomorrow

TARGET STANDARDS AND CERTIFICATION FOR CLEAN HYDROGEN AND AMMONIA

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

This roadmap supports the development of a **safe, high-quality,** and **globally competitive** hydrogen and ammonia ecosystem in Indonesia through standards, technology, and testing.

FOCUS AREAS	2024	2025	2026	2027	2028	2029
BASIC SAFETY & QUALITY STANDARDS Foundation for safety and quality	ISO 14687:2019, Hydrogen Fuel Quality	Standard Hydrogen Low Carbon Indonesia	ISO 17268:2020, Land Vehicle Refuelling Connection	ISO 16110-1:2007, Hydrogen Generators: Safety	IEC 62282-3-400:2016, Small Stationary Fuel Cell: Combined Output	IEC 62282-3-400:2016, Fuel cell technologies: Stationary fuel cell power systems
	ISO/TR 15916:2015, Basic Safety Hydrogen System	ISO 22734:2019, Hydrogen from Electrolysis	ISO 13985:2006, Liquid: Land Vehicle Tanks	ISO 16110-2:2010, Hydrogen Generators: Performance Test	IEC 62282-4-101:2022, Industrial Trucks Fuel Cell: Safety	IEC 62282-4-101:2022, Fuel cell power systems for electrically powered industrial trucks – Safety
	ISO/TR 19880-1:2020, Fuelling Station: General Requirements	ISO 22734:2019, Hydrogen Generator via Electrolysis	ISO 19881:2018, Gaseous: Land Vehicle Containers	ISO 11114-4:2017, Steel to Hydrogen Embrittlement Test	IEC 62282-4-102:2022, Industrial Trucks Fuel Cell: Performance Test	IEC 62282-4-102:2022, Fuel cell power systems for electrically powered industrial trucks: Performance test methods
HYDROGEN TECHNOLOGY & STORAGE Technology and hydrogen storage		ISO 19880-8:2019, Gaseous hydrogen – Fuelling stations – Part 3: Valves	ISO 11114-1:2020/ Amd 1:2023, Gas Cylinders: Gas Compatibility	ISO 16111:2018, Storage: Hydrogen Absorbed in Metal Hydride	IEC 62282-4-600:2022, Fuel Cell Hybrid Performance Test for Excavators	IEC 62282-4-600:2022, Fuel cell/battery hybrid systems performance test methods for excavators
FUEL CELL TECHNOLOGY & TESTING Technology and fuel cell testing		ISO 19880-8:2019, Gaseous hydrogen – Fuelling stations – Part 5: Dispenser hoses and hose assemblies		IEC 62282-3-100:2019, Stationary Fuel Cell: Safety	IEC 62282-5-100:2018, Portable Fuel Cell: Safety	IEC 62282-5-100:2018, Portable fuel cell power systems – Safety
		ISO 19880-8:2019, Gaseous hydrogen – Fuelling stations – Part 8: Fuel quality control		IEC 62282-3-200:2015, Stationary Fuel Cell: Performance Test	IEC 62282-7-1:2017, Polymer Electrolyte Fuel Cell: Performance Test	IEC TS 62282-7-1:2017, Test methods: Single cell performance tests for polymer electrolyte fuel cells (PEFC)
				IEC 62282-3-201: 2017/AMD1:2022, Small Stationary Fuel Cell: Performance Test		
				IEC 62282-3-300:2012, Stationary Fuel Cell: Installation		

- Standard development
- Technology & infrastructure
- Fuel cell technology & testing

Building a safe, reliable, and sustainable hydrogen and ammonia ecosystem through international standards, innovation, and collaboration.

- Enhance safety and reliability
- Accelerate adoption of clean hydrogen and ammonia
- Ensure quality and performance
- Support industry growth and investment
- Align with global standards and decarbonization goals

STANDARDS AND OTHER REGULATIONS RELATED TO CLEAN HYDROGEN AND AMMONIA

A comprehensive framework of international standards and regulations supporting the safe, reliable, and sustainable hydrogen and ammonia ecosystem.

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

SAFETY & RISK MANAGEMENT

- **ISO 13984:1999** Liquid Hydrogen: Land Vehicle Fuelling Interface
- **ISO 19882:2018** Gaseous Hydrogen: Thermally Activated Pressure Relief Devices
- **ISO/TS 19883:2017** Pressure Swing Adsorption: Safety
- **ISO 26142:2010** Hydrogen Detection Apparatus
- **EN 1797:2001** Cryogenic Vessels: Gas/Material Compatibility

PRODUCTION, STORAGE & TRANSPORT

- **ISO 21266-1:2018** Hydrogen Blending System: Safety
- **ISO 21266-2:2018** Hydrogen Blending System: Performance Test
- **ISO 15649:2001** Natural Gas Industries: Piping
- **EN 15339:2018** Safety Management Systems for Gas Network
- **ISO 17339:2020** Transportable Gas Cylinder: Carbon Composite
- **EN 17533:2020** Gaseous Cylinder and Tube for Stationary Use

QUALITY, PERFORMANCE & TESTING

- **ISO 14687:2019** Hydrogen Fuel Quality
- **ISO 17268:2020** Land Vehicle Refuelling Connection
- **ISO 16110-1:2007** Hydrogen Generators: Safety
- **ISO 16110-2:2010** Hydrogen Generators: Performance Test
- **ISO 11114-1:2020 / Amd 1:2023** Gas Cylinders: Gas Compatibility
- **ISO 21013-1:2008** Cryogenic Vessels: Non-redosable Valves
- **ISO 21013-2:2007** Cryogenic Vessels: Non-redosable Devices
- **ISO 21013-3:2016** Cryogenic Vessels: Sizing and Capacity

FUEL CELL & VEHICLE APPLICATIONS

- **IEC 62282-3-400:2016** Small Stationary Fuel Cell: Combined Output
- **IEC 62282-4-101:2022** Industrial Trucks Fuel Cell: Safety
- **IEC 62282-4-102:2022** Industrial Trucks Fuel Cell: Performance Test
- **IEC 62282-4-600:2022** Fuel Cell Hybrid Performance Test for Excavators
- **IEC 62282-5-100:2018** Portable Fuel Cell: Safety
- **SAE J2601** Fueling Protocol: Light Duty Hydrogen Surface Vehicle
- **SAE J2601/3** Fueling Protocol: Surface Vehicles (forklift)

AMMONIA PRODUCTION, HANDLING & CONTENT

- **ISO 7108:1985** Ammonia Solution: Ammonia Content
- **ISO 7105:1985** Liquefied Anhydrous Ammonia: Water Content
- **ISO 7106:1985** Liquefied Anhydrous Ammonia: Oil Content
- **ISO 21887:2019** Ammonia Mass Concentration: Manual
- **ISO 15859-11:2004** Ammonia Sampling and Testing in Flight and Ground Support

ENVIRONMENT & LIFE CYCLE

- **IEC 62282-9-101:2020** Environmental Evaluation: Life Cycle
- **IEC 62282-9-102:2021** Environmental Evaluation: Product Category Rules
- **ISO 14067:2018** Greenhouse Gases: Carbon Footprint of Products

ROAD VEHICLES & FUELLING

- **ISO 23273:2013** Fuel Cell Road Vehicles: Hydrogen Hazards Protection
- **EN ISO 17081:2014** Hydrogen Uptake and Transport in Metals
- **SAE J2600** Compressed Hydrogen Vehicle Fuelling Connection Device
- **SAE J2601/2** Fueling Protocol: Surface Vehicles (bus)
- **SAE J2601/4** Ambient Temperature Orifice Fueling

OTHER TECHNICAL STANDARDS

- **IEC 62282-8-201:2020** Reverse Fuel Cell Storage: Performance Test
- **IEC 60079** Explosive Atmosphere: All Parts
- **EN 17124:2018** Proton Exchange Membrane Fuel Cell for Road Vehicles
- **EN 17127:2020** Outdoor Hydrogen Refuelling Points and Dispensing
- **EN 45510-2-6:2000** Power Station Requirement: Generator

- **Safety & Risk Management** Standards for safety, risk mitigation, protection systems.
- **Production, Storage & Transport** Standards for production, storage, transportation, and infrastructure.
- **Quality, Performance & Testing** Standards for product quality, performance, and testing methodologies.
- **Fuel Cell & Vehicle Applications** Standards for fuel cell technology and applications in vehicles and equipment.
- **Ammonia Production, Handling & Content** Standards for ammonia production, handling, analysis, and content.
- **Environment & Life Cycle** Standards for environmental impact and life cycle assessment.
- **Road Vehicles & Fuelling** Standards for road vehicles and hydrogen refuelling infrastructure.
- **Other Technical Standards** Other relevant technical standards.

These standards and regulations form the foundation for building a safe, reliable, competitive, and sustainable hydrogen and ammonia ecosystem.

- Enhances safety and reliability
- Supports sustainable development
- Ensures quality and performance
- Accelerates industry adoption and investment
- Aligns with global standards and decarbonization goals

Toward NZE, coal retirement plan needs a comprehensive plan and transitional step

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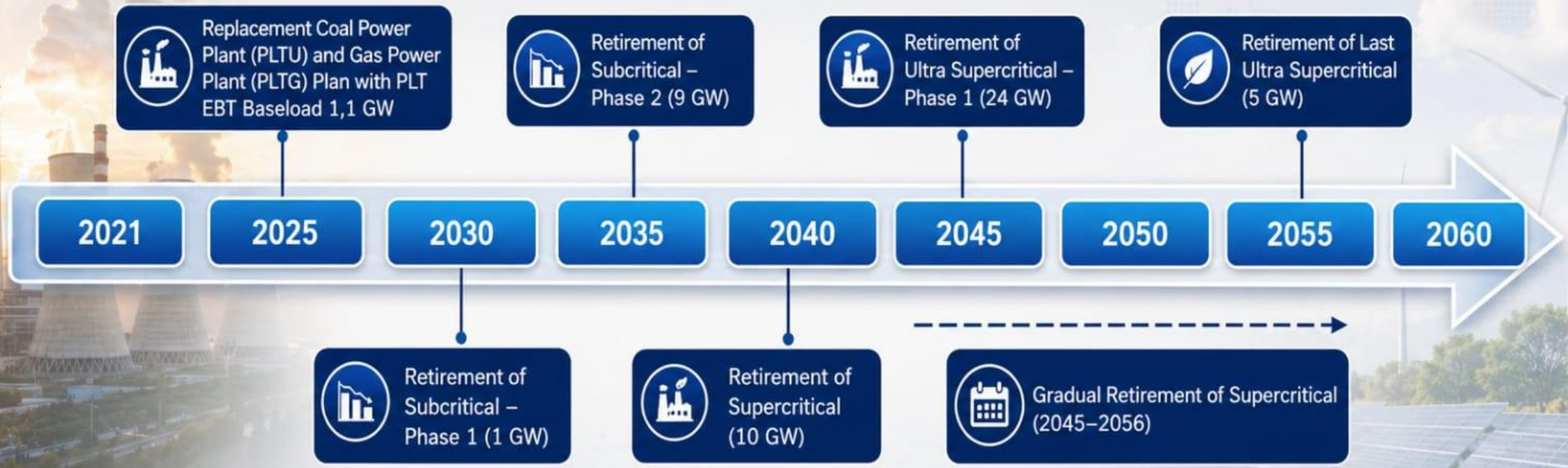
I. Retirement Coal-Fired Power Plant towards Carbon Neutrality 2060



- Support the national energy transition
- Reduce carbon emissions
- Ensure energy security and affordability
- Drive green investment and economic growth
- Strengthen collaboration for a sustainable future

TOWARD NET ZERO EMISSION 2060

ENERGY STRUCTURE IN NUSANTARA

Building a Clean, Reliable, and Sustainable Energy Ecosystem for a Net-Zero Future

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

ENERGY INFRASTRUCTURE

The energy supply strategy is designed to meet the net-zero emission target in the KPI.

ELECTRICITY

- Gas-insulated substation (GIS) with underground cable (UGC) transmission.
- Substations will be distributed to all KIKN and KPIIKN, close to locations where there is a load demand for electricity.
- Implement the smart-grid system.

GAS

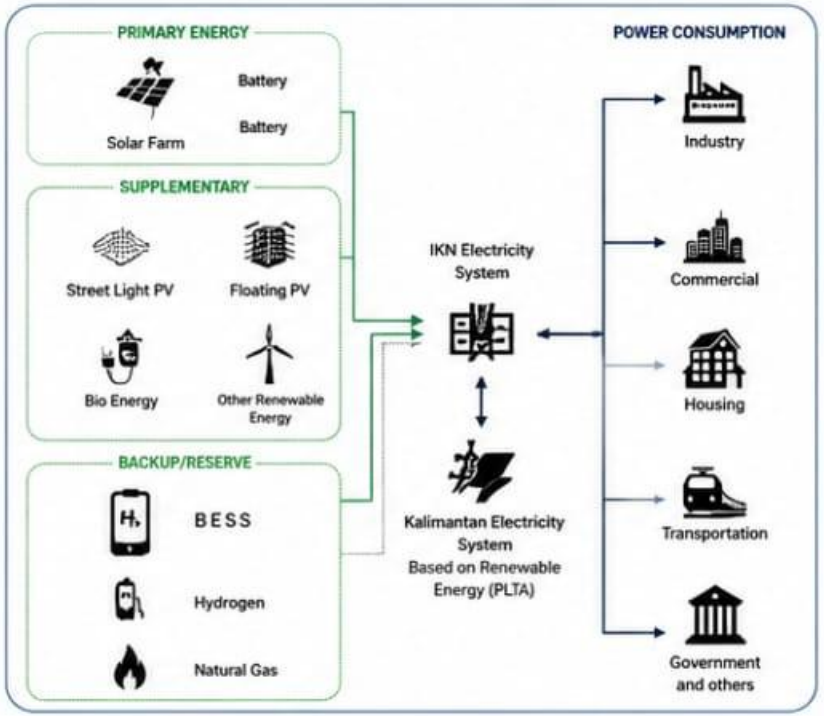
- City-scale gas is planned to be able to support the fulfillment of energy needs for households, offices, commercial, services, and other facilities.
- From the results of the study conducted, the options for the city gas supply system to be considered are hydrogen gas and natural gas.
- Solar farms are needed to support hydrogen production for the city's gas needs by 2045.

RELEVANT KPI's

4. LOW CARBON EMISSIONS

- 4.1 The installation of renewable energy capacity will meet 100% of IKN's energy needs
- 4.2 60% energy savings for energy conservation in buildings
- 4.3 *Net zero-emission for IKN (when operating) in 2045 in the area of 256K Ha*

100% of IKN's annual electricity needs are supplied by renewable power plants such as solar farms and rooftop solar panels. IKN will be connected to the Kalimantan Electricity System based on renewable energy. IKN will take the required supply from the Kalimantan Electricity System.

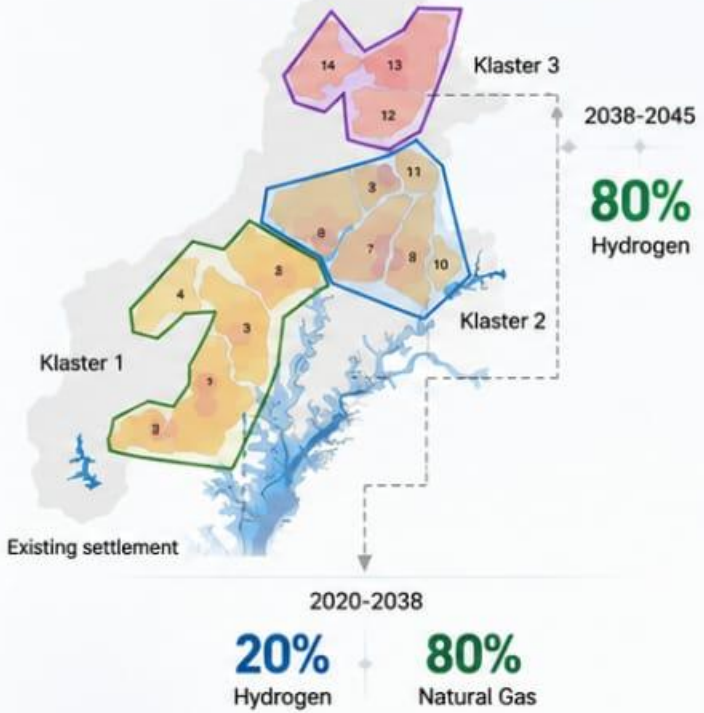


ENERGY FOR THE IKN TRANSPORT SYSTEM

H_2 & H_2 NET ZERO EMISSION

The city-scale gas energy supply at K-IKN will be supplied through the three-city gas network. Gas will be distributed through underground gas pipelines.

K-IKN WILL BE SUPPLIED THROUGH THE GAS NETWORK OF THREE CITIES



KEY BENEFITS

- Clean and sustainable energy supply
- Enhanced energy security and reliability
- Reduced carbon emissions
- Supports investment and economic growth
- Improves quality of life for future generations

Source: Bappenas

DEVELOPMENT OF HYDROGEN & AMMONIA TO SUPPORT POWER SECTOR

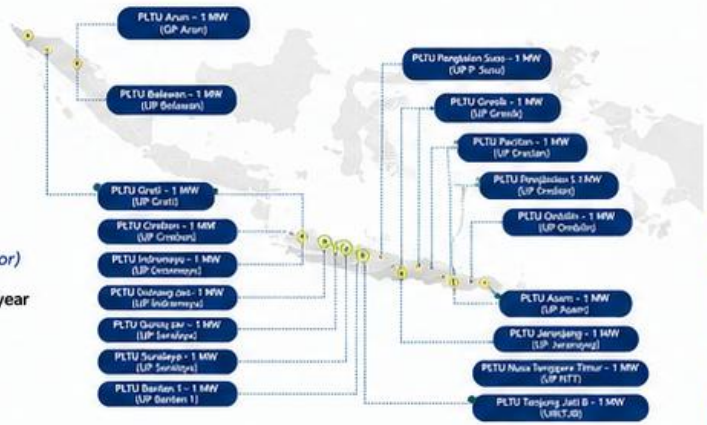
BRIN Badan Riset dan Inovasi Nasional | H_2 INDONESIA Hydrogen Economy

1 21 GREEN HYDROGEN PLANT (GHP)

Consists of: 12 units owned by PT PLN Indonesia Power, 8 units owned by PT PLN Nusantara Power, and 1 unit owned by PLN Induk Pembangkit Tanjung Jati B (UIKTJB).

PLN

- Total H_2 production = 199 tons/year
- Internal demand = 75 tons/year *(for cooling generator)*
- Excess = 124 tons/year



DESCRIPTION

- 12 units PT PLN Indonesia Power
- 8 units PT PLN Nusantara Power
- 1 unit UIKTJB

Total excess production **124** tons **per year**

Formal Ceremony, November 20, 2023

2 THE 1st GREEN HYDROGEN PLANTS FROM GEOTHERMAL (PLTP KAMOJANG)

- Developed by PLN Indonesia Power subsidiary. Green hydrogen production is around 4.3 tons/year.
- Hydrogen is produced from POME (Palm Oil Mill Effluent) at Palm Oil Mill in North Sumatra.
- A biogas plant is installed to process POME and produce CH_4.
- CH_4 is upgraded to produce 99.9% CH_4, then used as feedstock for SMR to produce hydrogen as a raw material.

POME Wastewater → Biogas Installation → CH_2 Upgraded CH_4 (99.9%) → Steam Methane Reforming (SMR) → H_2 Green Hydrogen (Feedstock)

3 HYDROGEN DEVELOPMENT FOR POWER PLANT BY HDF ENERGY

PROJECT PROFILE

Plant Arrangement
10 MW during the day (07.00 – 20.00) and 1.5 MW (20.00 – 07.00), >85% availability factor

Plant Performance
47 GWh of total energy yield in the 1st Year

Project Location
Renewstable Sumba Project is located at Mondu Village, Kanatang Subdistrict, East Sumba District

POWER PLANT CONFIGURATION & BENEFITS

Solar PV	Electrolyzer	Fuel Cell	Battery
30 MWp	10 MW	1.5 MW	28 MWh

Annual Electricity Production	Avoided Diesel/Year	Potential Saving/Year	Annual GHG Avoidance
47 GWh	11,600 kL	USD 2–5 Mio	25,676 tCO_2e

4 PILOT PROJECTS: GREEN HYDROGEN/AMMONIA CO-FIRING, HYDROGEN FUEL CELL GENERATOR

4 PILOT PROJECTS for hydrogen and ammonia co-firing

Province	Jakarta	South Sumatera	East Java	Bali
	Mitsubishi Power: Execution 2025	Mitsubishi Power: Not Feasible	IHI: Not Feasible	9fb: 2% Success
	Hydrogen co-firing at Tanjung Priok	Ammonia co-firing at Keramasan	Ammonia co-firing at Gresik	Hydrogen co-firing at Pangalengan
Total capacity	2830 MW	2 x 40 MW	2219 MW	200 MW
Testing capacity	30.1 MW (1 Unit)	40 MW (1 Unit)	100 MW (1 Unit)	16 MW (1 Unit)
Power plant type	Gas Turbine Combined Cycle	Gas Turbine Combined Cycle	Gas Fired Steam Power Plant	Gas Engine Simple Cycle
Co-firing resources	Hydrogen	Ammonia	Ammonia	Hydrogen
Source	TBD	PT Pupuk Sriwidjaja	PT Petrokimia Gresik	PT Tirta Austraindo

5 HYDROGEN REFUELING STATION IN SENAYAN

- HRS Senayan will utilize green hydrogen excess of 128.3 tons/year to serve around 438 FCEV-based hydrogen cars every year.
- This can reduce fuel imports (RON-92) by 1.59 million liters/year and can reduce CO_2 emissions by 4.15 million kg/year.

6 UNDER CONSTRUCTION OF HRS – PERTAMINA NRE

- HRS is located at the Coco Pertamina Daan Mogot gas station and will be used commercially in 2025, with a production of 450 kg H_2 per day.
- HRS will use gray hydrogen from natural gas with Steam Methane Reformer (SMR) technology.
- Pertamina has mapped the infrastructure to support the hydrogen ecosystem, with potential sources of green and blue hydrogen production in 17 locations that will feed SPBH.

- Support national industrial sector decarbonization targets
- Significantly reduce greenhouse gas emissions
- Drive clean and sustainable energy independence
- Strengthen Indonesia's competitiveness in the global green market

TOWARDS A GREEN INDUSTRY INDONESIA GOLD 2045

DEVELOPMENT OF HYDROGEN & AMMONIA TO SUPPORT INDUSTRIAL SECTOR DECARBONIZATION

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

01 Aceh PIM-2 Ammonia Plant

PRODUCTION CAPACITY
570,000
tons of urea granules per year

LOCATION
Lhokseumawe, Aceh

TECHNOLOGY
Hybrid Green Ammonia

PT Pupuk Indonesia, in collaboration with TOYO, is officially conducting a feasibility study for the development of a green ammonia plant in Indonesia based on the Heads of Agreement (HoA) for the development of the Pupuk Iskandar Muda (PIM) unit-2 *Hybrid Green Ammonia* project.

The study is conducted together with TOYO to assess the feasibility of building a 570,000 tons per year Ammonia-Urea PIM-2 plant using Hybrid Green Ammonia technology at Lhokseumawe, Aceh, to develop a *hybrid green* ammonia plant.

02 Hydrogen Production from POME Waste at Palm Oil Mill

POME Wastewater → Biogas Installation → CH_4 Upgraded Methane (99.9%) → Steam Methane Reforming (SMR) → H_2 Green Hydrogen (Feedstock)

- In the petrochemical sector, one of the best practices for green hydrogen is in North Sumatra.
- PT Nubika Jaya in North Sumatra has produced hydrogen from Palm Oil Mill Effluent (POME).
- PT Nubika Jaya has installed a biogas plant to process POME and produce CH_4.
- The produced CH_4 is upgraded to produce 99.9% CH_4, which is then used as feedstock for SMR to produce hydrogen used as a feedstock.

03 Gresik Petrochemical Ammonia Plant

The GH2 project is a collaboration between Pupuk Indonesia, ACWA Power, and PLN for an integrated green hydrogen project:

- Construction of a 180 MWp (DC) Solar Power Plant (PLTS) in the Tenaga Surya area, Banyuwangi, covering 120 Ha.
- Construction of a 150 kV Transmission Line spanning 25 km (PLTS – Gardu Induk Banyuwangi).
- *Green Hydrogen Plant* with a 100 MW *Electrolyzer* installation to produce 15,000 tons of H_2 per year, located in the Gresik Petrochemical Complex (PKG).

04 Hydrogen Plant owned by Samator

KE-57 PLANT IN BATAM

PRODUCTION UP TO 60 Nm³ PER HOUR

SUPPORTING LOW CARBON ENERGY TRANSITION

PT Samator Indo Gas, Tbk. has been conducting public expose and inaugurated the ke-57 plant in Batam, Riau Islands as a hydrogen plant supporting the low carbon energy transition in Indonesia.

The ke-57 plant in Batam is capable of producing hydrogen up to **60 Nm³ per hour**.

- Support national industrial sector decarbonization targets
- Significantly reduce greenhouse gas emissions
- Drive clean and sustainable energy independence
- Strengthen Indonesia's competitiveness in the global green market

TOWARDS A GREEN INDUSTRY INDONESIA GOLD 2045

HYDROGEN IN PETROCHEMICAL

From Palm Oil Mill Effluent (POME) to Green Hydrogen for Petrochemical Industry

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

PALM OIL MILL – PT NUBIKA JAYA, NORTH SUMATERA

PKS CAPACITY
45 tons / hour FFB
(24 hours operation/day, 90% efficiency)

TOTAL FFB PROCESSING
354 thousand tons / year

CPO PRODUCTION
70 thousand tons / year

POME GENERATION
≈ 60% of total FFB processing
(≈ 212 thousand tons / year)
Environmental impact if untreated

OVERVIEW

PT Nubika Jaya installed a Biogas Installation to treat POME waste.
Technology used: Continuous Stirred Tank Reactor (CSTR).

Biogas obtained contains 55% – 65% CH_4, H_2S and other gases.
The biogas is channeled to the desulfurization plant / H_2S cleaner.

Output of the biogas & desulfurization plant:
800 Nm^3 Biogas **$H_2S \leq 80$ mg/L**

Biogas feed (800 Nm^3, $H_2S \leq 80$ mg/L) is sent to the Steam Methane Reforming (SMR) unit to produce high purity green hydrogen.

FLOW PRODUCTION: FROM POME TO HYDROGEN

POME

Biogas Installation
(CSTR)

Desulfurization
(H_2S Removal)

CH_4

Biogas
(55% – 65% CH_4)

SMR
Steam Methane Reforming
(16 bar, 820 °C)

Pressure Swing Adsorption (PSA)
Hydrogen Purification

H_2

High Purity Hydrogen
(≥ 99% H_2, $H_2S \leq 0.8$ mg/L)

Delivered to Petrochemical Factory
(e.g. Stearic Acid Production)

STEAM METHANE REFORMING (SMR) PROCESS

STEP 1

STEAM METHANE REFORMING

$CH_4 + H_2O$ (steam) → $CO + 3H_2$

- CH_4 reacts with pressurized steam
- Pressure: 16 bar
- Temperature: 820 °C

510 Nm^3/hour Hydrogen

STEP 2

SHIFT CONVERSION REACTION

$CO + H_2O$ (steam) → $CO_2 + H_2$

- CO from the first process reacts again with steam
- Produces additional hydrogen

210 Nm^3/hour Hydrogen

KEY BENEFITS

- Reduce greenhouse gas emissions
- Utilize POME waste sustainably
- Produce high purity green hydrogen
- Support low carbon industry transition

TOWARDS NET ZERO EMISSION 2060

INDONESIA'S FIRST CO-FIRING AMMONIA PROJECT

AT LABUAN COAL-FIRED POWER PLANT (PLTU)

PLN, in collaboration with IHI Corporation and Pupuk Kujang, is developing Indonesia's first co-firing ammonia project at Labuan PLTU.

Photo: PLN

COFIRING HYDROGEN AND AMMONIA-BASED POWER PLANTS TO *ENHANCE DECARBONIZATION*

Driving Indonesia's Energy Transition with Cleaner, More Sustainable Power Generation

PLN | BRIN
BADAN RISET DAN INOVASI NASIONAL

	LABUAN, BANTEN	PESANGGARAN, BALI
	COAL FIRED POWER PLANT	GAS-DIESEL POWER PLANT
		
TOTAL CAPACITY	600 MW	299 MW
POWER PLANT TYPE	Coal Fired Power Plant	Gas-Diesel Power Plant
COFIRING SCHEME	3% for 8 hours	7% for 4 hours
SOURCE OF CO-FIRING	50 tons of Ammonia	90 kg of Hydrogen
ESTIMATED COST	500k USD	50k USD

KEY BENEFITS

- Reduces carbon emissions
- Supports Indonesia's energy transition
- Enhances energy security
- Promotes green investment
- Creates new jobs and opportunities

TOWARDS A CLEANER AND SUSTAINABLE ENERGY FUTURE

HYDROGEN-BASED POWER PLANTS TO REDUCE DIESEL ENGINE UTILIZATION IN MICROGRID

Clean Energy for Remote Areas, Stronger Communities, Sustainable Future

PLN | BRIN

	1 MEDANG, WEST NUSA TENGGARA	2 GILI KETAPANG, EAST JAVA	3 SUGE, BANGKA BELITONG	4 WAINGAPU, EAST NUSA TENGGARA
				
LOCATION				
INDICATIVE PROJECT COST	550k USD	625k USD	4,550k USD	85,000k USD
YEARLY ELECTRICITY FROM HYDROGEN	46 MWh	700 MWh	9,600 MWh	3,300 MWh
ELECTROLYZER CAPACITY	40 kW	3 x 45 kW (located on Gresik CCGT)	3,500 kW	4,000 kW
FUEL CELL CAPACITY	6 kW	100 kW	4,100 kW (distributed on 8 islands)	1,500 kW
PV CAPACITY	315 kWp	N/A	N/A	30,000 kWp

KEY BENEFITS

- Reduce diesel fuel use
- Lower emissions & cleaner air
- Strengthen energy independence
- Reliable electricity for remote communities
- Support sustainable development

POWERING A GREENER INDONESIA TOGETHER

REALIZATION OF *HYDROGEN REFUELLING STATION (HRS)*

#1 HRS SENAYAN

Senayan, Jakarta


Hydrogen Generator


Green Hydrogen Car Refuelling


Green Hydrogen EV Car Charging

- HRS Senayan by PLN has the capacity to serve around 438 tons of green hydrogen or 128.3 tons/year to fuel approximately 438 FCEV-based hydrogen cars every year.
- This can reduce fuel imports (RON-92) by 1.59 million liters/year and reduce CO_2 emissions by 4.15 million kg/year.
- HRS Senayan is also equipped with the *Hydrogen Centre* as the first hydrogen training center in Indonesia.

#2 HRS KARAWANG

Karawang, West Java

- HRS Toyota in Karawang is equipped with two pressure systems: 350 bar for forklift units and 700 bar for FCEV and Truck FC units.
- HRS Karawang is also equipped with xEV Centre facilities as a center for learning vehicle electrification technology in Indonesia.

#3 HRS DAAN MOGOT

Daan Mogot, Jakarta

- The Pertamina HRS at Daan Mogot is currently under construction.
- This will be Indonesia's first integrated commercial HRS, providing BBM, CNG, LPG, and hydrogen. With a fast refuelling concept, hydrogen refuelling is designed to take only 3–5 minutes at 700 bar pressure.

- Support the national hydrogen ecosystem
- Reduce CO_2 emissions and air pollution
- Support the energy transition towards Net Zero Emission 2060
- Drive innovation and education in hydrogen technology
- Strategic collaboration for a cleaner energy future


PLN mobile
PLN
H2
Hydrogen
Refueling Station
ZERO
carbon emission
STORAGE

HYDROGEN REFUELING STATION FACILITY

Powering Clean Mobility, Driving a Sustainable Future

Our Hydrogen Refueling Station (HRS) is designed to deliver safe, reliable, and efficient hydrogen fueling for a zero-emission future.

PLN Nusantara Power | IFHE Indonesia Fuel Cell Hydrogen Energy | BRIN

SAFE & RELIABLE
Built with advanced safety systems and continuous monitoring to ensure secure hydrogen fueling operations.

CLEAN & ZERO EMISSION
Enabling zero-emission mobility and supporting Indonesia's net-zero emission target.

ADVANCED TECHNOLOGY
High-pressure storage, precise dispensers, and smart control for efficient performance.

SUSTAINABLE SOLUTION
Supporting the transition to clean energy and strengthening the hydrogen ecosystem.

FACILITY OVERVIEW

Location
Jakarta, Indonesia

Hydrogen Pressure
350–700 bar

Dispensing Capacity
Up to 30 kg/day

Application
Fuel Cell Vehicles (FCV), Buses, Industrial Use

Compliance
International Safety Standards (ISO 19880, ISO 14687)


STATION OVERVIEW


HYDROGEN DISPENSER


HIGH-PRESSURE STORAGE


SAFE & SMART OPERATION

OUR COMMITMENT

- Promoting Hydrogen for a Cleaner and Better Future
- Driving Innovation and Local Capability Development
- Collaborating for a Strong and Sustainable Hydrogen Ecosystem
- Ensuring Safety, Quality, and Reliability in Every Operation

TODAY'S HYDROGEN, TOMORROW'S ENERGY.

ADVANCING HYDROGEN ENERGY

Innovative Solutions for a Sustainable Future

Clean Energy for a Better Future | Zero Emission Zero Compromise | Safe, Reliable and Sustainable

GREEN HYDROGEN ECOSYSTEM

HYDROGEN REFUELING STATION

PLN Hydrogen Refueling Station – Photo: ESDM

HYDROGEN FILLING STATION (HFS)

STRATEGIC COLLABORATION

H2 MOBILITY INNOVATION

BRIN
BADAN RISET DAN INOVASI NASIONAL

IFHE
Indonesia Fuel Cell Hydrogen Energy

PLN

- LOW CARBON SOLUTION
- CLEAN ENERGY TRANSITION
- STRONG COLLABORATION
- TOWARD NET ZERO EMISSION 2060

"Harnessing innovation and collaboration to build Indonesia's clean energy future."

H_2 Developing Hydrogen Ecosystem | Supporting Green Mobility | Innovative Technology for Sustainability | Committed to Net Zero Emission 2060

HYDROGEN REFUELLING STATION (HRS) DEVELOPMENT PLAN

TO SUPPORT TRANSPORT SECTOR TOWARDS PATIMBAN GREEN PORT

STRATEGIC HRS NETWORK

8 priority locations along the Jakarta – Karawang – Patimban corridor to support the hydrogen supply chain and clean mobility.

TRANSPORT SUPPORT

Supporting heavy-duty and hydrogen-powered buses for efficient logistics and lower emissions towards Green Port Patimban.

CLEAN & SUSTAINABLE ENERGY

Utilizing renewable energy sources to produce green hydrogen and support the national energy transition.

GREEN PORT INTEGRATION

Strengthening the hydrogen ecosystem from upstream to downstream to support clean port operations at Patimban.

KEY BENEFITS

- Reliable hydrogen supply chain
- Significant carbon emission reduction
- Support for Net Zero Emission 2060 target
- Driving green economy and job creation
- Strengthening Indonesia's energy security

DIESEL BUS CONVERSION TO *HYDROGEN* – *DIESEL DUAL FUEL (DDF) METHOD*

Towards Cleaner, More Efficient, and Sustainable Public Transportation

Through the DDF method, a diesel engine is converted to use a solar-hydrogen blend fuel consisting of **70% solar** fuel and **30% hydrogen**, without modifying the ***Internal Combustion Engine (ICE)*** structure.

Lower Emissions
Reduces CO_2, NOx, and particulate matter

Optimal Efficiency
Utilizes existing infrastructure and engines

Safe & Reliable
High-pressure gas storage design for maximum safety

Supports Energy Transition
A practical solution towards low-carbon transportation

CONVERSION PROCESS IMPLEMENTED WITHIN THE FOLLOWING SCOPE:

1. Diesel Engine Technology Analysis
2. Design & Placement of Gas Storage (Safety)
3. Conversion of Diseel Engine to Gas Engine
4. Performance Tuning and Energy Efficiency

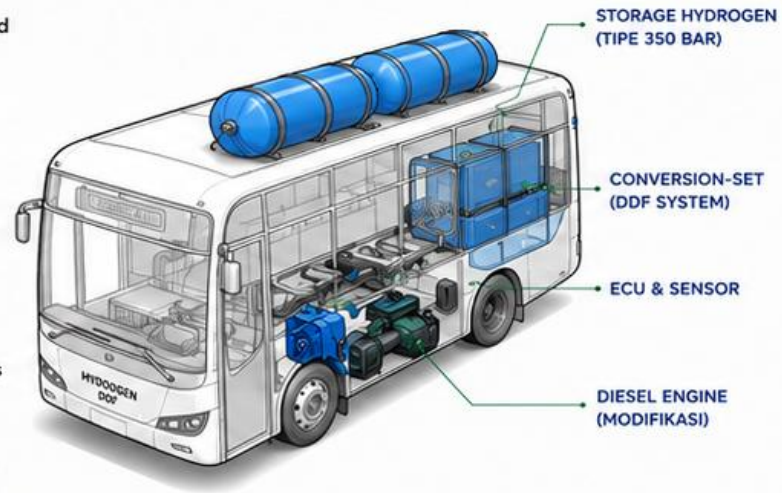
HYDROGEN BUS CONVERSION (DDF) DESIGN PLAN:

Hydrogen storage capacity is designed to enable the bus to operate up to **300 km/day** on a full tank.

Gas storage is placed at the bottom of the bus to maintain a low center of gravity and ensure structural safety.

The conversion-set design follows these principles:

- Fuel supply system via injectors for gas
- Solar fuel supply system (reduced)
- Fuel blending tuning via ECU
- Equipped with sensors for fuel control
- Performance achieved with clear energy efficiency



IDENTIFICATION RESULTS & RECOMMENDATIONS

A 12-meter large bus is recommended as the most suitable option because it provides more space for hydrogen storage (tank) and places the engine at the rear, making it more representative for important technology demonstrations and trials of hydrogen bus conversion.

- More optimal storage space
- Better weight distribution
- Higher safety standards
- More representative for demos & trials

STRATEGIC IMPACT

- Significant reduction in greenhouse gas emissions
- Reducing dependence on fossil fuels
- More optimal operational efficiency
- Encouraging green innovation & domestic industry
- Supporting Indonesia's Net Zero Emission 2060 target

DIESEL BUS CONVERSION TO HYDROGEN – DIESEL DUAL FUEL (DDF) METHOD

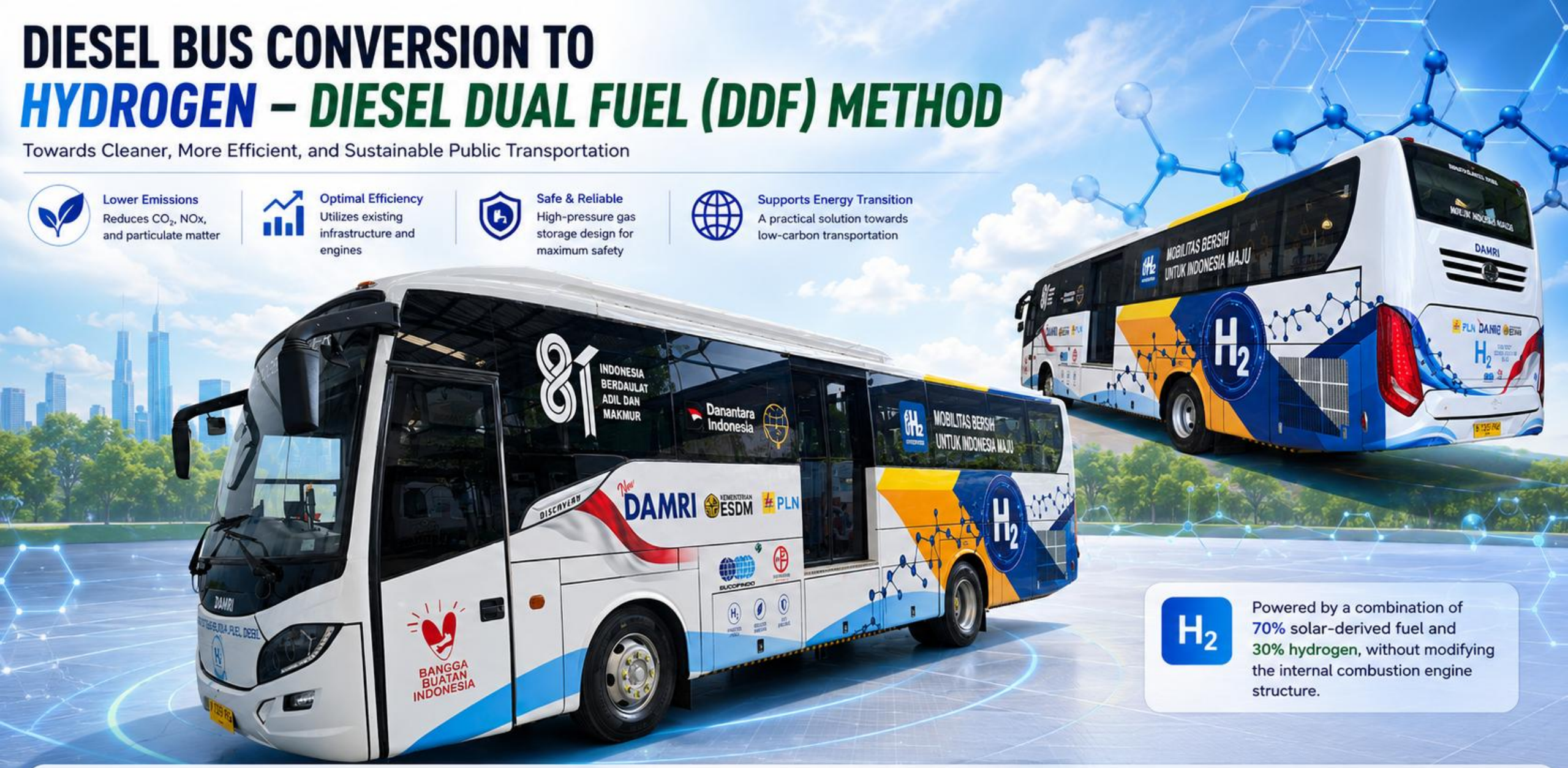
Towards Cleaner, More Efficient, and Sustainable Public Transportation

Lower Emissions
Reduces CO_2, NOx, and particulate matter

Optimal Efficiency
Utilizes existing infrastructure and engines

Safe & Reliable
High-pressure gas storage design for maximum safety

Supports Energy Transition
A practical solution towards low-carbon transportation



H_2 Powered by a combination of 70% solar-derived fuel and 30% hydrogen, without modifying the internal combustion engine structure.

- More optimal storage space
- Better weight distribution
- Higher safety standards
- More representative for demos & trials
- Significant reduction in greenhouse gas emissions
- Reducing dependence on fossil fuels
- Encouraging green innovation & domestic industry
- Supporting Indonesia's Net Zero Emission 2060 target

PEMFC, HYDROGEN PRODUCTION, AND HRS SYSTEM RESEARCH AT BRIN

IFHE Indonesia Fuel Cell Hydrogen Energy | BRIN Badan Riset dan Inovasi Nasional

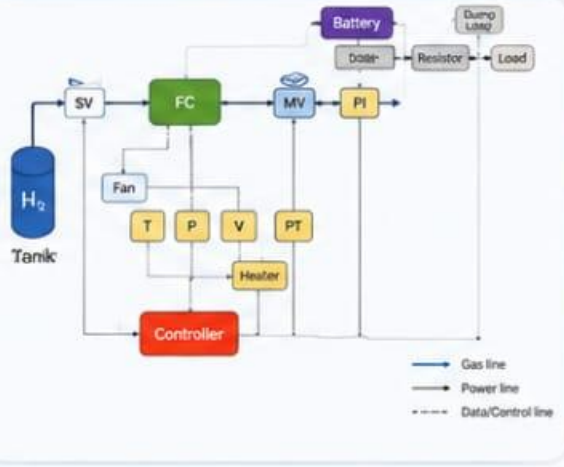
Innovating Clean Energy Solutions for a Sustainable Future

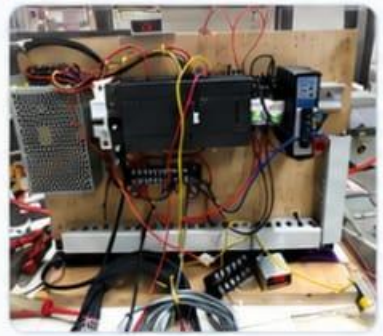
1 PEMFC VEHICLE DEVELOPMENT

1 kW PEMFC Fuel Cell Vehicle

2.5 kW PEMFC Fuel Cell Vehicle + 200 WP Photovoltaic

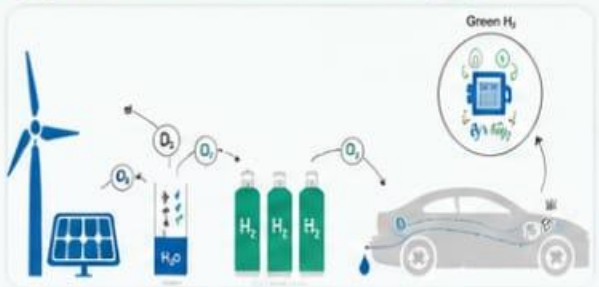
Fuel cell system will be developed for forklifts and other 4-wheeled vehicles.





Hydrogen Feeding Control on PEMFC

2 HYDROGEN PRODUCTION



Renewable Energy | Electrolysis | Green Hydrogen

Electrolysis-based Green Hydrogen Production

Mobile Hydrogen Storage & Delivery Unit

3 HYDROGEN REFUELING STATION (HRS) PROTOTYPE

OUR IMPACT

- Clean & Green Hydrogen Energy
- Sustainable Energy Solution
- Support for Green Industry & Mobility
- Strengthening National Innovation & Technology
- Collaboration for a Better Future

RESEARCH COLLABORATION

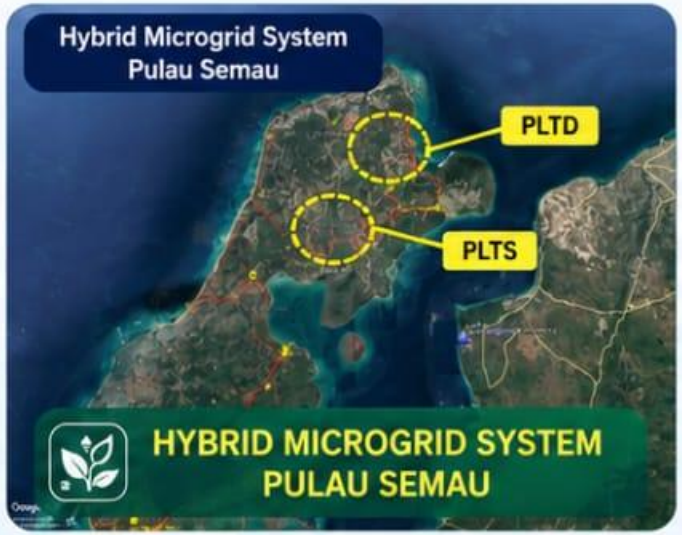
PLN HONDA The Power of Dreams IFHE Indonesia Fuel Cell Hydrogen Energy BRIN BADAN RISET DAN INOVASI NASIONAL

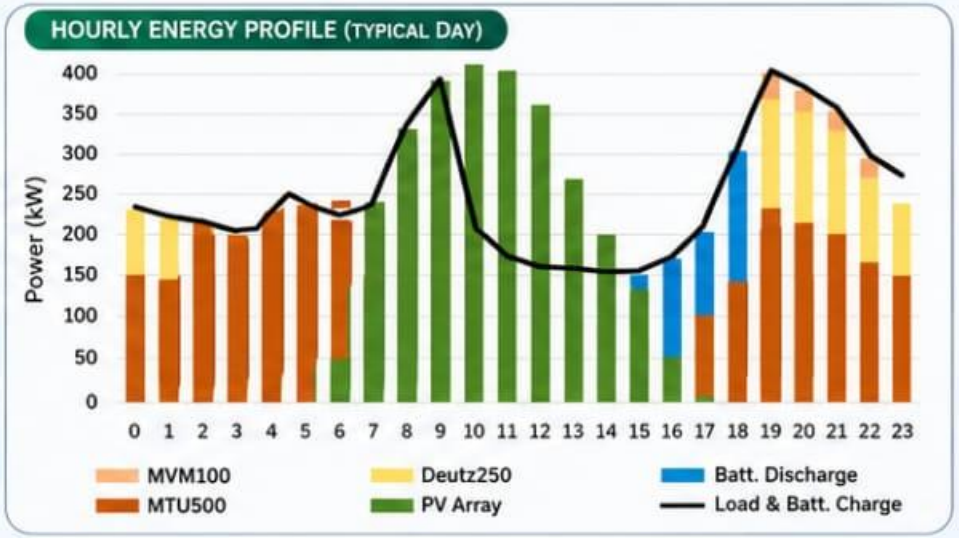
DE-DIESELIZATION PROGRAM; HYDROGEN

Collaborative research to develop a hybrid microgrid system using hydrogen fuel cell technology for clean and reliable energy in remote island communities.

80 kW PEMFC Honda

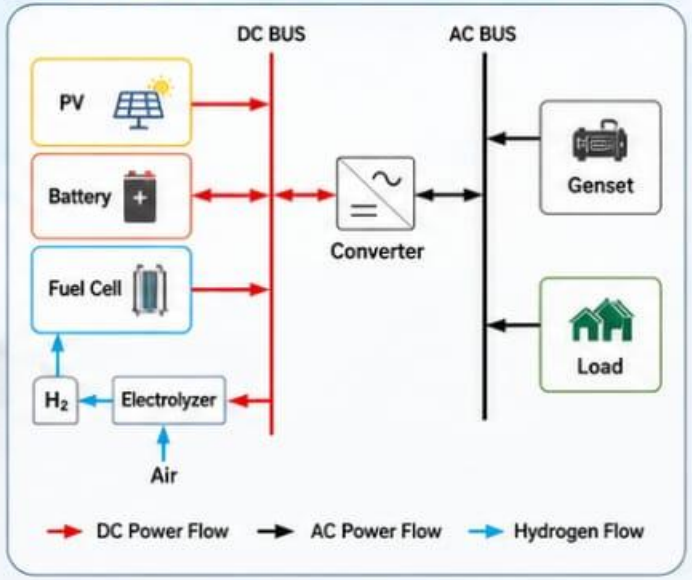
H_2

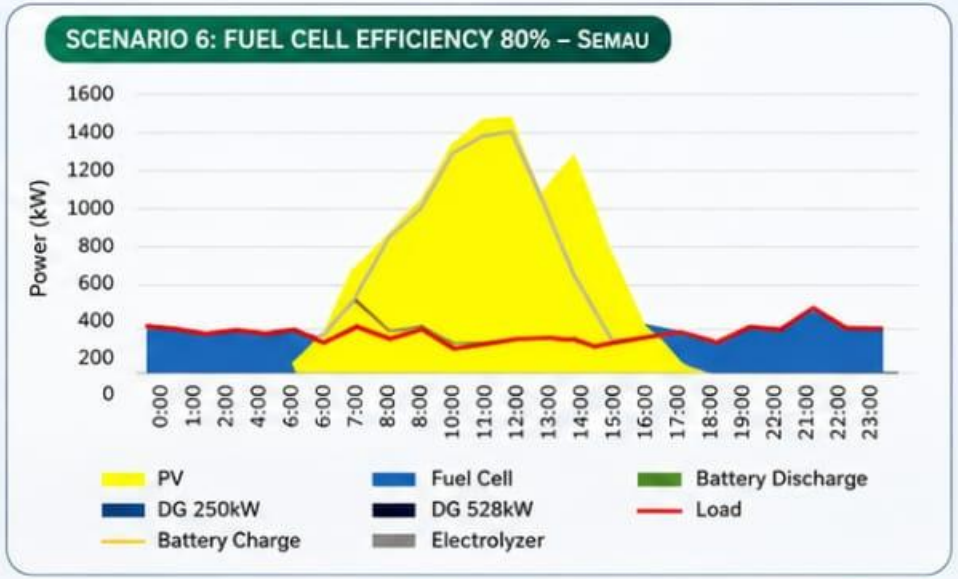




FIELD DEPLOYMENT TEAM

Strong Collaboration | Innovative Technology | Sustainable Impact





H_2 Hydrogen for Clean Energy

Reducing Diesel Dependency Lower Emissions

Reliable, Resilient Energy System

Empowering Remoto Communities for a Sustainable Future

HYDROGEN
AT SEMAKAU ISLAND

CLEAN • RENEWABLE • RELIABLE • RESILIENT

CLEAN ENERGY • SUSTAINABLE FUTURE

SEMAKAU ISLAND

91 kWh

LI-ION BATTERY BANK

High-performance lithium-ion battery storage.

DC GRID

Direct current power network from renewable sources and batteries.

BI-DIRECTIONAL INVERTER

Manages power flow between DC grids with [illegible] smart control.

AC GRID

Alternating current power network for distribution and utilization.

50 kWp PV BIFACIAL SOLAR ARRAY

High-efficiency bifacial solar panels for maximum energy harvest.

FUEL CELL
1 x 2.5 kW
INTELLIGENT ENERGY

Converts hydrogen into electricity with high efficiency and low emissions.

GRID TIE INVERTER

Synchronizes solar power with the grid for stable and efficient operation.

INVERTER DC/AC

Converts DC power to AC power for equipment and system usage.

H_2 STORAGE

Safe hydrogen storage system for energy supply.

ELECTROLYZER
2 x 2.4 kW ENAPTER

Produces green hydrogen from water using renewable electricity.

LOAD BANK

Provides controlled electrical load for testing and system stability.

H_2 Hydrogen for Clean Energy

Reducing Diesel Dependency Lower Emissions

Reliable, Resilient Energy System

Empowering Remoto Communities for a Sustainable Future

IN COOPERATION WITH
PT. CASCADIANT INDONESIA

Delivering Clean Energy Solutions Through Innovation and Collaboration

CASCADIANT
The Power Behind Your Network

IFHE
Indonesia Fuel Cell Hydrogen Energy

BRIN
BADAN RISET DAN INOVASI NASIONAL

CASCADIANT
The Power Behind Your Network

MANAGED SERVICES FUEL CELL

Reliable Power
Clean and stable power supply for critical infrastructure

Low Emission
Environmentally friendly energy solution

Integrated Solution
End-to-end solution from planning to implementation

Proven Collaboration
Strong partnership for sustainable impact

FIELD SURVEY & IMPLEMENTATION PROCESS

Site Survey & Access Preparation
Tekno Park Area, Sentul

Equipment Installation
Tekno Park Area, Sentul

Logistics & Equipment Transport
To Remote Site

Site Preparation & Civil Work
Tekno Park Area, Sentul

YOGYAKARTA

Type
Methanol PEM Fuel Cell

Capacity
5 kW

Application
For cooling buildings in the Baron Tekno Park area

Current System
Integrated with a 5 kW Photovoltaic System

JAKARTA

Type
Hydrogen PEM Fuel Cell

Capacity
5 kW

Application
As a backup power for servers in Gedung Tekno 3, Puspiptek Area, Serpong

OUR COMMITMENT

Clean Energy
Utilizing hydrogen fuel cell technology

Lower Emissions
Reducing carbon footprint for a greener environment

Reliable & Resilient
Providing stable power for critical applications

Stronger Together
Driving innovation and collaboration for Indonesia

Powering Indonesia with Clean Energy

GREEN HYDROGEN PLANT FACILITY

PLN · IFHE Indonesia Fuel Cell Hydrogen Energy · BRIN Badan Riset dan Inovasi Nasional

Innovating Today for a Clean, Sustainable Tomorrow

Our green hydrogen plant facility is designed to produce high-purity hydrogen through advanced and environmentally friendly technology.

OUR FACILITY HIGHLIGHTS

100% GREEN ENERGY
Powered by renewable electricity for zero-emission hydrogen production.

ADVANCED TECHNOLOGY
State-of-the-art electrolyzer system for efficient and high-purity hydrogen output.

SAFETY FIRST
Built with high safety standards and continuous monitoring systems.

COLLABORATION
A strong partnership between industry, research, and innovation institutions.

SUSTAINABLE IMPACT
Supporting Indonesia's energy transition and net-zero emission goals.

H_2 GENERATION SYSTEM

ELECTROLYZER STACK

OPERATION & TEAM

OUR MISSION

To deliver clean hydrogen solutions through innovation, collaboration, and operational excellence for a sustainable future.

- Clean Energy For a Better Planet
- Reliable Hydrogen For a Greener Future
- Stronger Together For Indonesia

BENEFITS OF GREEN HYDROGEN

ZERO EMISSION
No carbon emissions during production and use.

ENERGY SECURITY
Supports energy independence and diversification.

ECONOMIC VALUE
Creates new green jobs and drives sustainable economic growth.

ENVIRONMENTAL CARE
Reduces pollution and supports a cleaner environment.

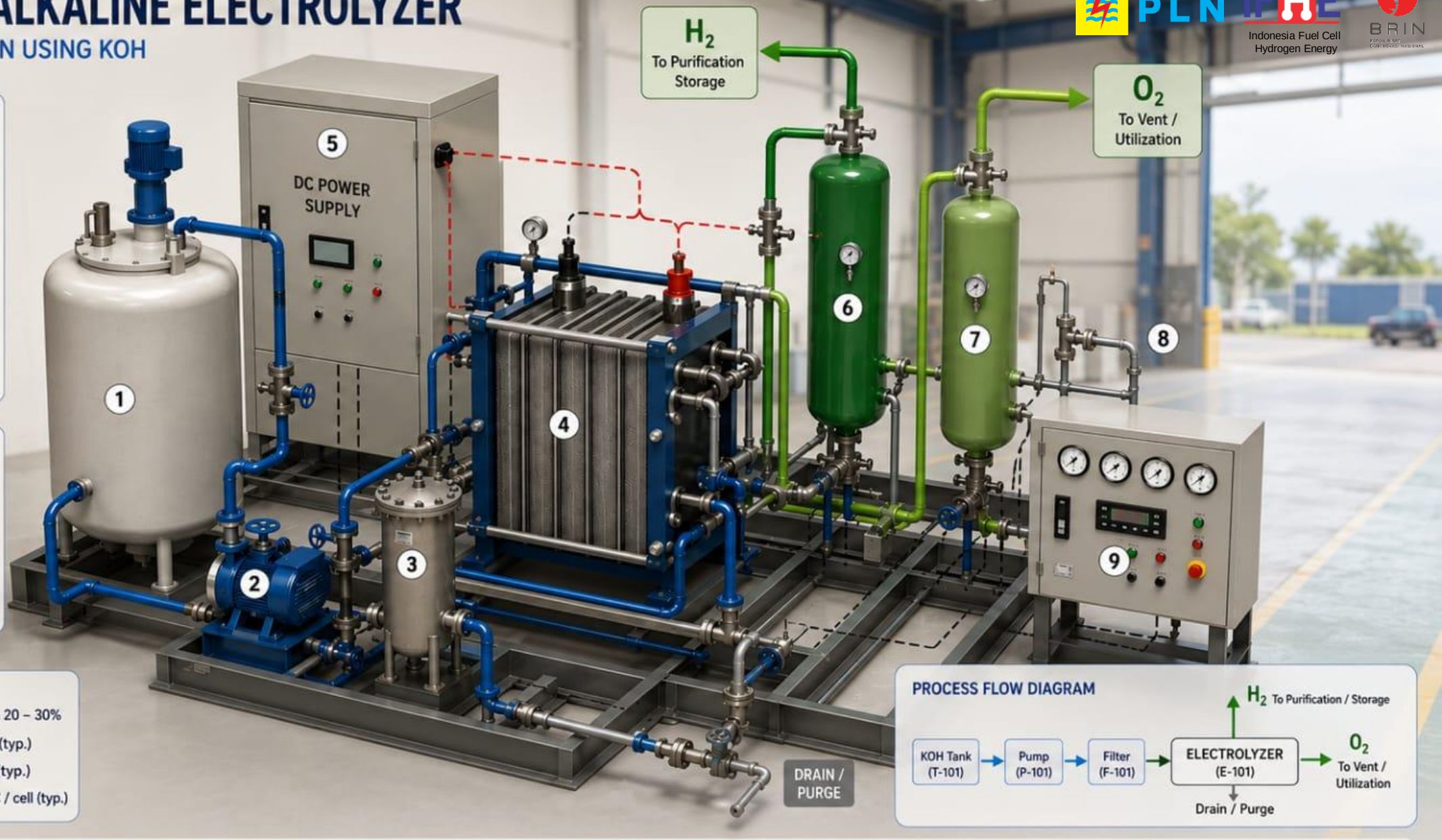
GLOBAL IMPACT
Contributes to global efforts against climate change.

3D SYSTEM – ALKALINE ELECTROLYZER

HYDROGEN PRODUCTION USING KOH

PLN IFHE Indonesia Fuel Cell Hydrogen Energy

BRIN



DESCRIPTION

1	T-101	KOH Solution Tank
2	P-101	Circulation Pump
3	F-101	Filter
4	E-101	Alkaline Electrolyzer
5	PS-101	DC Power Supply
6	H_2 Separator (Knock-out Pot)	
7	O_2 Separator (Knock-out Pot)	
8	Vent / O_2 Utilization	
9	Instrument Panel	
10	Piping & Valves	

PIPE COLOR LEGEND

- KOH Solution (Water + KOH)
- Hydrogen (H_2)
- Oxygen (O_2)
- Vent / Drain
- DC Power (Cable)
- Instrument / Signal

TYPICAL SPECIFICATIONS

- Electrolyte : KOH Solution 20 – 30%
- Operating Pressure : ±1 – 30 bar (typ.)
- Operating Temperature : 60 – 80 °C (typ.)
- Cell Voltage : 1.8 – 2.4 VDC / cell (typ.)

PROCESS FLOW DIAGRAM

SAFE & RELIABLE
Designed for maximum safety and reliability

ENVIRONMENTALLY FRIENDLY
Uses KOH that is non-toxic and highly efficient

HIGH EFFICIENCY
Stable performance with optimal energy consumption

HIGH PURITY HYDROGEN
Produces high purity hydrogen suitable for various applications

SCALABLE & MODULAR
Easily expandable to meet different capacity requirements

HYDROGEN PRODUCTION
BASED ON METAL HYDROLYSIS FACILITY

Innovative Technology. Clean Hydrogen. Sustainable Future.

PLN IFHE Indonesia Fuel Cell Hydrogen Energy BRIN BADAN RISET DAN INOVASI NASIONAL

Our metal hydrolysis facility produces high-purity hydrogen through a safe, efficient, and environmentally friendly chemical reaction process.

CLEAN HYDROGEN PRODUCTION
Metal hydrolysis reaction generates high-purity hydrogen with zero carbon emissions.

SAFE & RELIABLE OPERATION
Advanced control system ensures safe operation, continuous monitoring, and high process stability.

SUSTAINABLE TECHNOLOGY
Utilizes eco-friendly materials and produces minimal by-products for a greener future.

MODULAR & SCALABLE DESIGN
Flexible and modular system for easy scale-up and integration with various applications.

HOW METAL HYDROLYSIS WORKS

Metal + Water
Reactants are introduced into the reactor.

Hydrogen Generation
Chemical reaction produces hydrogen gas and by-products.

Gas Separation & Purification
Hydrogen is separated and purified to achieve high purity.

High-Purity Hydrogen
Clean hydrogen is ready for storage and various applications.

KEY SPECIFICATIONS

Hydrogen Purity	: 99.9%
Hydrogen Production	: Up to 30 Nm^3/h*
Operating Pressure	: Up to 10 bar
Operating Temperature	: Ambient – 80°C
Feedstock	: Metal (e.g., Aluminum, Zinc) + Water

*Capacity can be customized based on requirement

SUPPORTING A CLEAN ENERGY ECOSYSTEM

- Industrial Applications
- Fuel Cell Mobility
- Power Generation
- Towards Net Zero Emissions

Powering the Future with Innovation and Sustainability

CLEAN HYDROGEN FOR A BETTER TOMORROW

PROTOTYPE HYDROGEN STORAGE STATION TEST

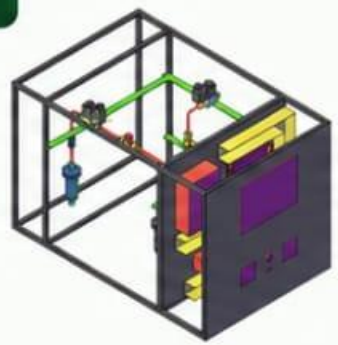
Based on Solid Material

Innovating Safe, Efficient, and Compact Hydrogen Storage Solutions

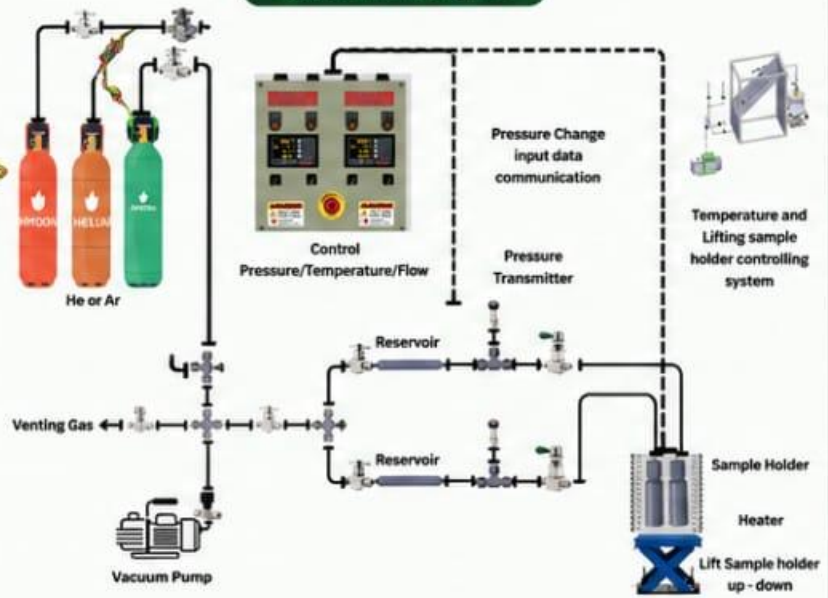
PLN IFHE Indonesia Fuel Cell Hydrogen Energy BRIN BADAN RISET DAN INOVASI NASIONAL

SOLID HYDROGEN STORAGE (CARBON-BASED)

Prototype Sievert System



System Flow Diagram



- Carbon-based solid material for safe and reversible hydrogen storage
- Integrated control system for pressure, temperature, and flow monitoring
- Designed for research on adsorption kinetics, capacity, and cycling performance

SOLID HYDROGEN STORAGE ($NaBH_4$-BASED)

$NaBH_4$ Prototype Test Unit

- $NaBH_4$ as chemical hydrogen storage material
- Hydrolysis reaction test and performance evaluation
- Safe, compact, and efficient hydrogen release system

OUR RESEARCH FOCUS & IMPACT

- Clean & Green Hydrogen Energy
- Advanced Solid Storage Technology
- Enhanced Safety and Reliability
- Scalable & Modular Prototype Design
- Supporting Indonesia's Hydrogen Ecosystem

COMPLETE 3D REACTOR SYSTEM DESIGN

CAPILLARY-FLOW AEM ELECTROCHEMICAL AMMONIA CRACKING REACTOR

for On-Demand High-Purity Hydrogen Production (Target TKT 5)

PLN

BRIN
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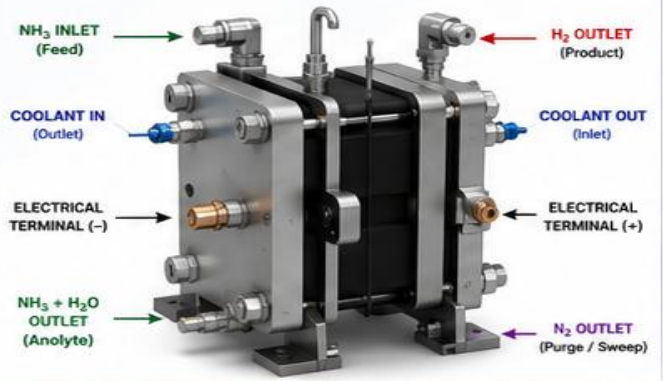
1 SINGLE CELL REACTOR – 3D OVERVIEW



SINGLE CELL SPECIFICATIONS

Active Area (cm^2)	100 cm^2 (100 mm × 100 mm)
Cell Voltage	1.6 – 2.2 V
Operating Temp.	30 – 80 °C
Operating Pressure	1 – 5 bar (Feed In) / 1 – 3 bar (Cathode)
NH_3 Feed Conc.	1 – 5 M NH_3 (Aqueous)
Target H_2 Purity	≥ 99.99% (Dry Basis)
Materials (Wet Part)	SS 316, GR PTFE, PEEK, PPE, EPDM, FKM

KEY FEATURES

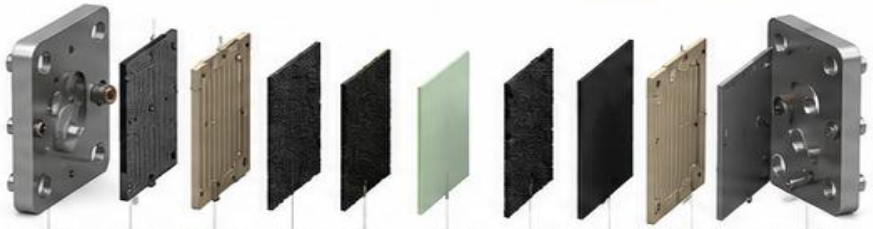
- ✓ Capillary-flow field for efficient mass transport
- ✓ AEM (Anion Exchange Membrane) electrochemical technology
- ✓ Optimal product channels (0.3 – 0.5 mm)
- ✓ Modular & scalable stackable design
- ✓ Precise ammonia distribution

2 EXPLODED VIEW – SINGLE CELL

ANODE (AOR): $NH_3 + 2OH^- \rightarrow 0.5N_2 + 1.5H_2O + 3e^-$

OH^-

CATHODE (HER): $3H_2O + 3e^- \rightarrow 1.5H_2 + 3OH^-$

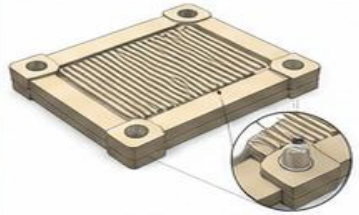


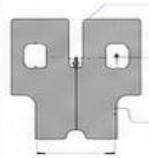
Metal / Current Collector | Flow Field (Capillary) | Gas Diffusion Layer (GDL) | Catalyst Layer | AEM Membrane

MATERIALS & COMPONENTS

End Plate	SS 316L	AEM Membrane	Commercial AEM (Sustainion® / PiperION®)
Flow Field (Capillary)	Graphite / PPS / SS 316L	Electrode (Anode)	Ni-based AOR Catalyst
Current Collector	Titanium (Ti)	Electrode (Cathode)	PtMo-based HER Catalyst
		Gasket	EPDM / FKM
		Carbon Paper / PTFE	Carbon Paper / PTFE

DETAIL FLOW FIELD – CAPILLARY TYPE





Capillary Channel (Width 0.3 – 0.5 mm)

Rib (Spacing 0.3 – 0.5 mm)

Depth (0.3 – 0.5 mm)

Uniform Feed Distribution for Optimal Ammonia Management

3 3D CAD ASSEMBLY – SINGLE CELL

MANIFOLD & PORT DESIGN

TOP VIEW (Port Layout)

SIDE VIEW (Port Layout)

- NH_3 Inlet
- H_2 Outlet
- Coolant Out
- $NH_3 + H_2O$ Outlet
- N_2 Outlet (Purge)
- Coolant Out

4 STACK ASSEMBLY – 3D (5-CELL EXAMPLE)

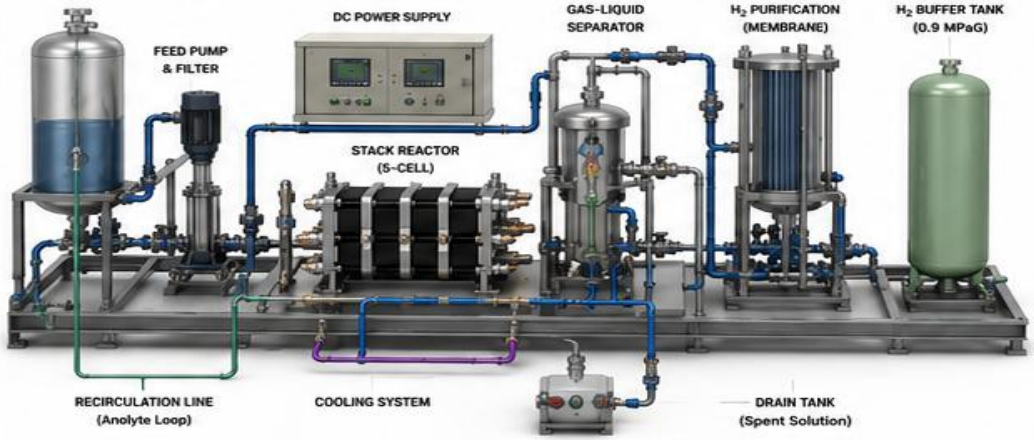
STACK SPECIFICATIONS (Example 5 Cells)

Number of Cells	5
Active Area per Cell	100 cm^2
Total Active Area	500 cm^2
Operating Current	0 – 50 A
H_2 Production (est.)	1 – 5 Nm^3/h (per stack)
Stack Voltage	8 – 11 V
Dimension (L×W×H)	450 × 240 × 280 mm
Weight (est.)	≈ 25 – 30 kg

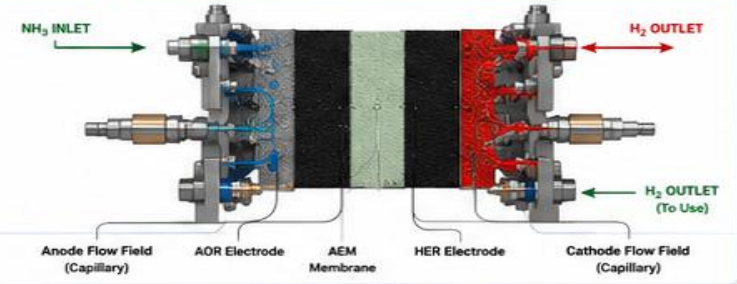
STACK FEATURES

- Modular & scalable
- Parallel flow distribution
- Uniform compression
- Integrated coolant channels
- Electrical isolation by gasket

5. REACTOR SYSTEM INTEGRATION – 3D SKID



6 SYSTEM SECTION VIEW – 3D (CUT VIEW)



KEY DESIGN CONSIDERATIONS

- Material corrosion resistance (NH_3, OH^-)
- Optimal catalyst & electrode performance
- Uniform feed distribution & transport management
- Optimal product channel (0.3 – 0.5 mm)
- Advanced electrode & membrane interface
- Stable cell sealing (wet – stack – system model)

HIGH EFFICIENCY
Capillary-flow design for better mass transport and energy efficiency

MODULAR & SCALABLE
Stackable architecture for flexible capacity and easy maintenance

HIGH PURITY HYDROGEN
Designed for ≥ 99.99% H_2 purity (dry basis)

INTEGRATED SKID SYSTEM
Compact, fully integrated skid for on-demand hydrogen production

SUSTAINABLE SOLUTION
Supports low-carbon energy transition and green hydrogen initiatives

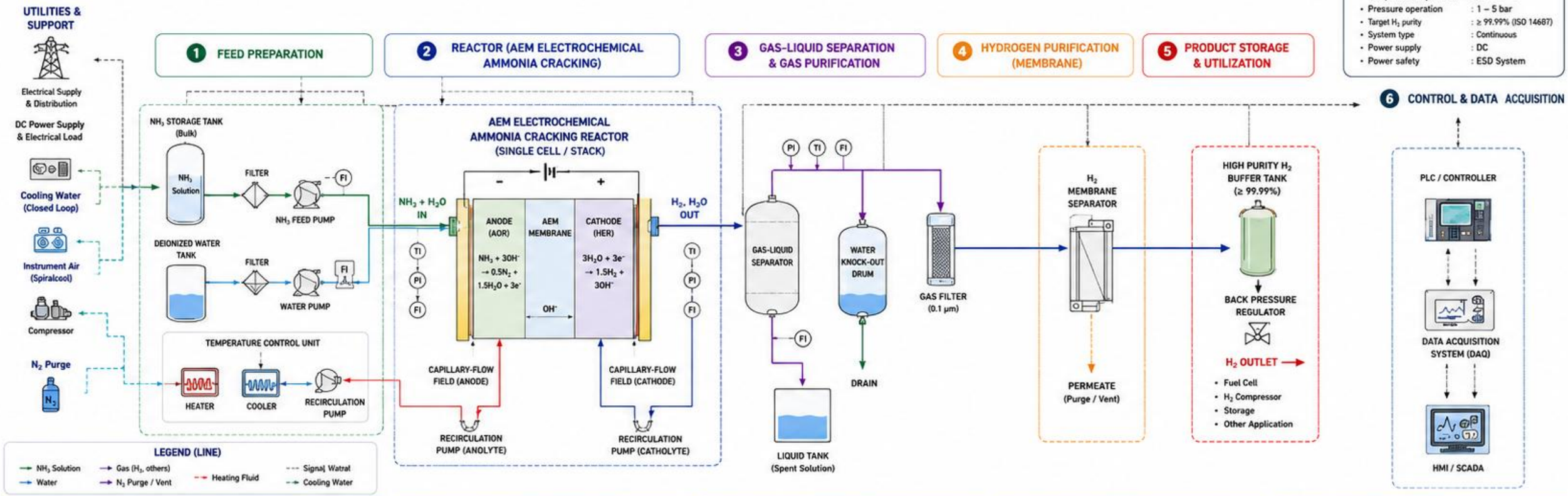
Research Center for Energy Conversion Technology

COMPLETE 2D SYSTEM DESIGN – CAPILLARY-FLOW AEM ELECTROCHEMICAL AMMONIA CRACKING SYSTEM

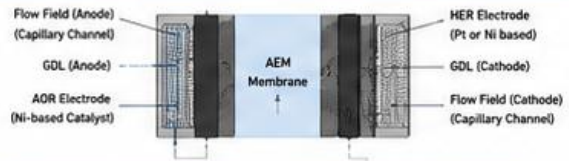
for On-Demand High-Purity Hydrogen Production (Target TKT 5)

DESIGN BASIS

- NH_3 feed concentration : 1 – 5 M
- Temperature operation : 30 – 80 °C
- Pressure operation : 1 – 5 bar
- Target H_2 purity : ≥ 99.99% (ISO 14687)
- System type : Continuous
- Power supply : DC
- Power safety : ESD System



DETAIL SINGLE CELL (AEM AMMONIA CRACKING)



ANODE (AOR)

$NH_3 + 3OH^- \rightarrow 0.5N_2 + 1.5H_2O + 3e^-$

CATHODE (HER)

$3H_2O + 3e^- \rightarrow 1.5H_2 + 3OH^-$

INSTRUMENTATION LIST (UTAMA)

TAG	DESCRIPTION	LOCATION	QTY
TI	Temperature Indicator	Feed, Reactor In/Out, Separator	6+
PI	Pressure Indicator	Feed, Reactor In/Out, Seperator, Drum	6+
FI	Flow Indicator	Gas, Liquid	4+
LI	Level Indicator	Liquid Tank, Drum, Tank, Storage Tank	3+
pH	pH Indicator (Optional)	Anolyte Outlet	1
MFC	Mass Flow Controller	NH_3 Feed, H_2O Feed	2
PSV	Pressure Safety Valve	Reactor, Separator, Storage Tank	3+
Conductivity	Conductivity Indicator	DI Water, Solution Circuit	2

SYSTEM SPECIFICATIONS (MAIN)

ITEM	SPECIFICATION
Reactor Type	AEM Electrochemical (Single Cell/Stack)
Active Area (per cell)	100 cm^2 (10 cm x 10 cm)
Cell Voltage	1.6 – 2.2 V
Current Density	0.1 – 2.0 A/cm^2
H_2 Purity (Product)	≥ 99.99%
H_2 Production Rate	1 – 5 Nm^3/h (per stack)
NH_3 Feed Concentration	1 – 5 M NH_3
Operating Temperature	30 – 80 °C
Operating Pressure	1 – 5 bar
System Availability	≥ 95%

SYSTEM ADVANTAGES

- Capillary-flow field for uniform distribution
- High NH_3 conversion with double membrane (optional)
- High energy efficiency and low operating temperature
- Low pressure operation
- Modular & scalable design
- Low NH_3 slip & high product purity
- Integrated safety & control system
- Low maintenance & easy operation
- ESD system & emergency shutdown

SAFETY FEATURES (FOCUS)

- NH_3 detector (area feed & vent)
- Pressure relief safety system
- Emergency shutdown (ESD)
- Hydrogen leak detection
- Electrical protection (grounding, MCB)
- High pressure protection
- Temperature monitoring & alarm
- Last vent & SOP operation

Note: This design is based on simulation, basic experiment, and laboratory data. Final design will be adjusted based on pilot testing and scale-up.

Research Center for Energy Conversion Technology

HYDROGEN OUTREACH
DRIVING A CLEANER FUTURE TOGETHER

Education • Innovation • Collaboration • Real Action

PLN IFHE Indonesia Fuel Cell Hydrogen Energy BRIN BADAN RISET DAN INOVASI NASIONAL

We bring hydrogen knowledge, technologies, and solutions closer to communities through engaging, inspiring, and impactful activities.

EDUCATION
Enhancing public understanding of hydrogen's potential and benefits for a cleaner future.

INNOVATION
Introducing safe, efficient, and environmentally friendly fuel cell and hydrogen technologies.

COLLABORATION
Partnering with strategic stakeholders to accelerate the development of Indonesia's hydrogen ecosystem.

REAL ACTION
Building awareness and encouraging collective action for a sustainable and low-carbon future.

OUR OUTREACH ACTIVITIES

Talkshow & Sharing Session


Hydrogen Technology Exhibition


Fuel Cell Technology Demo


Clean Energy Fun Walk & Campaign

> *"Through outreach, we build awareness today for a cleaner, safer, and more sustainable tomorrow."*

THE IMPACT

- Improving public literacy and awareness about hydrogen.
- Supporting the transition to clean energy and net zero emissions.
- Driving innovation and national hydrogen technology development.
- Strengthening multi-stakeholder collaboration for a resilient hydrogen ecosystem.
- Creating a cleaner, safer, and more sustainable future for Indonesia.

FUTURE JOINT RD&D OPPORTUNITY

Indonesia Biomethane-to-Hydrogen Platform

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INDONESIA
Hydrogen Economy

Microwave-Assisted Methane Pyrolysis (MMP)

A Strategic Pathway toward ASEAN Hydrogen Economy

We invite partners to collaborate on developing and demonstrating MMP technology to produce clean hydrogen and high-value solid carbon from Indonesia's biomethane, accelerating a scalable, low-carbon, and circular hydrogen ecosystem.

PROPOSED TECHNOLOGY

KEY ADVANTAGES

- No direct CO_2 emissions
- High energy efficiency
- Scalable & modular
- Dual benefits: clean H_2 and valuable carbon
- Suitable for decentralized and industrial applications

COLLABORATION FOCUS

- Advanced Reactor Design & Scale-up
- Catalyst & Additive Development
- Process Integration & System Optimization
- Characterization & Performance Evaluation
- Techno-Economic Analysis & Business Model
- Policy, Standardization & Market Development

EXPECTED OUTCOMES

- Scalable low-carbon hydrogen production technology
- High-value solid carbon for industrial applications
- Reduced carbon footprint for hard-to-abate sectors
- New green industry and job creation
- Stronger regional collaboration and technology leadership

POTENTIAL PARTNERS

- **Research Institutions** (Universities & R&D Centers)
- **Technology Providers** (Reactor, Microwave, Catalyst, Materials)
- **Industrial Partners** (Energy, Steel, Cement, Chemicals, Refineries)
- **Government & Policy Makers** (Energy, Environment, Standardization Bodies)
- **Investors & Development Partners**

INVITATION TO COLLABORATE

Let's co-create the future of hydrogen in ASEAN.

Together, we can transform Indonesia's biomethane into clean hydrogen and valuable carbon—driving innovation, sustainability, and shared prosperity.

BRIN: Connecting Indonesia to the World, Building the Hydrogen Future Together

SUSTAINABLE | INNOVATIVE | COLLABORATIVE | IMPACTFUL

BACKGROUND & STRATEGIC OPPORTUNITY

Building a Sustainable Hydrogen Ecosystem for Indonesia's Remote Areas

BRIN
BADAN RISET DAN INOVASI NASIONAL

H_2 INDONESIA
Hydrogen Economy

RELEVANT SDGs

7 AFFORDABLE AND CLEAN ENERGY
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
13 CLIMATE ACTION
17 PARTNERSHIPS FOR THE GOALS

1. CHALLENGE: REMOTE AREA ENERGY GAP

More than **3,400 villages** in Indonesia still face limited or unreliable electricity supply.

Dependence on diesel leads to **high cost, logistic difficulty,** and **carbon emissions.**

Indonesia's energy sector contributes **~40%** of total national emissions.

Reliable, affordable, and clean energy is essential to ensure inclusive development for remote communities.

2. OPPORTUNITY: ABUNDANT BIOMASS POTENTIAL

Indonesia has enormous biomass resources from agricultural residues, animal waste, and organic waste.

ESTIMATED BIOMASS POTENTIAL
(Million ton/year)

Total potential **> 200 million ton/year** sufficient to support green hydrogen production at national scale.

3. STRATEGIC OPPORTUNITY: HYDROGEN SOLUTION

Green hydrogen offers a clean, flexible, and locally producible energy carrier.

- Enables **energy independence** for remote and off-grid areas.
- Converts local biomass into **high-purity** hydrogen for clean energy.
- **Reduces greenhouse gas emissions** and supports Indonesia's net-zero commitment.
- Creates new **green economy** value chains and local job opportunities.

4. HYDROGEN ECONOMY OPPORTUNITY

LOCAL BIOMASS RESOURCES
Agricultural residues, animal waste, organic waste

→

WASTE-TO-HYDROGEN CONVERSION
Gasification / Reforming + Green Hydrogen Production

→

GREEN HYDROGEN PRODUCTION
Clean, reliable, and storable energy carrier

→

MULTI-SECTOR APPLICATION
Power Generation, Industry, Transportation, Maritime, Remote Communities

BRIN: Connecting Indonesia to the World, Building the Hydrogen Future Together

SUSTAINABLE | INNOVATIVE | COLLABORATIVE | IMPACTFUL

WHY METHANE PYROLYSIS (MP)?

Key Insights and Opportunities

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

LOW CARBON SOLUTION | DUAL PRODUCT VALUE | RESOURCE EFFICIENCY | MODULAR & SCALABLE | STRATEGIC FOR INDONESIA

CARBON PRODUCT REVENUE

MP's major advantage is the opportunity to generate carbon product revenue to offset the cost of hydrogen.

COST COMPETITIVE

Cost competitive with SMR with CCS at a carbon product price over $250 per ton of carbon products.

LOW EMISSIONS

MP offers the best emissions profile and resource requirements. Lower lifecycle emissions vs SMR w/ CCS, consumes less electricity than electrolysis, and less water than SMR and electrolysis.

RAMPABLE & SCALABLE WITH RENEWABLES

Using microwaves, H_2 can be generated immediately with no heat up/ramp up times, allowing it to scale with intermittent renewable energy.

MODULARITY

Compact MP reactors capable of producing ~1 ton H_2/day. Designed for modular deployment; scale production by adding more reactors as demand grows.

LEVERAGING EXISTING INFRASTRUCTURE

Can utilize existing natural gas infrastructure and generate diverse revenue streams (H_2 + carbon).

ENERGY EFFICIENT

MP is less energy intensive than current methods, even renewable hydrogen.

METHANE AWAY

Redirects methane from the atmosphere and incentivizes its capture from oil & gas sites, livestock farms, and landfills polluting gas into a useful hydrogen fuel.

LOCATED ANYWHERE

Requires only a natural gas (biomethane) hookup of sufficient capacity. Suitable for distributed production near the source.

LESS WATER CONSUMPTION

MP requires only water for cooling. Microwave reactors are designed with lower demands integrating closed-loop cooling systems.

METHANE PYROLYSIS REACTION

$$CH_4 \longrightarrow C_{(s)} + 2\,H_2$$

Methane → Solid Carbon + Hydrogen

No CO_2 is produced during the process.

TECHNOLOGY OPTIONS FOR MP

- Thermal Pyrolysis
- Molten Metal Pyrolysis
- Microwave-Assisted Pyrolysis
- Plasma Pyrolysis
- Entrained Flow / Drop Tube Reactor

Microwave-assisted MP is gaining strong interest due to fast start-up, energy efficiency, modularity, and compatibility with renewable energy.

KEY TAKEAWAYS

- MP provides a low-carbon, cost-competitive pathway for clean H_2.
- Produces high-value solid carbon as co-product, creating additional revenue.
- High flexibility, modularity, and low water requirement enable distributed deployment.
- Well aligned with BRIN roadmap toward hydrogen economy and Net Zero 2060.

Methane pyrolysis transforms biomethane into clean hydrogen and valuable solid carbon without CO_2 emission, offering a scalable, efficient, and economically attractive pathway toward a hydrogen economy.

IDEAL FEEDSTOCK

Biomethane (>97% CH_4) from landfill-based biogas upgrading

TECHNOLOGY OVERVIEW & TRL STATUS

Where We Are Today

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

INNOVATIVE TECHNOLOGY | SCALABLE SOLUTION | LOW CARBON IMPACT | ENERGY SECURITY | SUPPORTS NET ZERO 2060

METHANE PYROLYSIS REACTION

CH_4 (Methane) $\longrightarrow$ C (s) (Solid Carbon) + $2\ H_2$ (Hydrogen)

No CO_2 is produced during the process.

TECHNOLOGY OPTIONS FOR METHANE PYROLYSIS

Thermal Pyrolysis
Conventional heating using external heat sources.

Molten Metal Pyrolysis
Uses molten metals to transfer heat efficiently for high conversion.

Microwave-Assisted Pyrolysis
Microwave energy for rapid, selective, and efficient methane decomposition.

Plasma Pyrolysis
High-temperature plasma for fast decomposition and high carbon quality.

Entrained Flow / Drop Tube Reactor
Feedstock moves through hot zone for very fast reactions.

Microwave-assisted MP is gaining strong interest due to fast start-up, energy efficiency, modularity, and compatibility with renewable energy.

TRL (TECHNOLOGY READINESS LEVEL)

SMR (Steam Methane Reforming)	9
SMR + CCS	8 – 9
PEM Electrolysis	8 – 9
SOEC (Solid Oxide Electrolysis)	6 – 8
Thermal Methane Pyrolysis	5 – 7
Molten Metal Pyrolysis	5 – 6
Microwave Methane Pyrolysis	4 – 6
Plasma Methane Pyrolysis	4 – 6

Methane pyrolysis technologies are advancing rapidly. MP is approaching demonstration and early commercial stages.

TRL EXPLANATION

9	Commercially proven (Operating plants)
7 – 8	Demonstration scale (Pre-commercial)
4 – 6	Pilot / Pre-commercial (Technology validation)
< 4	Lab scale / Early research (Concept validation)

COMPARISON WITH OTHER HYDROGEN PATHWAYS

Pathway	CO_2 Emission (Direct)	Energy Intensity	Water Requirement	Maturity	Scalability	Cost Potential
SMR	High	High	High	★★★★★	★★★★☆	★★★☆☆
SMR + CCS	Medium	High	High	★★★★☆	★★★★☆	★★★☆☆
Electrolysis (PEM)	Zero	High	High	★★★★☆	★★★★☆	★★★☆☆
Methane Pyrolysis (MP)	Zero	Low – Medium	Low	★★★☆☆	★★★★☆	★★★★☆

MP offers the potential for zero direct CO_2 emissions, lower energy and water requirements, and valuable solid carbon co-product—positioning it as a future cornerstone technology for clean hydrogen production.

ZERO DIRECT CO_2
No CO_2 formed during the pyrolysis process.

LOWER RESOURCES
Less electricity and water compared to other routes.

DUAL VALUE
Produces clean H_2 and high-value solid carbon.

METHANE PYROLYSIS (MP) IN THE BRIN ROADMAP

From Landfill Leachate to Clean Hydrogen Economy

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

Turning waste into clean energy, clean hydrogen, and high value carbon for a sustainable future.

CLEAN ENERGY NET ZERO | HYDROGEN ECONOMY | BRIN INNOVATION ECOSYSTEM | GLOBAL PARTNERSHIP OPPORTUNITY

LANDFILL LEACHATE

Leachate Generation

UASB ANAEROBIC DIGESTION

High-rate Anaerobic Treatment

BIOGAS PRODUCTION

Biogas (55–65% CH_4)

BIOGAS UPGRADING

Biomethane (>97% CH_4)

METHANE PYROLYSIS (MP)

H_2 + Solid Carbon
(No CO_2 Emission from Process)

HYDROGEN (H_2)

Clean Hydrogen (>99.9%)

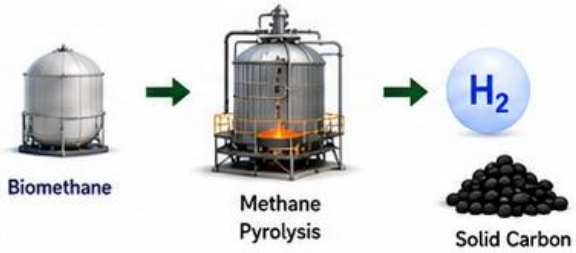
FUEL CELL APPLICATION

Clean Power & Heat (Electricity, Heat, Mobility)

CONVENTIONAL ROUTE (SMR)

CO_2 Handling / CCS Required

METHANE PYROLYSIS ROUTE (MP)



No CO_2 Emission from Process

KEY ADVANTAGES OF MP FOR BRIN ROADMAP

- Produces H_2 and valuable solid carbon
- No direct CO_2 emission
- Low water requirement
- Suitable for modular and distributed system
- Supports carbon negative pathway from landfill
- Multiple revenue stream: H_2 + carbon products
- Energy security and independence
- Cost competitive with carbon product revenue

Methane pyrolysis (MP) converts biomethane into clean hydrogen and high-value solid carbon without CO_2 emissions, creating a dual-product, low-carbon pathway aligned with BRIN's vision for a sustainable hydrogen economy.

CARBON BLACK AS SYNTHETIC FEEDSTOCK

High-Value By-product from Biogas Landfill via Methane Pyrolysis

Converting landfill biogas into clean hydrogen, high-value carbon black, and industrial heat with negative CO_2 emissions.

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

MAIN REACTION (METHANE PYROLYSIS)

$$CH_4 \rightarrow C\,(s) + 2H_2$$

ΔH° = +75 kJ/mol (endothermic)

NEGATIVE CARBON CONCEPT

Bio-CO_2 in landfill biogas ≈ Net Zero / Negative with carbon credit from solid carbon (C)

MARKET POTENTIAL

- Out of 4 kg Methane, Methane Pyrolysis generates 1 kg H_2 and 3 kg Carbon black.
- H_2 used for heat and power with zero emission.
- Carbon Black used as feedstock in several industries.
- Negative CO_2 emissions result from: Biomethane pyrolysis, and Carbon Black used to replace or supplement plastics, building materials, etc.
- **Price:** approx. 250–450 €/t

FROM LANDFILL BIOGAS TO CARBON BLACK

Landfill Biogas (Biomethane)
CH_4 55 vol%
(1 Nm³ basis)

Methane Pyrolysis
$CH_4 \rightarrow C + 2H_2$

Hydrogen
1 kg
(≈ 33% of CH_4)

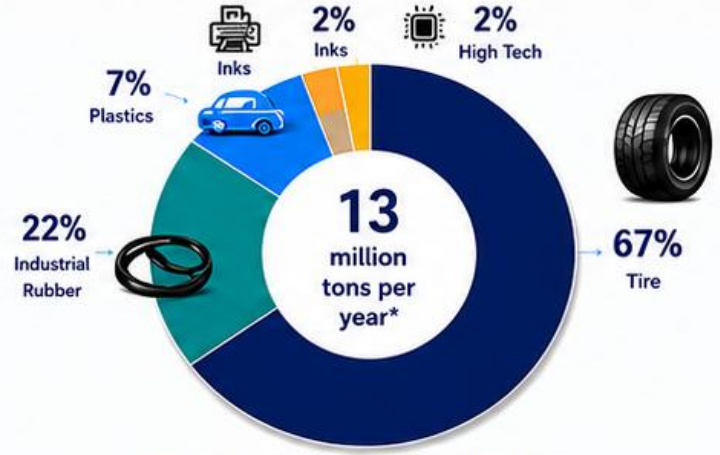
Carbon Black
3 kg
(≈ 67% of CH_4)

Typical Composition (vol%)	
CH_4	50 – 65
CO_2	30 – 45
H_2S	100 – 2,000 ppm
N_2	0 – 5
Others	0 – 5

Typical Operating Conditions

- Pyrolysis Temperature: 600 – 20,000 °C
- Residence Time: 1 – 10 ms
- CH_4 Conversion: > 95%
- H_2 Selectivity: > 95%
- Operating Pressure: ~ 1 bar(g)
- Reactor Medium: Ar (optional)

MAIN APPLICATIONS OF CARBON BLACK BY INDUSTRY SALES



Main applications of carbon black by industry sales – World Production: 13 million tons per year*

Global carbon black market size
USD 24.5 Billion (2023)
CAGR 5.0% (2024–2030)**

LARGE MARKET POTENTIAL: CARBON BLACK APPLICATIONS BASED ON CONTRIBUTION & MARKET VALUE

1. TIRE (RUBBER)

Largest application (~67%). Provides strength, durability, and performance in tires.

Estimated Market Value
≈ USD 16.4 Billion (2023)
Volume: ≈ 8.7 million ton/year

2. INDUSTRIAL RUBBER

Used in belts, hoses, seals, conveyor, vibration control, and other technical rubber products.

Estimated Market Value
≈ USD 5.4 Billion (2023)
Volume: ≈ 2.9 million ton/year

3. PLASTICS

Provides black color, UV stabilization, conductivity, and material strength.

Estimated Market Value
≈ USD 1.7 Billion (2023)
Volume: ≈ 0.9 million ton/year

4. INKS

Used as pigment in printing inks, coatings, and industrial inks.

Estimated Market Value
≈ USD 0.5 Billion (2023)
Volume: ≈ 0.3 million ton/year

5. HIGH TECH

Special applications: conductive carbon, batteries, capacitors, semiconductors, EMI shielding, etc.

Estimated Market Value
≈ USD 0.5 Billion (2023)
Volume: ≈ 0.3 million ton/year

FUTURE APPLICATIONS (GROWING)

- Concrete & Asphalt (strength & durability)
- Coffee Capsules (food grade CB)
- Soil Enhancement (carbon sequestration)
- Biochar Blends (added carbon value)
- Masterbatch & Advanced Composites

SUSTAINABLE & NEGATIVE CARBON FOOTPRINT

Landfill biogas (biomethane) + methane pyrolysis produces clean hydrogen and high-value carbon black with negative CO_2 emissions.

CO_2 Reduce CO_2 Emissions (Net Zero / Negative) → High-Value By-product Carbon Black → Replace Fossil-Based Materials & Plastics (Circular & Sustainable) → Support Industrial Decarbonization & Energy Security

* Source: Grand View Research, 2023
** Source: Fortune Business Insights, 2024
Note: Market value estimation (2023)

EXPECTED OUTPUTS & NATIONAL CONTRIBUTION

Delivering Innovation, Impact, and Leadership for Indonesia's Green Hydrogen Future

From pilot system to national impact – generating knowledge, technology, and solutions for a sustainable future.

BRIN BADAN RISET DAN INOVASI NASIONAL | H_2 INDONESIA Hydrogen Economy

01 1. PILOT SYSTEM & TECHNOLOGICAL OUTPUT

- 1 unit integrated pilot plant (PV–Biogas–MMP–H_2–Fuel Cell)
- Validated MMP (Microwave-Assisted Methane Pyrolysis) system
- Stable H_2 production from biogas with high efficiency
- Operational data for techno-economic and environmental analysis
- Modular & scalable design for remote area deployment

H_2 Production	System Capacity	Application	Feedstock
5 – 10 Nm³/day (Pilot Scale)	5 – 15 kW (Electrical)	Remote Area & Island	Biogas from Biomass Waste

02 2. SCIENTIFIC & INTELLECTUAL CONTRIBUTION

High-impact Publications
Peer-reviewed articles in Q1–Q2 journals on MMP technology, system integration, and hydrogen economy.

Patents & IP
Patents for MMP reactor design, integration system, and process optimization.

Human Capital Development
Training and capacity building for researchers, engineers, and students in green hydrogen technology.

Data & Knowledge Repository
Comprehensive dataset and knowledge base for future R&D and industrial development.

03 3. STRATEGIC & POLICY CONTRIBUTION

Support National Hydrogen Roadmap
Provide pilot data and policy inputs for Indonesia's hydrogen strategy and regulations.

Model for Remote Area Energy
Demonstrate replicable model for clean energy independence in 3T (Terdepan, Terluar, Tertinggal) regions.

Circular Carbon Economy
Utilization of solid carbon (carbon black) as valuable product for industrial applications.

Strengthen National Innovation Ecosystem
Foster collaboration among BRIN, universities, industry, and local communities.

04 4. SOCIO-ECONOMIC & ENVIRONMENTAL IMPACT

KEY ACTIVITIES

- >1,000 Nm³/h biomethane feed
- Hydrogen hub development
- Carbon products commercialization
- Export opportunity
- Strategic partnership & industrial scale-up

KEY OUTPUT

- Commercial plant operation
- Hydrogen & carbon market leadership
- Technology licensing & export
- National & global impact

Commercial Target (2038+)

H_2 > 1,000 Nm³/h CH_4 ↓ > 180 kg/day H_2 ↓ > 1 ton/day Solid Carbon

5. KEY PERFORMANCE INDICATORS (KPIs)

Hydrogen Production Efficiency	System Availability	Cost Competitiveness	GHG Reduction	Local Community Engagement
≥ 75% (Target)	≥ 90% (Target)	≤ 4 USD/kg-H_2 (Target in Scale-up)	≥ 60% (vs. Conventional)	≥ 3 Sites (Pilot Deployment)

6. DELIVERABLES

- Integrated Green Hydrogen Pilot Plant (Operational)
- Techno-economic & Environmental Assessment Report
- Scientific Publications & Conference Presentations
- Patents / Intellectual Property Rights
- Policy Brief & Recommendations
- Capacity Building & Training Modules
- Replication & Scale-up Roadmap

7. ALIGNMENT WITH SDGs

LONG-TERM VISION

Establish Indonesia as a regional leader in green hydrogen innovation and deployment.

Empowering islands, strengthening nations, sustaining the future.

This project will deliver innovative technology, scientific excellence, and real impact for Indonesia's green hydrogen journey.
From Indonesia, for Indonesia, and for a Sustainable World.

BRIN
BADAN RISET
DAN INOVASI NASIONAL

CTCN
UN Climate Technology Centre
& Network

UN environment programme

H_2 INDONESIA
Hydrogen Economy

THANK YOU

For Your Attention and Collaboration

RESEARCH | INNOVATION | DEMONSTRATION | COLLABORATION | HYDROGEN ECONOMY

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