UNEP CTCN
Regional Capacity Building Program on Green Hydrogen: Asia and Pacific

Summary Report

Green Hydrogen Technology for System Transformation in Energy and Sustainable Mobility Sectors

Date & Venue: 23rd – 26th May 2023, Busan (Centum Premier Hotel), Republic of Korea, In-person

Hosting organisations: UN CTCN (Climate Technology Center & Network, www.ctc-n.org: The operational arm of Technology Mechanism of UNFCCC) and Green Energy Institute (www.gei.re.kr) in partnership with National Renewable Energy Laboratory (https://www.nrel.gov/)

Background: Only a few Asia and Pacific (AP) countries consider green hydrogen as a climate technology solution for mitigation and adaptation. The retrospective analysis of 62 submitted National Determined Contributions (NDC) of AP countries found only 10 countries[1] had a brief plan on hydrogen technologies in energy systems and sustainable mobility sectoral transformation. For a technology to be best utilised as a solution for system transformation, the design and implementation of national plans supporting international cooperation in research and development are required. In this regard, in-depth understanding of the hydrogen technology mechanism, its application for potential GHG emission reduction measures and the ability to visualise the production of green hydrogen and ammonia fuels for use in power generation, industries, and transportation are the three most critical knowledge that the AP countries must be filled with.

Purpose: To support understanding of past, current, and the future of Hydrogen Technology in Energy and Sustainable Mobility sectors, peer-to-peer learning of existing national hydrogen policy plans, and matchmaking with local technology providers to incorporate economy and social shift strategies for sustainability.

Themes: Each day of the program covered topics of green hydrogen background, science and technology, and global market trend (refer to Annex I for the final concept note).

Approaches and activities: Mixed approaches were applied including capacity building for knowledge increase, peer-to-peer learning for knowledge sharing, voluntary-based technology talk, and pre-arranged matchmaking for bridge-building of South-South Collaborative RD&D facilitation. Pre and post program survey was conducted to evaluate effectiveness of each program activity (full questionnaires of pre-post surveys available upon request).

Key outputs and outcomes

In general, 13 NDEs from 10 Asia (i.e. Bhutan, Cambodia, Laos, Sri Lanka, Thailand, Vietnam, Mongolia, Nepal, Japan, Korea) and 3 Pacific (i.e. Papua New Guinea, Fiji, Maldives) regions attended the

[1] Australia, Bhutan, China, Jordan, Qatar, Republic of Korea, Saudi Arabia, Thailand, United Arab Emirates, Viet Nam

program. The pre-and-post program survey was completed by 7 countries (i.e. Mongolia, Cambodia, Sri Lanka, Viet Nam, Nepal, Thailand, Papua New Guinea).

Over first two days of the program, 2 Keynote speeches from Green Climate Fund (GCF) and National Renewable Energy Laboratory (NREL) and 9 presentations on green hydrogen technologies were delivered. The following consideration points were communicated to the participating NDEs:

A. At the <u>early stage</u> of Green Hydrogen driven climate technology innovation for system transformation of Energy and E-mobility sectors

- Necessity of Green Hydrogen National Roadmap/Vision (e.g. USA, Japan, Thailand) including sector-coupling strategies (e.g. DNV, Singapore example)
- Government support on primary research on green hydrogen (e.g. KIST)
- Government support on demonstration research (e.g. Boil-off strategies, near-shore platform)
- Accumulation of successful case studies/examples over different fields of system (e.g. KRRI, Jeollanam-do)
- High construction costs of liquid hydrogen (e.g. KEPCO)

B. At the <u>mid-late stage</u> of Green Hydrogen driven climate technology innovation for system transformation of Energy and E-mobility sectors

- Government support to create market (e.g. subsidies, Hyosung)
- Social awareness on safety of green hydrogen technology

C. In establishing Green Hydrogen ecosystem and governance

- Formation of national-level Green Hydrogen Consortium (e.g. USA's H2NEW, Japan's green hydrogen supply chain, Thailand's stakeholder group)
- Financial investment (e.g. USA's loan guarantees, Japan's Green Innovation Fund)
- Bridging national green hydrogen pioneers to South-South, North-South collaboration activities including exchange for learning visits and joint RD&D projects

On average, 78% of NDEs and their representatives who completed the post-program survey (n = 7) correctly answered 16 knowledge testing questions. The incorrect answer rate indicates following suggestions for communication of CTCN to our main audience of NDEs:

- Content on UNFCCC governance including CTCN, TEC, and FMs
- Concept of TM and FM linkage (for example, sharing of SB dialogues on linking mechanisms)
- Themes of each system transformation areas with examples

Table 1 Knowledge assessment

Tested	Questions (True/False)	Incorrect answer (%)
Knowledge related to TM and CTCN	CTCN is a policy arm of Technology Mechanism	72
	Traditional steps of technical assistance project development require 1) Submission of a request form, 2) Meeting with potential implementing institutions and 3) Open international bidding for matching Network members	28
	Technology Mechanism supports countries to enhance climate technology development and transfer	15
	Only the registered Network members can implement CTCN TA requests submitted by developing countries	14
	Digitalisation is only enabler of CTCN's 3rd Programme of Work	14

Knowledge related to FM and Climate Finance	CTCN TA can only be scaled up, in collaboration with, the Green Climate Fund (GCF)	42
	National Designated Authorities are government institutions that serve as the interface between each country and the Fund	28
	Global Environment Facility (GEF) is an implementing arm of Finance Mechanism	28
	Climate finance refers to local, national, or transnational financing that seeks to support mitigation and adaptation actions to address climate change	0
Knowledge related to Technology	Green hydrogen mobility are fuel cell electric vehicles	28
	Development of energy efficiency certifications is only way to enact energy system transformation	28
	Global transformational change refers to a systematic and technological change at a national level	14
	System innovation requires institutional, technological and societal change	14
	Supporting gender and youth entrepreneurship initiatives is one way to enable business and industry transformation	14
	A technological innovation may involve both soft and hard technologies, depending on the approach	0

Evaluative analyses of participants' perceived capacity, opportunity, motivation, empowerment, and engagement before and after the program, revealed strong positive correlation between perceived capacity and empowerment ($p < 0.01$). This imposes the increase of perceived capacity will increase the level of empowerment that NDEs feel towards designing effective and sustainable TAs. Among NDEs with experience of designing and implementing average 3 TA projects (4 out of 11), the average rate on perceived benefit and ownership of the TA were 7.5.

Table 2 Evaluation of previous TA designing experience

NDEs with experience of designing and implementing TA projects	**Questions asked**	**Average rating (Out of 10)**
Lao PDR Thailand Cambodia Bhutan	To date, how many technical assistance projects have been implemented in your country, designed by yourself?	2.75
	How beneficial TA was in increasing your country's climate mitigation/adaptation capabilities?	7.5
	How applicable TA was in increasing your country's climate mitigation/adaptation capabilities?	6
	To what extent, do you feel ownership of the TA implemented?	7.5

When the question on ranking areas of system transformation by its urgency was asked, the Water-Food-Energy nexus was most frequently rated as urgent by six countries (i.e. Fiji, Lao PDR, Thailand, Nepal, Bhutan, Cambodia) followed by Energy systems (n = 4, Maldives, Sri Lanka, Viet Nam, Mongolia), and Buildings and Infrastructure (n = 1, PNG). Business and Industry was the least urgent area of transformation that NDEs have identified (n = 5, Maldives, Fiji, Lao PDR, Thailand, Bhutan).

Table 3 Countries priority of 5 system transformation areas (1 being most urgent, 5 being least urgent)

Countries	**Water-Food-Energy Nexus**	**Building and Infrastructure**	**Sustainable Mobility**	**Energy Systems**	**Business and Industry**
Sri Lanka	2	3	5	1	4
Viet Nam	2	5	4	1	3
Mongolia	4	5	2	1	3

Cambodia	1	2	4	5	3
Lao PDR	1	4	3	2	5
Thailand	1	4	3	2	5
Nepal	1	5	2	3	4
Bhutan	1	2	3	4	5
Papua New Guinea	2	1	5	3	4
Maldives	2	3	4	1	5
Fiji	1	3	4	2	5

Thematic analyses of NDEs' word association to keywords of 'TA', 'CB', 'NE', 'RD&D', and 'Impact' revealed NDEs' lack of linking the concept/service of TA to the 'impact', clear misunderstanding on the concept of 'Collaborative RD&D', and lack of knowledge on potential activities and purpose of 'network engagement' in CTCN's services.

Table 4 Word association test

Keywords	**NDEs' expression of keywords by three words**
Technical Assistance (TA)	• providing expert service • Renewable Energy, Development of Roadmap, Feasibility Studies • Upskilling of technical skills • From CTCN and other organization • technology transfer, national system integrated • help, guidance, knowledge • technical assistant is required for feasibility study of green hydrogen in Sri Lanka • Green Hydrogen • Energy, Mitigation, NDC • Consult, solution, recommendation, feedback, • technology
Capacity Building (CB)	• enhancing knowledge • Renewable Energy, Climate Technology, Policy Development and Implementation • Resourcing areas of lack • At technical officer and policy maker • workshop, networking, multi-disciplinary • training, knowledge, programs • Capacity building is required for green hydrogen • Capacity Building • Training, Study tour, net-working • knowledge, experience, learning, result • tailored made
Network Engagement (NE)	• sharing ideas • Enhanced Collaboration, Awareness of Contact Networks, Awareness on types TA available • Partnership with organizations and groups • Need more improve • conference, personal connection, key person • discussions, private sector, government • network engagement will be helped to increase the knowledge and share the technology • Yes • Networks related to green and mitigation technology • cooperation, sharing, goal, outreach • institutions and institutes
Collaborative Research	• sharing of finding of research • Enhancing Renewable Energy Capabilities, Sustainable Energy Sources, Green Hydrogen

Development and Disseminatio n (RD&D)	• Opportunity for information sharing • On green hydrogen • consortium, multi-disciplinary, knowledge sharing • knowledge, experiments, design • research and development need to develop the green hydrogen in Sri Lanka • Yes • mitigation technology transfer and implementation • planning, research, development, coordination, report • technology
Impact	• climate change impact • Eye Opener, Need for Contextualization of International Practices, Lack of Capabilities of Developing Nations • Degree of change • NDC particularly on mitigation • long-term, national, external (negative) impact • environment, society, people • increasing the renewable energy capacity of the energy mix. • NDC and long term strategy for carbon neutrality • Capacity building, mitigation implementation • outcome, process, overcome • community

However, when questions on what are the three most factors, resources, and essential impacts they consider in designing the next TA project were asked, the NDEs referred to as the followings:

- Definition of impact identified by success factors mentioned: National goal-driven, cost-benefit, and people (national experts);
- Resources are in-need for future TA success: Information to develop national climate governance for human resource acquisition and financial support.

Table 5 Summary of responses on success factors and resources

Country	**What are the three most important factors you consider in designing next Technical Assistance project?**	**What are the three most important resources you consider in designing next Technical Assistance project?**	**What are the three most essential impacts you expect from CTCN's Technical Assistance project?**
Sri Lanka	- The present issues are facing the country in the energy sector - NDCs of the country - Financing	- Technology - Knowledge sharing - Finance	- Technical assistance for study the green hydrogen in Sri Lanka - Finding investment through a proper feasibility study
Viet Nam	- Contribute to implement the mitigation objectives of NDC - Cost-benefit - Suitable with national circumstances	- Designing agency - Implementing agency - Collaboration/funded agencies	- Capacity building - Contribute to implementation of mitigation objective - Extend cooperation with many international organizations
Mongolia	- Resources - Guideline - Advise	- Finance - Consultant - Information	- Policy - Progress - Planning
Cambodia	- Green hydrogen capacity Building - Piloting	- Financial support - Concept note preparation	- To meet Cambodia's NDC and long term strategy

Lao PDR	- Green hydrogen action plan - V &A Assessment and mapping - Focal point capacity building	- R&D development - Human resource - Funding	- NZE 2050 - Update and implementation of NDC implementation on National strategy on climate change
Thailand	- Lacks of expertise, and resources in the country - Impact and urgency of the topics - Active players and existing resources in the country	- Key resource person in the country - Existing knowledge in the country - Countries funding	- Align and contribute to policy formulation - Can connect to the national innovation system - Link to fund resources
Nepal	- national priority - budget	- expert - budget - time	- Capacity building - Fulfilling national priorities
Bhutan	- Impacts - Sustainability strengthening	- Technolog - experts - resources	- to build the reliable data and bankable projects
Papua New Guinea	- Policy development, capacity building and technical assistance	- Natural resources - government goals - financial incentives	- Hydrogen Policy Formulation - Energy transition and security Plans for the country - networking and partnership
Maldives	- Impact to the country The importance of that technology that is needed to the national situation - How it would impact us	- Human resources (Need capacity building) - Infrastructure Past knowledge	- Understanding whether or not a technology maybe feasible - People (in the sector) become more knowledgeable - More developments in the future
Fiji	- Important factors will include alignment of TA requested to national priorities, ensure that TA will address areas that the country lacks capabilities and the need for NDE to provide more awareness to various Government agencies on the the types of TAs that the CTCN can provide assistance on such as Agriculture, Energy, Transport, etc. Need for NDEs not to operate in silos	- -Technical Expertise - Data to justify request for TA - Evidenced based request - There is political will to support request and implementation	- The TA addresses key priority areas identified at national level - Need for TA to be locally contextualized and relevant - M&E to be embedded in the TA implementation

In collaboration with the MSIT Korea, 4 multi-lateral meetings were prearranged to foster RD&D collaboration on Green Hydrogen. As a trial of executing bridge building activities to allow NDEs take leading role in findings counter partnering national technology experts for collaborative RD&D, the following steps were applied:

Step 1. MSIT provided summary of Korean Network members' technology capabilities and preferred country for collaboration (N = 31)

Step 2. CTCN reviewed the summary and selected 14 technologies of 6 Korean Network members to narrow the scope of RD&D collaboration facilitation to green hydrogen (Annex II)
Step 3. MSIT arranged the multi-lateral meeting with the selected Korean Network members
Step 4. NDEs find matchable national experts to the Network members met
Step 5. CTCN follow up on South-South collaboration opportunities upon countries' request

Based on the pre-matched needs of the NDEs and Korean Network members, in-person multilateral meetings were facilitated during the World Climate Industry Expo 2023. All participating countries attended the meeting and had 15 minutes of technology talk with each Network member. The talks involved 10-minute presentation of technology from the Network member and Q&A.



Figure 1 Bridge-building activities with Green Hydrogen experts of Network members

After the program, 6 countries submitted an expression of interest for CTCN to support RD&D collaboration for green hydrogen. Of those 3, NDEs presented a list of matchable national experts to the Korean network members they met.

Table 6 Results of Bridge-building activity

Countries requested CTCN's support on South-South collaborative RD&D	**Korean Network members and their technologies**	**Matchable national experts identified by the NDEs**
Cambodia	• KIST (Korea Institute of Energy Research) – Solid-state hydrogen storage materials for safe hydrogen storage • KIER (Korea Institute of Energy Research) – Anion Exchange Membrane (AEM) Water Electrolysis Technology for Green H2 Production • KIER (Korea Institute of Energy Research) – Green hydrogen production technology using renewable energy • KIMS (Korea Institute of Materials Science) – High Entropy Alloy Commercialization Technology for Liquid Hydrogen Storage and Hydrogen Vehicle	(a) Roral University of Phnom Pemh Institute of Technology for Green Hydrogen
Mongolia		(a) Sainbileg Enkhbileg, focal point, Climate Change Information Transparency Institute (CCITI), email: sainaa81223@gmail.com (b) Tamir Enkh-Amgalan, capacity building specialist, NDC Partnership, email: tamir.ea4@gmail.com
Vietnam		(a) Institute of Energy, Ministry of Industry and Trade (b) University of Electricity; Viet Bac Mining Chemical Company Limited - MICCO
Thailand		To be confirmed
Lao PDR		
Fiji		

Additionally, 4 multi-lateral meeting for collaboration for general climate technology RD&D were facilitated following steps:

Step 1. MSIT provided summary of 3 Korean Network members' technology capabilities and their preferred countries for future collaboration (i.e. Vietnam, Thailand, Lao PDR, and Mongolia)
Step 2. CTCN reviewed the summary of 4 technologies of 3 Korean Network members to ensure their technologies are aligning to our PoW
Step 3. CTCN facilitated in-person meetings between 4 NDEs and 3 Korean Network members



Figure 2 Technology talks with digitalisation and energy related technology experts of Network members

Two Korean Network members on digitalisation of Buildings and infrastructure were:

- KICT (Korea Institute of Civil Engineering and Building Technology) – Open data-based building energy care service
- ETRI (Electronics and Telecommunication Research Institute) – Customized factory energy management systems (FEMS) for high energy-consuming industry processes

Whereas two Network members presented on energy transformation-related technologies:

- KITECH (Korea Institute of Industrial Technology) – Biomass gasification system for distributed heat and power generation
- KICT (Korea Institute of Civil Engineering and Building Technology) – Central air-conditioning system and active soil filter for improving indoor air quality in a school classroom

On average, each NDE had 8 voluntary-based technology talks during their visit to the local climate technology exhibition that CTCN facilitated.

On the last day of the program, bilateral meetings were held with 6 countries upon request. The participating countries were Cambodia, Lao PDR, Mongolia, Thailand, Fiji, and During the bilateral, 3 countries requested TA on vision and strategy development for green hydrogen. Also, preparation of GCF readiness proposals for TNA update was requested by two countries.

Training on climate policy tools was most mentioned (n = 4) out of all types of capacity building activities that NDEs hope to engage in 2023 onwards, followed by training on climate finance schemes and TNA/TAP and a workshop on designing the next TA project.

Out of 7 countries, 4 countries mentioned they are hoping to engage in 'Structured direct dialogue with GCF/GEF/AF focal points'. Networking with Global Network members, specifically research institutions were the second most mentioned activity that NDEs hope for the CTCN to support.

Conclusion

Overall, two action points are identified for the TA development. The action point 1: Technology managers to follow up with the following countries for green hydrogen roadmap and vision strategy TA:

- Cambodia
- Lao PDR
- Mongolia

These TA projects could turn into a multi-country project including activities of energy mix strategy development reflecting the analysis of NDCs within 10-15 pages.

The action point 2: Technology managers to follow up with the following countries for GCF readiness proposal development:

- Cambodia
- Lao PDR

These proposals may focus on update of each country's technology need assessment as part of GCF readiness proposal. Indirect consultation with GCF prior to following up with countries may require assuring our proposals are accepted by the GCF.

Related to earning extra resources for collaborative RD&D support, a direct conversation with MSIT for funding on multi-country green hydrogen technology RD&D project can be followed up. The countries verbally confirmed their participation were Cambodia, Fiji and Thailand.

In relation to the communication, the following points are suggested for future consideration:

- Content on UNFCCC governance including CTCN, TEC, and FMs
- Concept of TM and FM linkage (for example, sharing of SB dialogues on linking mechanisms)
- Themes of each system transformation areas with examples and its expected economic and social impacts – direct distribution of contents to the countries with high interest in 1 of 5 transformation areas (i.e. water-food-energy nexsus for Fiji, refer to Table 3).
- Concept of Collaborative RD&D as foundation to build human resources of developing countries

Lastly, development of online training to move beyond one-time-point knowledge transfer/sharing is suggested to increase the impact of capacity building program. The content could be covering climate policy tools and TNA and TAP.

Annex I Program Agenda



Day 1 (Tuesday, May 23rd)

Opening Ceremony and Introduction to the program

10:00~10:05	**Opening Remarks** Rajiv Garg (Director (a.i), Climate Technology Center and Network, UN Environment Programme)
10:05~10:10	**Welcome Remarks** Dongsik Joo (President of Green Energy Institute)
10:10~10:15	**Group photoshoot and the Introduction to the program** - COVID-19 HYGIENE PROTOCOL - Toilet location - Food and drinks location - Expected general program activities

Session 1: Past, Current, and the future of Hydrogen Technology

10:15~10:45	**Technology Mechanism for Green Hydrogen and System Transformation** Jeawon Kim (Capacity Building and Network Engagement Specialist, Climate Technology Centerand Network, UN Environment Programme)
10:45~11:00	**Financial Roadmap to Build the Green Hydrogen Economy** Carolina Fuentes (Director of the Country Programming Division, GCF)
	Lunch break (90 minutes)

Session 2: Green Hydrogen: Production and storage

12:30~13:10	**Green Hydrogen Production: Technical Overview and Research Trends** Hyun S. Park (Principal Research Scientist, Korea Institute of Science and Technology)
13:10~13:40	**Hydrogen Boil-Off Reduction Strategies for Safe and Efficient Transportation of Liquefied Hydrogen** Hyunchul Oh (Professor at the Department of Chemistry, Ulsan National Institute of Science and Technology)
13:40~14:00	**Hydrogen Liquefaction for Storage and Transportation: Hyosung's Business** Hyosung Yim (Vice President of Corporate Strategy Center Hyosung Corporation)
14:00~14:20	**Q&A session**
	Break-time (10 minutes)

Session 3: Green Hydrogen: Conversion/Transport and End Uses

14:30~15:00	**Near-shore green hydrogen production / conversion & transport (platform) technology linked with renewable energy** Jihyun Hwang (Professor at Department of Energy Engineering Korea Institute of Energy Technology (KENTECH))
15:00~15:30	**Green Hydrogen End Use Technology - Energy System (Industry)** Sung Ho Chang (General Manager(Senior Researcher) of Hydrogen Energy Group, KEPCO Research Institute)
15:30~15:50	**K-Hydrogen Powered Railway** Joon-Hyoung Rhy (Principal Researcher, Korea Railroad Research Institute)
15:50~16:10	**Current Status and Future Plans for Fostering the Hydrogen Industry in Jeollanam-do** Yong-seok Bae (Head of Offshore Wind Power Industry Department, Jeollanam-do Provincial Government)
16:10~16:30	**Development of hydrogen value chains in APAC** James Laybourn (Regional Sales Director and Hydrogen Segment Lead, DNV)
16:30~16:50	**Q&A session**

Day 2 (Wednesday, May 24th)

Session 1: Policies for System transformation by Countries

10:00~10:25	**Green Hydrogen and System Transformation** Mark Ruth (Manager of NREL, Department of Energy, USA)
10:25~10:50	**Japan's Green Hydrogen Plan and Roadmap** Norihiro Kimura (Japan NDE)
10:50~11:15	**CTCN TA: Green Hydrogen Roadmap** Norachai Rungsivichitprapa (Thailand NDE)
11:15~11:35	**Q&A session**

Session 2: Calling from Future

11:35~12:00	**Ideating the next TA on Green Hydrogen Technologies** - All NDEs
	Lunch Break (90 mins)
13:30~14:30	**Drafting the CTCN TA concept note** - All NDEs

Session 3: Collaborative RD&D

14:30~15:00	**Keynote Speech - Introduction to CTCN's collaborative RD&D** Suil Kang (Coordination Officer, Climate Technology Center and Network, UN Environment Programme)
15:00~15:20	**Instructions for Bridge-building and Networking activities** - Jeawon Kim

Day 3 (Thursday, May 25th)

World Climate Industry Expo (WCE 2023) for collaborative RD&D

10:30~12:00	**Opening ceremony of WCE2023**
12:00~13:00	**Lunch**
13:00~15:00	**Bridge-building meetings with Korean RD&D institutions (*Pre-arranged)** 1F Hall 4, Climate Technology Zone
15:00~17:00	**Climate Future forum 2023 (Technology-oriented)** 1F Exhibition Center 2 Hall 4, Seminar room 121 – 123

Day 4 (Friday, May 26th)

Networking with prospective strategic partners for RD&D collaboration

09:00~10:30	**Bridge-building meetings with Korean RD&D institutions (*Pre-arranged)** 1F Hall 4, Climate Technology Zone
10:30~12:00	**Networking and Partner seeking activity** 1F Exhibition Center 2 Hall 1~2, Future Mobility, Clean Energy Zone
12:00~13:00	**Lunch**
13:00~	**Bilateral meeting with CTCN (*Upon request)**

Annex II Summary of 6 Korean Network members' 14 technology capabilities (Green Hydrogen-focused)

Sub-category		Institute	Technology	Technology Introduction
A1. Eco-friendly Energy Transition				
Hydrogen (Production)	A1-8	KIER (Korea Institute of Energy Research)	Green hydrogen production technology using renewable energy	- The technology is a 'water electrolysis stack available to respond to load variations' that can produce safe, high-efficiency hydrogen from volatile and intermittent renewables such as solar and wind. - Specifically, developed electrodes and separator membranes on their own that maintained a high durability and efficiency with the supply of highly variable and intermittent renewable energy, and it has modularized the water electrolysis system by using this stack technology.
	A1-9	KIER (Korea Institute of Energy Research)	'Reversible high-temperature cells using multi-scale solid oxide' video	- Video presentation of heat and power generation technologies using renewable hybrids (waste, solar, wind, etc.) and future energy storage technologies that use them to produce hydrogen and then return it as electricity when needed.
	A1-10	KIER (Korea Institute of Energy Research)	Anion Exchange Membrane(AEM) Water Electrolysis Technology for Green H2 Production	- AEM water electrolysis, out of green hydrogen production techniques, has advantages such as use of low-priced non-precious metal catalysts, high current density, rapid production of high purity, high-pressure hydrogen, smooth response to load fluctuations, etc. - For next-generation AEM water electrolysis, technologies for non-precious metal catalysts with high activity and high durability; high performance, large-area uniform electrode, and MEA; and high efficiency stacking optimization technology, and full cycle technology connecting material-component-system at marketable level obtained.
Hydrogen (Storage)	A1-11	KIST (Korea Institute of Science and Technology)	Solid-state hydrogen storage materials for safe hydrogen storage	- In order to expand the share of hydrogen energy, it is essential to develop hydrogen storage technology. There are various methods of hydrogen storage, including high-pressure gas storage, liquid storage, and solid storage, but solid storage has the advantage of being safe because hydrogen is absorbed and released into the material at room

				temperature and near normal pressure
	A1-12	KIMS (Korea Institute of Materials Science)	High Entropy Alloy Commercialization Technology For Liquid Hydrogen Storage and Hydrogen Vehicle	- Development of cost-effective hydrogen embrittlement resistant/cryogenic high entropy alloy. - Development of customized process technology for liquid hydrogen storage and hydrogen vehicle. - Development and fabrication method of high entropy alloy through use-specific design.
Hydrogen (Utilization)	A1-14	KIER (Korea Institute of Energy Research)	Mock-up of polymer fuel cell stack configuration	- Mock-up of polymer fuel cell stack configuration
	A1-15	KIER (Korea Institute of Energy Research)	Developing 'flat-tubular cells' that make both hydrogen and electricity	- A flat-tubular cell is a core component of the reversible high-temperature water electrolysis-fuel cell technology and this technology is a promising energy storage technology that generates hydrogen from water by using electric energy and, if necessary, coverts hydrogen into electric energy. - This technology is the first in Korea and is used to manufacture the core component of flat-tubular solid-oxide cells with large active surface area of 100cm2. And it has higher power density per volume while guaranteeing higher efficiency and stability, advantages of flat cells and tubular cells, respectively.
	A1-16	KIST (Korea Institute of Science and Technology)	A working model of Fuel Cell Electric and Electric vehicle	- A working model that allows viewers to experience the principles of hydrogen fuel cell electric cars and electric cars.
Others	A1-18	KITECH	Biomass gasification system for distributed	- The Korean biomass gasification consortium, in which KITECH participates, developed a commercial-scale biomass gasification system based on a bubbling fluidized bed technology.

		(Korea Institute of Industrial Technology)	heat and power generation	- This system can be applied to distributed heat&power generation and energy transformation of industrial sectors by replacing fossil fuels. - The capacity of the gasifier is 50 tons/day based on 3,300 kcal/kg biomass, which corresponds to 8 MWth and can generate 2 MWe. The minimum load is 30 ton/day, and the maximum is 60 ton/day. - Fluidized bed reactors can utilize economical fuels with various properties such as wood chips, forest by-products, and agricultural by-products. - In addition, the gasifier can minimize wastewater generation by utilizing activated carbon and oil scrubber and has the advantage of removing Tar at high temperatures and improving the quality of syngas.
	A1-19	KIMS (Korea Institute of Materials Science)	High-Performance and Cost-Effective Permanent Magnets for High-Efficiency Motors	- Next-generation technology of permanent magnet that not only replaces expensive, yet scarce Nd with inexpensive and abundant Ce but also exhibits equivalent or better magnetic performance compared to existing magnet. - Next-generation grain boundary diffusion technology to dramatically reduce the usage of Dy and Tb, both of which are key elements to high performance of permanent magnets but expensive. - Waste rare-earth magnet recycling/regeneration technology.
Renewable Energy	A1-20	KIMS (Korea Institute of Materials Science)	New TiAl Alloys for Transport Devices and Power Generation	- Development of new TiAl alloys for high-temperature applications. - Precision casting process, forging process, and 3D printing. - World's highest heat strength up to 950℃ and oxidation resistance - Customized alloy design and process technologies are owned for each process.

	A1-21	KIMS (Korea Institute of Materials Science)	Photovoltaic + Electrochromic Integrated Smart Window	- Hybrid smart window with the transparent solar cell and electrochromic film technology combined. - Self-operrent solar cell. - Convergence-type smart window model of various forms. - Volumetric fabration of electrochromic devices using energy generated through the transpaication is available based on a roll-to-roll process.
	A1-24	KIST (Korea Institute of Science and Technology)	Highly efficient transparent CIGS thin film solar cell for urban building window applications	- This technology offers highly stable and efficient semi-transparent solar panels that can be utilized as builidng windows for energy self-sufficiency. It has been implemented in CIGS thin-film solar cells by applying a methodology that allows for adjustable transparency. To achieve this, a bifacial light-absorbing CIGS cell structure was developed, and micro-openings that are difficult to visually identify were formed using laser scribing process. This technology allows for easy control of colorless transparency and exterior color representation, without affecting the interior color of the window.
	A1-25	Gachon University	Open Platform Technology of Energy Cloud	- A project to develop core technology for open platforms of Energy Cloud - Energy Cloud is a service/system concept that provides on-demand and pay per use service instead of directly owning the facilities and S/W required for the energy business - Same as cloud computing in that it provides flexible facility use, sharing and scale benefits, expansion and adjustment according to the situation, and cost reduction - Area of Core Technology - (Network) network flexibility enhancement with energy router technology

				- (Informatics) quantum security technology for energy data protection - (Softwarization) XAI based Energy balance prediction and open platform service - (Provisioning) Digital Twin technology for optimal energy supply - Expected Contribution - Efficient operation of distribution network and resources with open platform - Increase in renewable energy hosting capacity - Reduction of energy cost