FACTSHEET

16 Low-Carbon Energy Research (LCER) projects awarded to support Singapore's National Hydrogen Strategy and Promising Low Carbon Energy Areas

$55 million committed to projects under the Directed Hydrogen Programme (DHP) and Emerging Technology Grant Call (ETGC)

1. The Low-Carbon Energy Research (LCER) Programme[1] is an initiative funded by the National Research Foundation (NRF) and hosted by the Agency for Science, Technology and Research (A*STAR) to support research, development and demonstration projects to advance low-carbon technologies, and to enable decarbonisation of the power and industry sectors. In October 2022, Deputy Prime Minister and Minister for Finance, Mr Lawrence Wong, announced that the Government would be embarking on Phase 2 of the LCER programme.[2]

2. In August 2023 and October 2023, the Directed Hydrogen Programme (DHP) and the Emerging Technology Grant Call (ETGC) respectively, were launched under Phase 2 of the LCER Programme. Following rigorous evaluation of the proposals received, $55 million has been awarded to support six DHP projects and ten ETGC projects.

Directed Hydrogen Programme (DHP)

3. The DHP supports Singapore's National Hydrogen Strategy by enabling the development of technologies to build capabilities across the hydrogen supply chain and its end-uses (including carriers) for Singapore to safely and economically import and utilise hydrogen. A grant call was launched, inviting research proposals across three priority areas: (i) hydrogen and ammonia safety and regulatory standards, (ii) ammonia cracking and utilisation, and (iii) hydrogen transport and distribution.

4. Around $43 million will be awarded to support six projects[3] under the DHP across these three priority areas. These projects, if successful, can help accelerate the technical viability and commercial scalability of hydrogen-related technologies and promote the adoption of hydrogen in Singapore's energy transition.

[1] 12 Projects Awarded $55 Million to Accelerate Decarbonisation in Singapore (ema.gov.sg)
[2] PMO | DPM Lawrence Wong at the Singapore International Energy Week
[3] Details on the six DHP projects can be found at Annex A.

Emerging Technology Grant Call (ETGC)

5. The ETGC supports nascent yet promising low-carbon energy R&D areas at lower technological readiness levels (TRLs 1-2) such as hydrogen, carbon capture utilisation and storage (CCUS) and other low-carbon energy areas that have the potential to open up more options for abating the emissions of the power and industry sectors.

6. Around $12 million will be awarded to support ten projects[4] under the ETGC to fund R&D in low concentration carbon capture, advanced catalysts for ammonia cracking, and coatings for hydrogen pipeline.

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Annex A: Details of Awarded DHP projects
Annex B: Details of Awarded ETGC projects

[4] Details on the ten ETGC projects can be found at Annex B.

ANNEX A

Details of Awarded DHP Projects

SN	Value Chain	Proposal Title	Proposal Description	Project Investigator (PI) Team
1.	Safety and Regulatory Standards	Post-Release Impact Mitigation Evaluation (PRIME)	Project aim: To create a platform for developing standard testing methodologies and numerical simulation tools to: • Optimise land use and reduce Health and Safety (H&S) buffer zones • Identify inherently safer design concepts and mitigation measures • Implement risk-based metrics in regulatory guidelines and standards for ammonia-related infrastructure with public agencies (e.g., Major Hazards Department (MHD)). Potential benefits: Reducing H&S buffer zones would address our land constraints, where we do not have much land to allocate as safety buffers for new ammonia facilities. The research outcomes would also help quantify and mitigate risk from large-scale H_2/NH_3 storage in Singapore.	Lead PI Institute: Agency for Science, Technology and Research (A*STAR) Institute of Sustainability for Chemicals, Energy & Environment ($ISCE^2$) Lead PI: Dr Salim Shaik, A*STAR's $ISCE^2$ Project Team: Dr Nguyen Vinh-Tan, Institute of High Performance Computing (IHPC), A*STAR; Asst Prof Zhang Huangwei, NUS; and Dr Xu Linfang, Institute of Microelectronics (IME), A*STAR; Asst Prof Wong Wee Chin, Singapore Institute of Technology (SIT); Dr Kang Chang Wei, A*STAR's IHPC; Dr Lim Tau Yee, A*STAR's $ISCE^2$; Dr Cui Shan, National Metrology Centre (NMC), A*STAR; Dr Kai Fuu Ming, A*STAR's NMC

				Academic/Industry Collaborator(s): University of Surrey; University of Newcastle; Singapore Institute of Technology; Malayan Daching Co Pte Ltd; S. K. Rosenbauer Pte Ltd; Air Products Pte Ltd; Mitsubishi Heavy Industries Asia Pacific Pte Ltd; Bureau Veritas Marine Pte Ltd; Eaglestar Marine Pte Ltd; Bluenergy Solutions Pte Ltd; Jurong Port Pte Ltd; Assets Training & Technical Services Pte Ltd; MPiCS Innovation Pte Ltd; Centre for Strategic Energy and Resources Ltd; Itochu Singapore Pte Ltd; Kellogg Brown & Root Asia Pacific Pte Ltd; American Bureau of Shipping; Vopak Terminals Singapore Pte Ltd
2.	Ammonia Cracking	Energy-efficient Ammonia Cracking by 3D printing and system optimisation	Project aim: To develop a more efficient catalyst and reactor system for ammonia cracking, which has better heat utilisation and energy efficiency, and uses novel catalysts that can achieve efficient ammonia cracking with lower cost and higher durability. Potential benefits: Releasing H_2 from ammonia is an energy intensive process. An	Lead PI Institute: A*STAR's ISCE^2 Lead PI: Dr Poh Chee Kok, A*STAR's ISCE^2 Project Team: Dr Zhang Lili, A*STAR's ISCE^2; Prof Alex Yan Qingyu, Nanyang Technological University (NTU); Dr Zhang Jia, A*STAR's IHPC; Dr Wang Pei, A*STAR's IMRE; Dr Zhu

			improved and more efficient process will reduce the energy penalty of transporting H_2 in the form of ammonia and reduce the cost of H_2 adoption in Singapore.	Qiang, A*STAR's IMRE; Dr Zhang Zhiqian, A*STAR's IHPC; Dr Van Bo Nguyen, A*STAR's IHPC and Dr Ye Shaochun, A*STAR's NMC Academic/Industry Collaborator(s): Fudan University; Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences; Malayan Daching Co Pte Ltd; Kellogg Brown & Root Asia Pacific Pte Ltd; BNF Engineering Pte Ltd; Richz Holdings Pte Ltd; Vnergy Pte Ltd; CADFEM SEA; Measurement Advanced Engineering Pte Ltd; Fraction Technologies Pte Ltd; ST Engineering; Linde Gas Singapore Pte Ltd; KoolLogix Pte Ltd; Orient Technology Pte Ltd
3.	Ammonia Cracking	Development of on-site, on-demand ammonia-to-hydrogen e-cracking bench-top chemical mini-factory	Project aim: To develop a decentralised ammonia cracking technology that will strengthen the power-to-ammonia-to-usage value chain by ensuring efficient and strategic ammonia utilisation at the point of use. Potential benefits: Releasing H_2 from ammonia is an energy intensive process. An	Lead PI Institute: Nanyang Technological University (NTU) Lead PI: Prof Xu Zhichuan Jason, NTU Project Team: Prof Chen Wei, NUS; Prof Adrian Charles Fisher, Cambridge Centre for Advanced

			improved and more efficient process will reduce the energy penalty of transporting H_2 in the form of ammonia and reduce the cost of H_2 adoption in Singapore.	Research and Education in Singapore (CARES); Dr Kamal Elouarzaki, NTU; Dr Chen Luwei, A*STAR's ISCE^2; Asst Prof He Qian, NUS Academic/Industry Collaborator(s): NTU; University at Buffalo; AGC Asia Pacific Pte Ltd; Surbana Jurong Pte Ltd; Sydrogen Energy Pte Ltd; iSEACO Shipmanagement Pte Ltd; Synfuels China Technology Co. Ltd; China Hydrogen Energy Technology Co. Ltd; Jiangsu Mesocatalysis Materials Technology Co. Ltd
4.	Ammonia Utilisation	Development of an integrated system of ammonia partially cracking and gas turbine combustion with cascade waste heat utilisation	Project aim: To improve the integration of ammonia cracking technology and gas turbine (GT) combustion, achieving scalable advancements in decarbonising power generation. This is done through: (a) Developing scalable cracking technologies to partially decompose ammonia; (b) Enhancing flame stability of partially cracked ammonia; (c) Reducing NOx emissions from ammonia combustion; and (d) Integrating and scaling up the combustion and cracking system using efficient waste heat recovery.	Lead PI Institute: National University of Singapore (NUS) Lead PI: Asst Prof Zhang Huangwei, NUS Project Team: Assoc Prof Yan Ning, NUS; Asst Prof He Qian, NUS; Dr Nguyen Van Bo, A*STAR's IHPC; Assoc Prof Duan Fei, NTU; Dr Kang Chang Wei, A*STAR's IHPC; Prof Epaminondas Mastorakos, Cambridge

			Potential benefits: Integrating ammonia cracking with a gas turbine and recycling the waste heat from the turbine for use in the cracking process will not only increase the overall energy efficiency, but also reduce the land footprint for cracking which is critical for Singapore.	Centre for Advanced Research and Education (CARES) Academic/Industry Collaborator(s): Cardiff University; Tohoku University; King Abdullah University of Science and Technology; Siemens Energy Pte Ltd; Keppel New Energy Pte Ltd, Sembcorp Industries Ltd, CADFEM SEA Pte Ltd
5.	Hydrogen Transportation and Distribution	Light-weight, low leakage, high-pressure hybrid composite materials for hydrogen transmission, distribution, and on-board storage	Project aim: To develop H_2/NH_3 tolerant pipelines / storage tanks made up of novel advanced materials (multiscale multicomponent thermoplastic composites, MMTC) These pipelines/vessels would be • corrosion/embrittlement-free • tolerate higher working pressures (leading to higher transport/storage capacities) • display low leakage and high durability (making them very safe) • lightweight, and are recyclable/sustainable	Lead PI Institute: A*STAR's Institute of Materials Research and Engineering (IMRE) Lead PI: Dr He Chaobin, A*STAR's IMRE Project Team: Dr Zhang Yong-Wei, A*STAR's IHPC; Dr Kong Junhua, A*STAR's IMRE; Dr Natalaray Thaddie, A*STAR's Advanced Remanufacturing and Technology Centre (ARTC); Dr David Khoo Wee Yang, A*STAR's NMC; Prof Tay Tong-Earn, NUS; and Mr Ng Jun Wei, A*STAR's ISCE^2 Academic/Industry Collaborator(s):

			Potential benefits: Improve durability and safety of pipelines and vessels by preventing hydrogen embrittlement and leakage, addressing the foundational infrastructure issues that Singapore would need for deployment of hydrogen.	NTU; Polymore Materials Pte Ltd; SCG Chemicals Co Ltd; Aqua Power; ST Engineering; Halliburton Pte Ltd; TUV SUD; Cetim Matcor (Matcor Technology & Services Pte Ltd); BNF Industries Pte Ltd; New Universe Manufacturing Pte Ltd; Sunningdale Pte Ltd; Jurong Port Pte Ltd; SP Group; Measurement Advanced Engineering Pte Ltd; Omni Plus system; ECOPLUS International Pte Ltd; Cylinder Management Services
6.	Hydrogen Transportation and Distribution	In-Service Structural Health Monitoring (IS-SHM) for Predictive Maintenance	Project aim: To develop an in-service structural health monitoring (IS-SHM) platform for relevant infrastructure to enable the safe and cost-effective transportation / distribution of hydrogen. This platform addresses the limitations of current schedule-based or risk-based inspection, maintenance, and repair (IMR) strategy (e.g. operation interruptions, inefficiency due to unnecessary down time). Potential benefits: Provides a feasible and cost-effective way for the power and maritime sectors to monitor their hydrogen	Lead PI Institute: A*STAR's Institute for Infocomm Research (I^2R) Lead PI: Dr Dora Hu Juan Juan, A*STAR's I^2R Project Team: Dr Wang Yixin, A*STAR's I^2R; Dr Wang Xuejun, A*STAR's IHPC; Dr Liu Zhuangjian, A*STAR's IHPC; and Dr Zhang Lei, A*STAR's IMRE Academic/Industry Collaborator(s):

			pipelines, addressing the infrastructure issues that Singapore would need for deployment and large-scale adoption of hydrogen.	Norwegian University of Science and Technology; Sun Yat Sen University; NUS; iFocus Pte Ltd; Yokogawa Engineering Asia Pte Ltd; DNV Singapore Pte Ltd; SIMTRUM Pte Ltd; Wavelength Opto-Electronics (S) Pte Ltd; Rain Tree Photonics Pte Ltd; Penguin Marine Offshore Services Pte Ltd; HiPA Photonics Pte Ltd; PetroLNG Pte Ltd; CIMC Offshore Co Ltd; Vopak Terminals Singapore Pte Ltd

ANNEX B

Details of Awarded Projects Under the ETGC

SN	Research Theme / Value Chain	Proposal Title	Proposal Description	Project Investigator (PI) Team
1.	CCUS / Capture	High-throughput screening of redox-active adsorbents for electrochemically mediated carbon capture	Project aim: This proposal develops an energy efficient and space efficient carbon capture technology that can capture CO_2 from low-concentration sources, using electrochemically mediated carbon capture (EMCC) concepts. Potential benefits: Promote a solution to capture diluted flue gas from power generation facilities.	Lead PI Institute: National University of Singapore (NUS) Lead PI: Asst Prof Mao Xianwen, NUS Academic/Industry Collaborator(s): NUS; Massachusetts Institute of Technology; Altara Infrastructure Services Pte Ltd
2.	CCUS / Capture	A New Class of Two-Dimensional Covalent Organic Framework-Based Membranes for Competitive Carbon Capture	Project aim: This proposal develops an energy efficient and space efficient carbon capture technology that can capture CO_2 from various sources with versatility, using covalent organic framework (COF)-based membranes concepts.	Lead PI Institute: Nanyang Technological University (NTU) Lead PI: Prof Wang Rong, NTU Project Team:

			Potential benefits: Promote a solution to capture CO_2 from both flue gas and syngas of power generation facilities.	Prof Zhao Yanli, NTU Academic/Industry Collaborator(s): State University of New York
3.	CCUS / Capture	High efficiency, direct CO2 capture using direct joule heating of conductive, porous solid absorbents	Project aim: This proposal develops an energy efficient and space efficient carbon capture technology that can capture CO2 from low-concentration sources, using electrically-powered Absorbents. Potential to be retrofitted to current CCUS modules that are based on amine-based technologies. Potential benefits: Promote a solution to capture diluted flue gas from power generation facilities.	Lead PI Institute: NUS Lead PI: Prof Barbaros Oezyilmaz, NUS Project Team: Assoc Prof Daria Andreeva-Baeumler, NUS; Prof Konstantin Sergeevich Novoselov, NUS Academic/Industry Collaborator(s): NUS; SS-Alloy Co Ltd
4.	CCUS / Utilisation	Plastic waste upcycling through polyolefin functionalization with carbon dioxide	Project aim: This proposal combines waste streams of carbon dioxide and plastics and upcycle it in a carbon-negative process using cheap base metal catalysis.	Lead PI Institute: NUS Lead PI: Assoc Prof Koh Ming Joo, NUS

			Potentially scalable, as plastic waste is the fourth largest solid waste stream currently. Potential benefits: Valorising two waste products, carbon dioxide and plastics, towards a circular economy.	Project Team: Dr Jason Lim Yuan Chong, A*STAR's IMRE; Assoc Prof Wu Jie, NUS
5.	CCUS / Utilisation	Enzymatic CO2 utilization: towards efficient biocatalytic carboxylation of aromatics to produce useful chemicals	Project aim: This proposal aims to engineer enzymes that turns carbon dioxide into useful acids/chemicals with enhanced activity and stability. Potential benefits: Potential to produce useful chemicals in a carbon-negative process, as well as environmentally friendly way (i.e. no need high temperature/pressure).	Lead PI Institute: NUS Lead PI: Assoc Prof Li Zhi, NUS
6.	H2 / Ammonia Cracking	Rational design of single-atom catalysts toward ammonia electrooxidation	Project aim: This proposal cracks ammonia in a more efficient manner using novel electricity-powered catalysts.	Lead PI Institute: NUS Lead PI: Asst Prof Zhao Ming, NUS Project Team:

			Potential benefits: A possible solution to obtain hydrogen as a by-product, which can be used for other purposes (i.e. power generation).	Prof Chen Wei, NUS Academic/Industry Collaborator(s): Huazhong University of Science and Technology
7.	H2 / Ammonia Cracking	Development of decentralized, on-demand ammonia-to-hydrogen e-cracking chemical mini-plant using decoupled split pH fuel cell	Project aim: This proposal cracks ammonia in a more efficient manner using components of a fuel cell. Potential benefits: The proposed setup will not require energy inputs as it can be powered by the hydrogen generated via the fuel cell. A possible solution to obtain hydrogen as a by-product, which can be used for other purposes (i.e. power generation).	Lead PI Institute: NTU Lead PI: Dr Kamal Elouarzaki, NTU Project Team: Prof Jason Xu Zhichuan, NTU; Prof Adrian Charles Fisher, CARES
8.	H2 / Hydrogen Transportation and Distribution	Coatings Development for the Prevention of Hydrogen Embrittlement of	Project aim: This proposal develops a novel coating that is suitable to increase the hydrogen resistance of infrastructure.	Lead PI Institute: A*STAR's Institute of Sustainability for Chemicals, Energy & Environment ($ISCE^2$) Lead PI:

		Large Infrastructural Components	Potential benefits: This supports the retrofitting of existing surfaces, which makes it more versatile than developing entire components made of hydrogen-resistant composites or alloys from scratch.	Dr Satyasankar Jana, A*STAR's ISCE^2 Project Team: Dr Krishna Mohan Gupta, A*STAR's ISCE^2
9.	H2 / Hydrogen Transportation and Distribution	Enhancing Hydrogen Pipeline Connectivity with Novel Impermeable and Repairable Thermoplastic Composite Couplers	Project aim: This proposal develops pressure-resistant composite couplers that link pipe infrastructure together for hydrogen transportation. Potential benefits: Possibly provides an efficient solution for connecting retrofitted metallic natural gas pipelines to fibre reinforced thermoplastic (FRTP) pipes, addressing material compatibility, structural design, and pressure resistance.	Lead PI Institute: A*STAR's Singapore Institute of Manufacturing Technology (SIMTech) Lead PI: Dr Wang Chen, A*STAR's SIMTech Project Team: Dr Su Zhoucheng, A*STAR's IHPC; Dr Logesh Shanmugam, A*STAR's SIMTech Academic/Industry Collaborator(s): NUS; NTU; Hanyang University; Arkema Pte Ltd

10.	Others / Energy Harvesting	Plug flow pattern for harvesting rain energy via solid-liquid charge separation	Project aim: This proposal proposes the harvesting of electricity from rain droplets using advanced types of materials. Potential benefits: This can be applicable for tropical settings due to the heavy rainfall and be an alternative way for Singapore to generate renewable electricity.	Lead PI Institute: NUS Lead PI: Assoc Prof Soh Siow Ling, NUS Project Team: Assoc Prof Zhao Dan, NUS