LIQUEFIED NATURAL GAS POWER GENERATION FROM GAS TURBINE AND STIRLING ENGINE

PROJECT SUMMARY

The project developed a novel combined system using a microturbine unit and a thermoacoustic Stirling engine. It targets to improve power generation efficiency of gas turbines.

- The LNG is regasified to natural gas to feed the microturbine unit for the first electric power generation. The waste heat from the exhaust gas of the microturbine is stored in a phase change material (PCM)-based energy storage tank.
- The cryogenic energy is utilised in the cold heat exchanger part of the novel self-designed thermoacoustic Stirling engine, while the storage hot energy is used to maintain the hot heat exchanger of the engine. Between the hot and cold end heat exchangers, the Stirling engine produces zero-emission power for the second electric power generation.

The combined system can be used for power generation, hot water/steam generation and even carbon dioxide (CO_2) capture purposes. In the project, micro-scale engineering studies have been performed to develop the novel thermoacoustic engine design and PCM thermal energy storage tank. The component-scale studies provide the performance improvements of energy efficiency and power generation. Following the component-scale studies, system-scale performance assessments have been conducted according to daily, weekly, monthly, and annual data by applying the thermodynamics, economics, environmental, and sustainability models including life cycle analysis approaches.

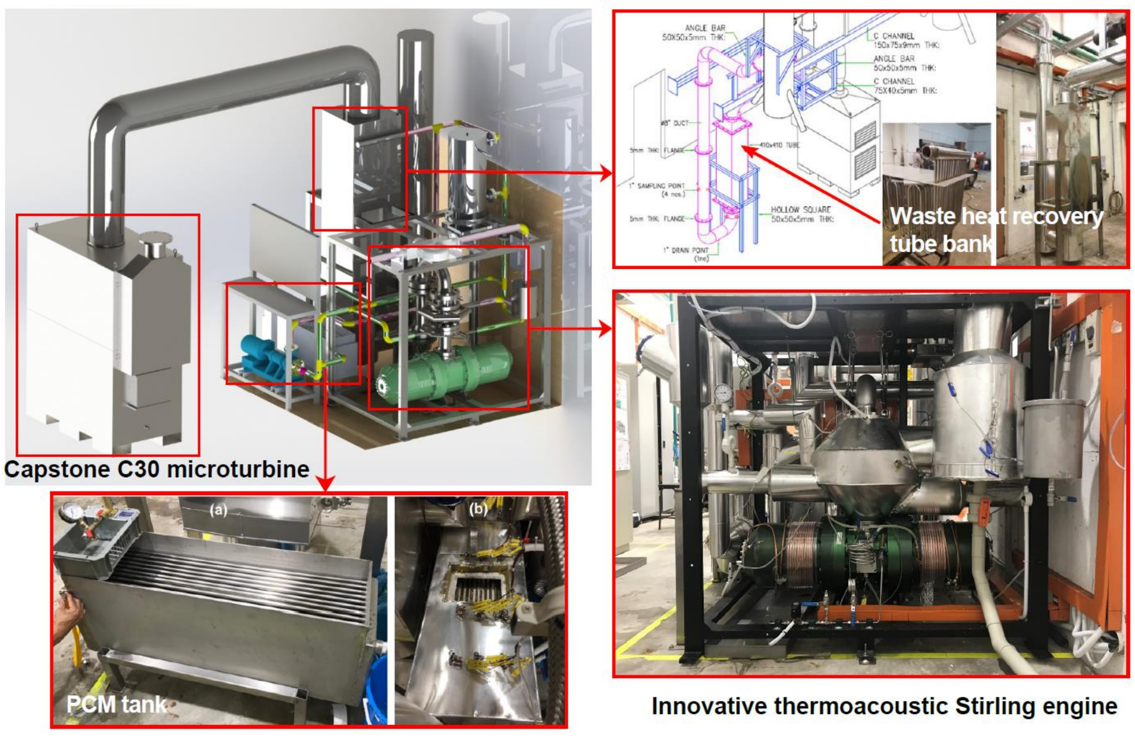

Figure 1: Hybrid power cogeneration system with LNG-fuelled gas turbine and thermoacoustic Stirling engine.

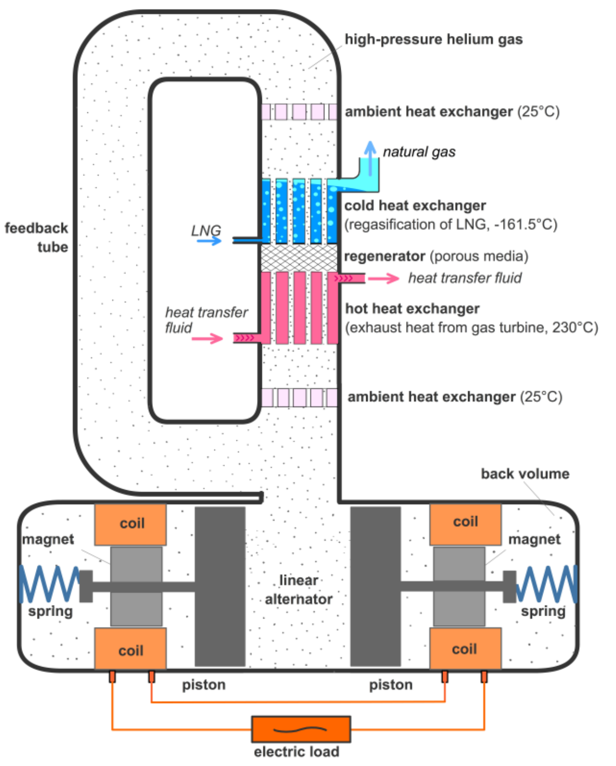

Figure 2: Schematic of thermoacoustic Stirling engine.

PROJECT OUTCOMES

The lab-scale prototype of the hybrid power cogeneration system has been built with the Capstone C30 microturbine and the customised thermoacoustic Stirling engine. Stable power generation has been achieved at above 27 kilowatt (kW) in the tropical conditions of Singapore, and the novel system has increased overall energy efficiency by up to 10%. The thermoacoustic Stirling engine can generate the electric power in the kW-level, and it is the world's first thermoacoustic engine to utilise cold energy from cryogenic fluid regasification and waste heat from microturbine.

The cogeneration system was highlighted by in "**Advances in Engineering**" and "**Cold Facts**" (Cryogenic Society of America, Inc.). Two patents were awarded (**US Patent 10,577,983** and **Singapore 11201801740R**). The project has also developed capabilities in designs of the **cryogenic heat exchanger** for LNG regasification and the **PCM energy storage unit** for the waste energy collection from gas turbines.

In relation to Singapore's annual mean temperatures, the integration of a thermoacoustic engine has potential to improve the power generation for a microturbine. The cogeneration efficiency is found above 70% for all operating conditions in Singapore, with a second law-based exergy efficiency of above 26%. The payback period of the proposed system is found to be ~4 to 5 years, with thermoeconomic assessments demonstrating that the cogeneration system will become more economically feasible with decreasing LNG fuel cost.

When considering the economic feasibility of the emissions, the environmental payback period (EPP) will be ~7 to 8 years. To decrease carbon emissions, the cryogenic CO_2 capture unit could also be integrated with the developed system. Due to high investment and operational costs of the cryogenic CO_2 capture units, the EPP would be increased. Further CO_2 collection would be required to evaluate the potential and address higher EPP challenges to reduce carbon emissions for the novel power cogeneration system.

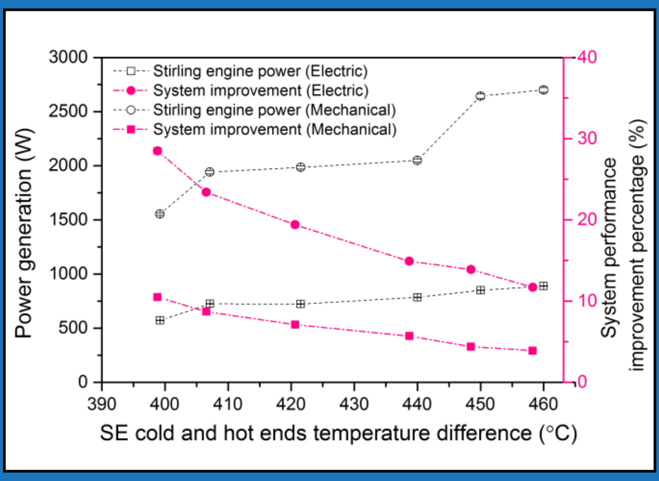

Figure 3: Cogeneration system performance improvement with the thermoacoustic Stirling engine.

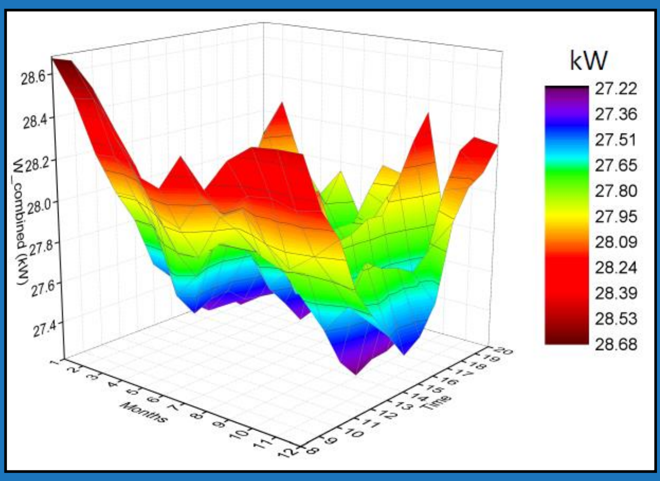

Figure 4: Dynamic and annual power generation trends of the LNG-fueled combined Stirling engine and microturbine system; the data show the combined system provides continuous power generation in the range of 27.2 and 28.7 kW for Singapore's conditions.

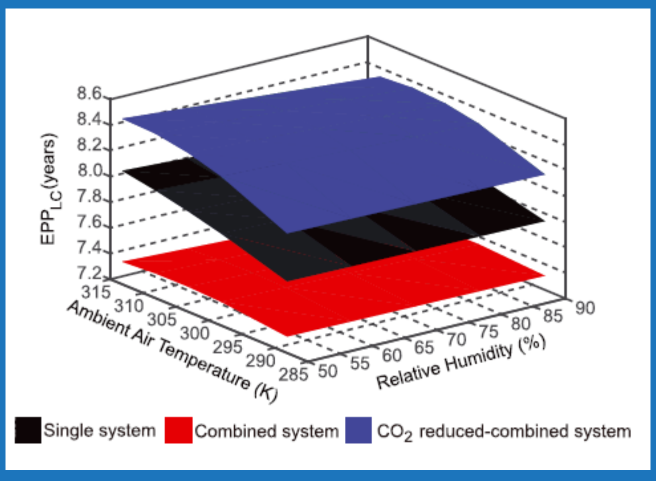

Figure 5: Environmental payback period (EPP) of the single system (microturbine), the combined (Stirling engine and microturbine), and the CO_2 capture unit-integrated combined systems. Further research will need to be conducted to address the higher EPP due to high costs of the CO_2 capture equipment.

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