ANNEX A

DETAILS OF AWARDED PROJECTS

SN	Research Theme	Proposal Title	Proposal Description	Project Investigator (PI) Team
1.	Hydrogen (H_2)	Ammonia Cracking: New Catalyst Development, Reaction Engineering and System Design	Project aim: To develop more efficient processes to release H_2 from ammonia, by examining the development of robust and efficient ammonia cracking technologies suitable for use in Singapore. Potential benefits: H_2 is difficult to transport in its native state, which requires high pressures and extremely cold temperatures to compress. One way to make it easier to transport is to convert the H_2 into a carrier such as ammonia. However, releasing H_2 from ammonia is an energy intensive process. An 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.	PI Institute: National University of Singapore (NUS) Lead Project Investigator: Assoc Prof Yan Ning, NUS Project Team: Prof Chan Siew Hwa, NTU and Asst Prof He Qian, NUS; Academic/Industry Collaborator(s): Surbana Jurong Infrastructure Pte Ltd and NUS

2.	H_2	Miniature H_2 leakage and purity sensors for downstream H_2 use	Project aim: To develop two types of H_2 sensors, a hydrogen purity sensor and a hydrogen leakage sensor, with small form factor, high selectivity minimal interferences and immunity to poisoning for downstream use. Standards will also be created for H2 sensors evaluation and quality. Potential benefits: Improve the safety of H_2 use, allow deployment of sensors economically to enable trading and safety and increase confidence towards adoption of H2 for downstream uses.	PI Institute: Institute of Microelectronics (IME), Agency for Science, Technology and Research (A*STAR) Lead Project Investigator: Dr. Doris Ng Keh Ting, A*STAR's IME Project Team: Dr Cai Hong, A*STAR's IME; Dr Kai Fuu Ming, National Metrology Centre (NMC), Agency for Science, Technology and Research (A*STAR); Assoc Prof Zhao Dan,NUS; Dr Liu Jihang, A*STAR's IME; and Dr Subhranu Samanta, A*STAR's IME Academic/Industry Collaborator(s): Hydrogen and Fuel Cell Association of Singapore (TAC)
3.	H_2	Methane Pyrolysis for H_2 and Carbon Nanotube Production via Novel Catalytic Membrane Reactor System	Project aim: To develop an improved process for methane pyrolysis, i.e. catalytic cracking and separating natural gas/methane into H_2 gas and solid carbon. It examines development of a novel bi-functional catalytic membrane reactor (CMR) process, where ultra-pure H_2 and highly-ordered carbon nanotubes (CNTs) are co-produced via methane (natural gas) pyrolysis process with zero carbon dioxide (CO_2) emission.	PI Institute: NUS Lead Project Investigator: Assoc Prof Sibudjing Kawi, NUS Project Team: Prof Wang Chi-Hwa, NUS; Assoc Prof Yang Wenming, NUS; and Dr Chang Jie, Institute of Chemical and Engineering Sciences (ICES), Agency for Science, Technology and Research (A*STAR)

			Potential benefits: Methane pyrolysis is a potential pathway to producing low-carbon H_2 in Singapore. The process is currently costly and energy intensive. If successful, this can reduce the cost of H_2 production in Singapore whilst producing valuable carbon products at the same time.	Academic/Industry Collaborator(s): Dyna Mac Engineering Services; Sembcorp Industries Ltd; University of California@Davis; Curtin University; Université de Toulouse-Centre RAPSODEE-CNRS and A*STAR's ICES,
4.	H_2	Liquid Organic Hydrogen Carriers (LOHCs) Technology for Singapore	Project aim: To develop new catalysts and systems to reduce the costs of extracting hydrogen from methylcyclohexane (MCH) as an LOHC technology and to design a minimum-cost hydrogen supply chain network for Singapore. Project benefits: MCH can be transported in liquid state at ambient conditions using the existing petroleum infrastructures, but the process to extract hydrogen from the MCH molecule requires high-performance and cost-effective catalyst and is energy intensive. This proposal could improve the performance and reduce the cost of existing SPERA catalyst from Chiyoda and design new reactors of better heat transfer, therefore reducing the cost of importing hydrogen using this carrier. A comprehensive financial model to access	PI Institute: NTU Lead Project Investigator: Prof Xu Rong, NTU Project Team: Asst Prof Tej Choksi, NTU; Assoc Prof Raymond Lau Wai Man, NTU; Asst Prof Paul Liu, NTU; Assoc Prof Alessandro Romagnoli, NTU; Prof Iftekhar A. Karimi, NUS; Prof Farooq Shamsuzzaman, NUS Academic/Industry Collaborator(s): Chiyoda Corporation; PSA Corporation Limited; Sembcorp Industries Ltd; City Gas Pte Ltd; Jurong Port Pte Ltd; Singapore LNG Corporation and Mitsubishi Corporation;

			the cost of the hydrogen supply chain in Singapore will also be developed by collaborating with our industrial partners.	
5.	Carbon Capture, Utilisation and Storage (CCUS)	Alternative Sand from Carbon Dioxide and Waste Materials	Project aim: To examine the processes for the capture and mineralisation of CO_2 into alternative sand that can be used for building and construction purposes. Project benefits: Captured CO_2 can be used to make useful products such as construction material in this case.	PI Institute: A*STAR's ICES Lead Project Investigator: Dr. Bu Jie, A*STAR's ICES Project Team: Asst Prof Liu Wen, NTU; Assoc Prof Pang Sze Dai, NUS; and Mr Yeo Tze Yuen, A*STAR's ICES Academic/Industry Collaborator(s): Samwoh Innovation Centre Pte Ltd and EnGro Corporation Ltd
6.	CCUS	Capturing waste with waste: Continuous carbon capture using highly efficient sorbents derived from	Project Aim: To develop a carbon capture process (calcium looping) by using novel sorbents derived from calcium-rich incineration ashes, collected from Singapore's waste-to-energy facilities. Potential benefit: This will enable the use of incineration ash, which is a waste material, for CO_2 capture. Both waste streams: incineration ashes and CO_2, can be	PI Institute: Nanyang Technological University (NTU) Lead Project Investigator: Asst Prof Liu Wen Paul, NTU Project Team: Prof Simon Redfern, NTU; Snr Scientist Dr Bu Jie, A*STAR's ICES; Asst Prof Grzegorz Lisak, NTU; Prof Lim Teik Thye, NTU; Snr Research Fellow Dr Andrei

		incineration ashes	subsequently turned to sustainable construction materials after carbon capture.	Veksha, NTU and Snr Research Fellow Dr Chan Wei Ping, NTU Academic/Industry Collaborator(s): Surbana Jurong Infrastructure Pte Ltd; Mursun Pte Ltd; Tsinghua University; and Kunming University of Science and Technology
7.	Carbon Capture, Utilisation and Storage (CCUS)	Towards Energy Efficient Electrochemical CO_2 Reduction to Synthetic Chemicals: A Paradigm Shift in Sustainable Chemical Production	Project aim: To examine the development of a sustainable technology to produce important commodity chemicals for Singapore (e.g., ethylene and propanol), using only CO_2 and water as feedstock. Thus, reduce the energy intensity of producing chemicals from CO_2. Potential benefits: Converting CO_2 to fuels/chemicals is a potential utilisation pathway for captured CO_2. Reducing the energy requirement for such processes will improve the economic viability of such CO_2 utilisation pathways.	PI Institute: NUS Lead Project Investigator: Prof Chen Wei, NUS Project team: Prof Xu Zhichuan, NTU; Dr Zhang Jia, Institute of High Performance Computing (IHPC), A*STAR; Asst Prof Lum Yanwei, Institute of Materials Research and Engineering (IMRE), A*STAR/NUS; Asst Prof Wang Lei, NUS; and Asst Prof Hou Yi, NUS Academic/Industry Collaborator(s): NUS; Stanford University; Tsinghua University and ExxonMobil.
8.	CCUS	Development and module scale validation of novel hollow	Project Aim: To develop more efficient ways to capture CO_2 from exhaust streams. It aims to develop and validate hollow fiber membranes for efficient carbon capture via novel chemistry and machine learning. The	PI Institute: NUS Lead Project Investigator: Asst Prof Zhang Sui, NUS

		fiber membranes for CO_2 capture	performance of the developed and scaled membranes will be validated through in-house pilot testing under simulated conditions as well as field-testing on larger pilot under real-world conditions. Potential benefits: To improve the capture efficiency of CO_2 from existing exhaust/flue gas which is the first step in CCUS.	Project Team: Provost Chair Prof Neal Chung Tai-Sheng, NUS and Dr Gudipathi Chakravarty, START, NTUitive Academic/Industry Collaborator(s): Chevron Singapore Pte Ltd; Surbana Jurong Infrastructure Pte Ltd and NUS
9.	CCUS	Stable and long term carbon dioxide hydrate based storage (CO_2-HyStore) in deep ocean sediments	Project aim: To demonstrate a proof-of-concept requiring design, build and validation of potential of CO_2 storage in deep-ocean sediments as gas hydrates. It will help to validate the possibility of storing CO_2 in deep ocean sediments (as opposed to conventional sites which require specific geological formations) Potential benefits: This may open possibilities for long term storage of captured CO_2.	PI Institute: NUS Lead Project Investigator: Prof. Praveen Linga, NUS Academic/Industry Collaborator(s): ExxonMobil; NUS; Purdue University and Lawrence Berkeley National Laboratory
10.	CCUS	Process Systems Engineering for Guiding R&D on Low-Carbon Technologies	Project aim: This project proposes a new paradigm in which materials research is conducted under the continuous of Process Systems Engineering (PSE) in order to keep focus on the KPIs right from the start of research.	PI Institute: NUS Lead Project Investigator: Prof Iftekhar A Karimi. NUS Project Team: Prof Shamsuzzaman Farooq, NUS

			Potential benefits: It develops digital toolkits that predict the system-level performances of several CCUS and H_2 projects, helping to guide them to faster and successful scale-up.	Academic/Industry Collaborator(s): ExxonMobil and NUS
11.	CCUS	Adsorptive Carbon Capture Using Framework Materials	Project Aim: To develop more efficient ways to capture CO_2 from exhaust streams. This project enhances CO_2 capture by using state-of-the-art framework sorbents engineered for high CO_2 selectivity, high intrinsic stability, and facile regenerability from moisture. Potential benefits: Improve the capture rate of CO_2 from existing exhaust/flue gas which is the first step in CCUS.	PI Institute: NUS Lead Project Investigator: Assoc Prof Zhao Dan, NUS Project Team: Assoc Prof Jiang Jianwen, NUS; Prof Shamsuzzaman Farooq, NUS; Prof Jiang Donglin, NUS; and Asst Prof Grzegorz Lisak, NTU Academic/Industry Collaborator(s): ExxonMobil; NUS; and Northwestern University
12.	CCUS	Nanostructured Catalysts for Direct CO_2 Hydrogenation to Higher Alcohols and Fuels	Project aim: To reduce the energy intensity of producing higher alcohols and fuels from CO_2. It examines development of nanostructured catalysts and computational capability in catalyst design and reaction modelling, including process optimisation. Potential benefits: CO_2 to fuels/chemicals is a potential utilisation pathway for captured	PI Institute: NUS Lead Project Investigator: Prof Zeng Hua Chun, NUS Project Team: Asst Prof Paul Wen Liu, NTU; Scientist Dr Kelvin M.Y. Kwok, A*STAR's ICES; Asst Prof

			CO_2. Reducing the energy requirement for such processes will improve the economic viability of such CO_2 utilisation pathways.	He Qian, NUS; Assst Prof Sergey Kozlov, NUS; and Assoc Prof Jiang Jianwen, NUS Academic/Industry Collaborator(s): NuStar Technologies and NUS