# SMART DEMAND SIDE MANAGEMENT (SMART-DSM) INTEGRATION WITH ENERGY EFFICIENT THERMAL STORAGE SYSTEM

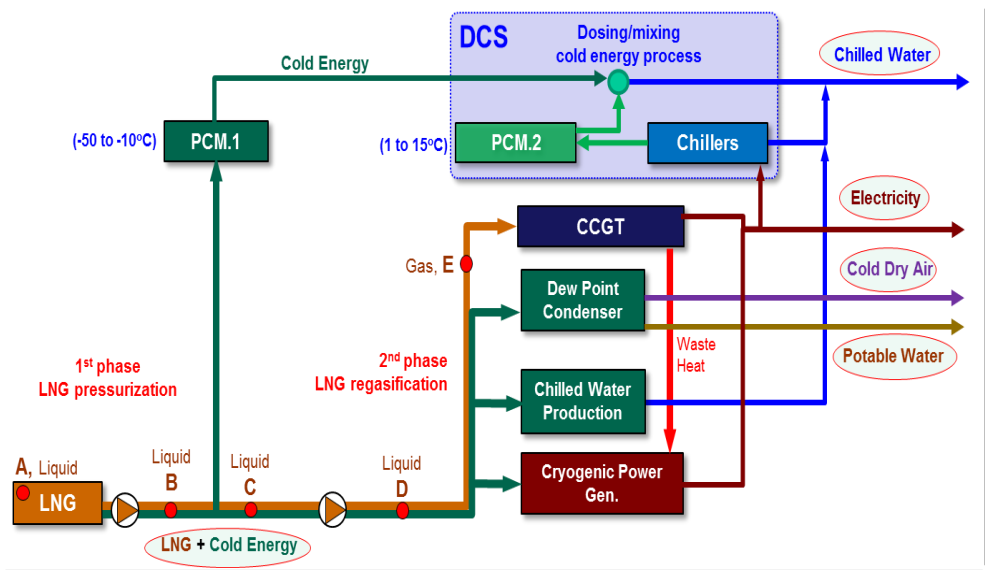
## PROJECT SUMMARY

Regasification of Liquefied Natural Gas (LNG) for combustion in power plants often results in a large amount of latent cold energy being lost to the environment via seawater. Cold recovery methods from the regasification seek to utilise the cold energy in various applications to prevent complete loss of this energy to the environment.

A multi-stage cascading cold recovery system concept is established in this work, which is conceived as part of a larger decentralised, district-level combined cooling, heat and power (CCHP) plant to efficiently utilise the cold energy being harvested. The core technology explored in this study are latent thermal energy storage (LTES) systems, which uses solid-liquid phase-change materials (PCM) for higher thermal energy storage capacities.

The study focuses on two core applications of such PCM LTES in the overall context of a CCHP:
i. "Cold" energy storage for a District Cooling System (DCS)
ii. Low temperature cryogenic cold energy extraction from LNG regasification

The core advantages of LTES systems over conventional ice and chilled water storage systems are the higher thermal energy storage densities as well as the flexibility in phase-change properties to accommodate a wide range of operating temperatures and conditions. Tailoring the PCM and system design to better fit the application also allows for long-term cost savings.



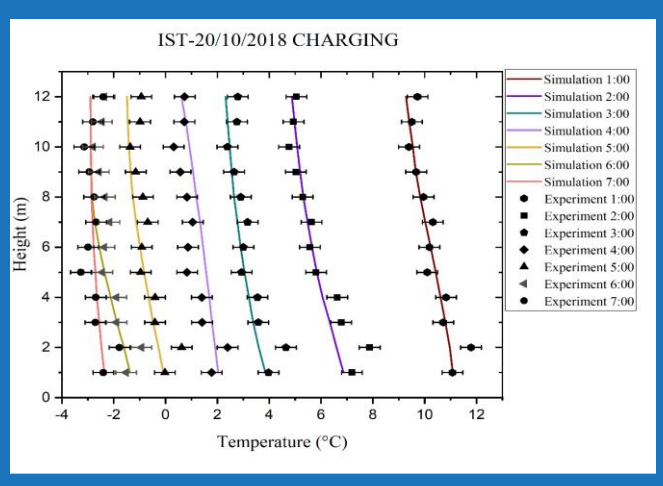

*Schematic of CCHP integrated with LNG regasification system concept*

*Pilot-scale PCM LTES integrated into DCS @ Keppel DHCS*

## PROJECT OUTCOMES

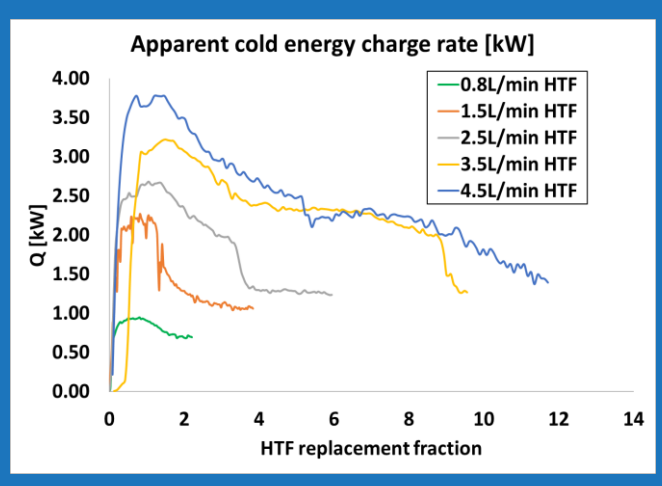
1. Integration of PCM LTES in District Cooling System (DCS)
   - Novel paraffin mixture PCM developed for commercial DCS operating temperature range (5 – 12$^0$C).
   - Developed a computational fluid dynamics model for modelling sphere type PCM packed beds, and validated with industrial data (obtained from Keppel DHCS) from an encapsulated ice storage system and lab-scale paraffin-based encapsulated PCM LTES test rig.
   - 150RTh Pilot-scale PCM LTES tank designed for integration into existing DCS at Keppel DHCS Changi Business Park.
   - **Key Findings:**
     - ✓ **Up to 3 times thermal energy storage density compared to chilled water storage tank**
     - ✓ **Around 12% annual cost savings and up to 8 years payback period**

2. Low-temperature cold energy recovery from LNG regasification
   - Multi-stage cascading recovery system for generation of low-temperature latent thermal storage, chilled water cooling, dehumidification and electrical power.
   - Designed, simulated and constructed lab-scale PCM LTES heat-exchanger using commercial eutectic salt-based PCM.
   - Validation of system-level thermodynamic model and genetic algorithm employed for optimisation of design and analysis of scalability.
   - **Key Findings:**
     - ✓ **Between 60-80% realisable cold recovery efficiency under experimental conditions**
     - ✓ **High scalability for optimal operating conditions over large range of LNG flow rate demands**




*Validation of sphere-column model with commercial ice storage tank*

*Freezing of synthesized paraffin-based PCM in lab-scale EPCM LTES test rig*




*Cold energy storage rates versus HTF replacement fraction of the cryogenic PCM LTES heat exchanger over different HTF flowrates*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