Annex

ABOUT THE RESEARCH GRANT PROJECTS

GAS TECHNOLOGY PROJECTS			
No.	**Title**	**Description**	**Project Team**
Harvesting cold energy from the conversion of liquefied natural gas (LNG) to natural gas			
1.	Using Cold Energy from Re-gasification of Liquefied Natural Gas (LNG) for Novel Hybrid Seawater Desalination Technologies **Project summary:** Using energy from LNG re-gasification for clean water and salt production	Liquefied natural gas (LNG) imported by Singapore's LNG Terminal must first be re-gasified (through transfer of heat from the warmer seawater) before it can be used. The amount of cold energy produced by LNG re-gasification is a high-quality energy source. However, this energy is currently not harvested for any use. This project will develop novel membrane-based desalination technologies for potable water production that taps on the cold energy from LNG re-gasification. The process will provide Singapore with new desalination technologies and new business opportunities in the field of clean water and salt production.	**Principal Investigator:** Prof Neal Chung Tai-Shung, NUS **Co-Investigator:** NUS **Collaborators:** NUS; Jiangsu Kaimi Technology Co Ltd (China); PUB; West Pomeranian University of Technology (Poland); New Jersey Institute of Technology (US)
2.	LNG Cold Energy Utilisation to Desalinate Seawater Employing the Hydrate Based Desalination (HBD) Process **Project summary:** Harvesting energy from LNG re-gasification to desalinate sea water	Conversion of natural gas to liquefied natural gas (LNG) requires the cooling of natural gas to a very low temperature (-162 °C). The cold energy harvested from the conversion can potentially be used to warm the LNG back into the gaseous phase (20°C) for use in power generation. However, most LNG terminals worldwide currently do not harvest this cold energy during LNG re-gasification. The project will develop and test a hydrate based desalination (HBD) process to harvest this cold energy to desalinate seawater. The research work is of interest to Singapore as it could potentially contribute to addressing our energy and water challenges through an environmentally benign process.	**Principal Investigator:** Asst Prof Praveen Linga, NUS **Co-Investigators:** NUS **Collaborators:** BG Group (Singapore)
Monitoring gas pipelines for damage			

3.	Advanced Multi-Sensor Anomaly Monitoring and Analytics for Gas Pipelines **Project summary:** Robust monitoring system for detecting anomalies in gas pipelines	Robust and real-time condition monitoring of the underground gas distribution network in Singapore is critical to ensure interruption-free power supply. Advanced monitoring of the underground gas pipelines using signature parameters, such as temperature and pressure, will allow for early detection of anomalies like leakages and third-party damages. This project will use advanced analytics on signature parameters collected from the pipelines, as well as pipeline traceability information and historical data, to identify locations requiring preventive maintenance and potential failure-prone zones along the gas pipelines. Field testing will be done at the test-rig provided by SP PowerGrid as the project collaborator.	**Principal Investigator:** Asst Prof Abhisek Ukil, NTU **Co-Investigator:** NTU **Collaborators:** SP PowerGrid – Powergas; ENGIE
4.	Condition Monitoring of Gas Pipelines in Critical Locations using Ultrasonic Guided Wave Technology **Project summary:** Real-time monitoring system for detection of corrosion in gas pipelines	Close monitoring of the change in pipeline wall thickness will help estimate the corrosion rate of the pipe networks for cost-effective operations and also pre-empt gas leakages. Currently, this requires the manual scanning of probes over gas pipelines, which is tedious and challenging for remote locations. This project will use ultrasonic guided wave technology, in conjunction with tomography principles, to establish an on-line condition monitoring system for critical areas in the pipeline network susceptible to corrosion. The system will be able to accurately measure corrosion rates and send early warning signals immediately when the thickness of a region is below a threshold. This will save costs in setting up measurements for difficult-to-access regions.	**Principal Investigator:** Asst Prof David Fan, NTU **Collaborators:** Lloyd's Register Global Technology Centre; Sembcorp Industries
5.	Integrated Fibre Optic Sensor Based Monitoring System for LNG Terminal **Project summary:** Non-intrusive system to detect anomalies in gas facilities and pipelines	Liquefied natural gas (LNG) is an important fuel source for Singapore, and the safe operation of the Singapore LNG Terminal will contribute to a secure energy supply for Singapore. However, the cryogenic environment of LNG presents challenges for safety monitoring and consequence analysis of potential incidents at the LNG terminal, including LNG rollover, tank and gas pipeline leakages. This project will develop a real-time monitoring system using Fibre Bragg Grating (FBG) cryogenic sensors for the safe monitoring and incident consequence analysis of LNG terminals. The incident consequence analysis will estimate the likelihood of potential hazards and their consequences, leading to safer operation of LNG terminals.	**Principal Investigator:** Assoc Prof Cai Wenjian, NTU **Co-Investigators:** NTU **Collaborators:** Purdue University (US); University of Alberta (Canada); Shandong University (China); Xi'an Jiaotong University (China); SLNG
6.	Millimetre-wave Phased Arrays	Onshore receiving facilities (ORF) and gas pipelines are critical assets in gas	**Principal Investigator:**

	System for the Inspection of Cracks, Corrosion and Damages for On-Shore Receiving Facilities (ORF) & Pipelines **Project summary:** Detection and localisation of cracks and damages in gas network	transportation and the petrochemical supply chain. To protect ORF and gas pipelines from corrosion, impact and cracks, a variety of insulation methods such as rock shield, high density polyethylene, paint and primer are used. However, corrosion, cracks or damage could still potentially set in and affect the integrity of ORF and gas pipelines. The project will design and develop a handheld, real-time, near-field millimeter-wave phased array-based non-destructive inspection system that can rapidly detect cracks, corrosion and damages on the ORF and pipelines (which may be insulated) with high accuracy and resolution. This will help minimise disruption and downtime to our gas supply.	Dr Muhammad Faeyz Karim, I^2R, A*STAR **Co-Investigator:** I^2R, A*STAR **Collaborators:** Olympus Singapore; Asian Resources Centre
7.	Integrated Leakage Detection and Localisation Model for Natural Gas Pipelines **Project summary:** More efficient monitoring of gas pipelines for early detection of issues	Pipelines play a significant role in the safety, reliability and efficiency in oil and natural gas transportation. The majority of pipelines is buried and often passes through remote areas as well as heavily built-up cities, such as Singapore. The occurrence of small leaks (leak flow < 1.0%) caused by pipeline cracks, corrosion, pressure surges and third-party interference are increasing. To ensure the safe operation of gas pipelines, operators of these systems face the challenging task of detecting and locating these leaks. This project will develop a method that includes a reliable and computationally efficient model to detect and identify the leakage and to pinpoint the location of the leakage in a high-pressure transmission gas pipeline network. The integrated leak detection and localisation system employs *state estimation* technique that incorporates mass/volume balance and the acoustic wave signal samples. This project can enhance pipeline transmission safety and reliability for oil and gas industry operators and contribute in elevating Singapore's technical and research capabilities in natural gas transportation and transmission.	**Principal Investigator:** Dr Luo Rongmo, NMC, A*STAR **Co-Investigators:** NMC, A*STAR; NUS **Collaborators:** SP PowerGrid

Increasing energy efficiency of the LNG Terminal on Jurong Island			
8.	Energy Minimisation at the SLNG Re-gasification Terminal: Boil-off Gas Management and Process Integration **Project summary:** Reducing energy consumption of LNG terminals through operation simulation and optimisation	Storage and the long distance transport of natural gas requires it to be in a very cold liquid state (at -162 ºC) and at atmospheric pressure, known as liquefied natural gas (LNG). Due to its low temperature, LNG is continually vaporised at the receiving re-gasification terminal, producing boil-off gas (BOG). For transportation of natural gas within our gas network, the pressure of the BOG needs to be increased from atmospheric pressure to the higher pressure of the gas network. This requires considerable energy and is a major operating cost for LNG terminals. This project will develop and evaluate ways to reduce the overall energy consumption of LNG terminals through modelling, simulation, and optimisation. If implemented, the promising options could help enhance LNG terminals' energy efficiency and reduce operational costs.	**Principal Investigator:** Prof Iftekhar A Karimi, NUS **Co-Investigators:** NUS **Collaborators:** SLNG

SMART GRIDS PROJECTS			
No.	**Title**	**Description**	**Project Team**
Enhancing the security of our electricity grid against cyber-attacks			
1.	PoPSeCo: Power Plant Security through Advanced Sensing and Computing **Project summary:** Innovative and cost-effective grid security solutions against cyber attacks	The increasing use of information and communication technologies in the power sector has resulted in improved system efficiency, but it has also given rise to greater cyber-security risks. This project will develop innovative sensing and detection approaches for Singapore's power system that cost less than existing market solutions with comparable cyber-attack detection capabilities. It will be piloted at Senoko Energy's facilities.	**Principal Investigator:** Prof David Yau, Singapore University of Technology and Design (SUTD) **Co-Investigators:** NTU; SUTD; Power Automation **Collaborators:** Senoko Energy; Ministry of Home Affairs; University of Illinois Urbana-Champaign (US); Argonne National Laboratory (US); Purdue University (US)
2.	Securing Last-Mile Communication Systems for Smart Grids **Project summary:** Multi-layer protection system to enhance security of grid with wireless/wired networks and other smart applications	Grid monitoring and management is usually implemented today using wire-line networks. Wireless networks are more cost-effective, but are assessed to be less secure. This project will develop a multi-layer protection system against security threats (e.g. data eavesdropping, malware injection, Denial-of-Service attacks) associated with last-mile communication systems for smart grids in Singapore and overseas. A test-bed will be deployed to validate the developed system.	**Principal Investigator:** Dr Wu Yong Dong, I^2R, A*STAR **Co-Investigators:** Advanced Digital Sciences Centre (ADSC); I^2R, A*STAR; Mirai Electronics **Collaborators:** University of Illinois at Urbana-Champaign (US); University of Malaga (Spain); R&D Centre for Logistics and Supply Chain Management Enabling Technologies (Hong Kong)

Managing the impact of intermittent solar energy generation on the stability of the power grid			
3.	Ramp Rate Power Injection Demonstrator (RAPID) **Project summary:** Innovative energy storage control methods to better control power injection and mitigate the effects of intermittent solar PV energy generation on the stability of the grid	Energy storage systems have the potential to mitigate fluctuating power output from intermittent generation sources such as solar photovoltaic (PV). These systems, however, require proper design, ramp-up and ramp-down control and management to function optimally. This project will build a 200kW technology-agnostic ramp rate power injection demonstrator platform, which can test and validate near-to-market energy storage control solutions for grid applications. It aims to reduce the overall distributed energy storage systems capacity by up to 50 percent compared with current methods.	**Principal Investigator:** Dr Inam Ullah Nutkani, EPGC, A*STAR **Co-Investigators:** EPGC, A*STAR **Collaborators:** Meiden; SP PowerGrid
Developing smarter and more efficient energy systems			
4.	Novel Hierarchical Transactive Energy Management System Incorporating Predictive Assessment Techniques for Enhanced Community Market Participation **Project summary:** More efficient energy management system that is also responsive to demand and market price fluctuations	Existing energy management systems (EMS) are computationally demanding and complicated. This project will develop a lightweight, scalable, and hierarchical transactive system that improves the co-ordination and control of intermittent distributed energy sources and increases end-user energy efficiency. It will also yield an assessment tool that can facilitate the participation of loads in a demand response market. This project will be piloted at Nanyang Technological University.	**Principal Investigator:** Assoc Prof Gooi Hoay Beng, NTU **Co-Investigators:** NTU; Energy Research Institute@NTU **Collaborators:** Clean Technology Centre, DNV GL – Energy
5.	Self-Regulating Integrated Electricity-Cooling Networks (IE-CN) **Project summary:** Hybrid electrical-thermal energy storage network for wider application of district cooling systems	District cooling is the centralised production and distribution of chilled water to clusters of commercial and industrial buildings within a district, for cooling and other purposes. Thermal energy storage can be an integral part of district cooling networks. For example, liquid in tanks can be cooled down into "ice" when electricity prices are low. This "ice" can then be melted to produce chilled water when electricity prices are high, allowing the chillers to be ramped down during such times. The project will develop a novel hybrid energy storage system that combines conventional energy storage systems (e.g. lithium-ion batteries) coupled with thermal energy storage in district cooling systems. The project will give rise to an innovative integrated electricity-cooling network that has the potential to participate in the frequency regulation electricity market.	**Principal Investigator:** Dr Chai Chin Choy, I²R, A*STAR **Co-Investigator:** Singapore District Cooling, Singapore Power **Collaborators:** I²R, A*STAR; Clean Technology Centre, DNV GL – Energy; Singapore District Cooling, Singapore Power