GREEN DATA CENTRE PROGRAMME (GDCP)
GRANT CALL

S/N	sPotential Research Capabilities
1	A new cooling technology involving phase changes in solid state ferroelectric materials driven under electrical field. This is a high efficient electrocaloric effect (ECE) for realizing refrigeration function, with the change of temperature (adiabatic temperature change) and entropy (isothermal entropy change) of the solid ferroelectric material induced by external electric field. The ECE cooling materials and devices have the potential to achieve higher efficiency, lower noise, zero greenhouse gas emission, and smaller sizes than the currently used compressor air-conditioner. We have the material capability critical to overcoming the major technical barrier and making innovations to further move forward from current study on mechanism and material to the real cooling technology applications. Our proposed plan will have the opportunity to realize energy-saving and environmental friendly ground-breaking cooling technology, promising for meeting the demand from Data Centre and even changing the paradigm of cooling industry in the future.
2	The development of software and algorithms for automating the management of IT systems and infrastructure in data center: • Using deep learning to predict data systems' failures for a pro-active faults handling • Using machine learning for IT load balancing integrated with infrastructure management for improving overall efficiency in resources and energy consumption • Software Define Networking for adaptive multipath routing increasing the bi-sectional throughput of the network bandwidth
3	• The development of file system and software storage stacks for integrating the next generation non-volatile memory (NVM) into data storage and compute system to improve transactional data I/Os performance, resources utilization and energy efficiency. • Large scale storage development for autonomous data lifecycle, and system scalability, performance, reliability and cost efficiency through the integration of hybrid storage media (NVM, SSD, HDD, Tape and Optical).
4	• Development data analytics platform based on Hadoop for improving fault handling of failure jobs execution through the use of distributed checkpoints resumption mechanism. • Use of data analytics for dark data analysis for insights into cold data sets for better contents management and retrieval.
5	• Conduct various benchmarking and evaluation testing to validate and obtain empirical performance of various software, servers, network and storage technologies used in data centers.
6	Integrated AI, sensor, virtual data centre for smart control • Proposed a new hybrid sensor-modelling approach for smart DC control to overcome sensing nonuniformity, reduced order solutions for virtual DC to overcome modelling efficiency problem • Virtual DC to optimize the rack and servers CAC/HAC • Develop a new control strategy using AI for different control requirements • Integrate the new approach with real controller • Minimise risk, maximise energy saving for new or retrofit DC
7	Cold Energy Recovery for Data Centre Cooling Refrigeration is a large electricity consuming class of technology worldwide. One of the limiting factor affecting the PUE in data centre is the efficiency of chiller. In order to improve the situation, we aim to adopt phase change material as thermal storage. Phase change material (PCM) is a material that changes phase at a certain temperature. During the phase change process, a PCM absorbs or releases a large amount of heat in order to carry out the transformation. Possible cold energy source is through LNG. The regasification of LNG to ambient temperature

	yields cold energy (cold waste energy). The study will explore potential application of Phase Change Material (PCM) for cold energy recovery and energy storage.
8	On-demand Passive Refrigerant Cooling Technology • On-Demand Passive System (Using Refrigerant) • Cluster of 10 X 12 kW Back Panel Cooling • Economizes by leveraging on available system parameters • Suitable for low ceiling and low raise floor DC to cater to high density requirement • Leveraging on Independent Chilled Water Cooling in Grey Space (Non-Intrusive to White Space) • No compressor or pump required on Evaporator side
9	Best Practices for Cool Air Management Systems for Greener and Safer Data Centre Cool air management system in a data centre is critical to create “comfortable” working environment for servers so as to ensure their life expectancy. Besides, the good design of air management system can significantly reduce the energy usage in green data centre. A clear guideline in this regard is necessarily useful for industrial designers or practitioners. In this proposal, different designs of cool air management system will be evaluated comparatively using computational fluid dynamics (CFD) techniques. Both airflow and heat transfer will be simulated for a given data centre with various design options for cool air management system. Effectiveness about each air management system, related to the minimization of hot spots in space, will be assessed and addressed. In addition, the impact on energy consumption related to respective cooling strategy will be focused in study. Energy modelling for respective design option will be conducted and compared with one another in order to quantify the energy efficiency of respective design. Operational conditions corresponding to both full load and partial load will be simulated and analysed.
10	R&D on Augmented and Virtual Reality for Green DC Immersive technologies have many use cases and applications within green data centers. e.g efficiency of data center rack, air flow management and optimization. AR/VR technologies can help to visualize the cost of electrical power consumption, or shows where does the energy flows. This includes human-centred visual environments in the control room for supporting decision-making as well on-site aid via mobile augmented interfaces for MRO. • simulation and Green DC operation centres • build & design: generic building block that can be used for a broad range of applications, extending performance and reducing energy • facility management • marketing and sales • logistics and utilities • connectivity (physical + virtual) (semantical representation, ontologies) • Data Centre Interoperability • Data Center Infrastructure Management (DCIM)

11	Secure Automation and Semantic Representation New technologies to provide interfaces and capabilities to acquire endpoint attributes and states from green DC devices, store and preserve their semantic relationship to each other, and provide them in a representation that can be consumed by automated processes. Semantically link DC-specific data sources link with the current form of the network topology in order to be able to provide context information in a timely and highly detailed manner. Green DCs must reliably determine what devices, software and services are on the network, how those devices are configured from a hardware perspective, what software products are installed on those devices, and how those products are configured. Green DCs need to be able to determine, share, and use this information in a secure, timely, consistent, and efficient automated manner to perform asset discovery, bottleneck, availability/reachability and SLA enforcement, or compliance automatically with the capability of representing complex network features, e.g. nested topologies (overlay networks, virtual networks or service graphs).
12	Green Data Center with Tiered Memory Pool Energy consumption is increasingly becoming major challenge for future data center. With huge amount of data generated, large number of memory and disk/SSD are used to process and store data in the data center. Consequently, energy consumption by memory and disk is becoming critical factor for data center's scalability, performance and cost. For instance, 32 Gigabyte of DDR4-2133 already consumes about 11W of energy. Projecting this further, one terabyte (TB) of DDR4-2133 would consume about 352W of power. This would exceed the 115W TDP (total dissipated power) of one 14-core Xeon E7-4850 v3 chip. The energy consumption of storage subsystem including hard disk, SSD and PCIe/NVMe SSD is also high. In recent years, a number of non-volatile memory (NVM) technologies have been touted. Because of their non-volatile nature, these are significantly more energy efficient compared to DRAM/storage technologies. The objective of this project is to reduce power consumption of storage and memory without performance lost by redesigning data centre with emerging non-volatile memory. Fig.1 shows the architecture. Following are research areas. 1) Power-aware Tiered Memory Pool: Cluster-level hybrid memory pool with power management by exploiting the performance and energy features of DRAM and NVM. With pooled memory, number of server can be reduced. 2) Energy Efficient storage stack: Design NVM-based storage stack to reduce power consumption of main storage including disk, SSD or NVMe SSD. E.g. it is feasible to use large capacity low RPM disk with a small amount of NVM to achieve power saving without performance lost. 3) AI-based workload monitoring, prediction and scheduling: Design AI algorithm to monitor, predict and schedule workloads to maximize power saving and performance. 4) Cooperative power saving among main memory and storage: collaborate between main memory and storage to create more opportunities for power saving.

13	Proactive Failure Management for Sustainable Green Data Centre Energy saving is one of the main targets of green data centre. With the reduction of power consumption, temperature will increase in data centre which will lead to higher failure risk of devices and system components. In order to sustain reliability and performance, future data centres need to provide proactive monitoring and failure management for devices and systems. We worked on software-managed data centre before, with focus on proactive failure management of storage hard disk drives (HDDs). As shown in the following figure, data are firstly collected from various data sources, and then are visualized intuitively. A deep learning module is developed to proactively predict failures based on the data. Our module can predict HDD failure with very high accuracy as 99.6%. If the module predicts that a failure is going to happen, remediation actions will take place automatically to continue data service and prevent data loss on the HDD. The proactive failure management can also reduce human involvement in data centres and reduce cost eventually.
14	Green Data Centres FPGAs Current data centres are using large number of servers based on CPUs. Despite the progress in CPU performance over the last decade, more and more algorithms are now ported to GPUs using the latest NVIDIA Tensor Cores. In the last few years, we have witnessed new trend with Field-Programmable Gate Array (FPGA) used as hardware accelerators. This is mainly driven by new Xilinx FPGAs UltraScale+ and the takeover of Altera by Intel. As much as GPU architectures are good for standard HPC tasks, they are not always optimal for the new wave of Machine Learning (ML) and Deep Learning (DL). As FPGAs leverage on circuit design, they allow full customization of the architectures, from an algorithm point of view, for specific applications. Advanced power-management capabilities can reduce consumption compared to GPU. Furthermore, current GPU are tied to PCI interface, while FPGA can integrate multitude of communications interface, e.g. Gen-Z, suitable for new paradigms such as Memory-Centric Computing
15	Pro-environmental decision-making for minimising sustainability risk and maximising energy saving • Environmental, community, organizational and behavioural interventions and strategies to improve liveability in urban environments and pro-health behaviour decision making. • User (occupant) behaviour quantification through both objective and subjective measures, such as through monitoring movement of people within enclosed spaces, and subjective measures through direct data collection via purpose-built survey instruments. • Survey instrument development integrating social, psychological, behavioural elements • Analysis of usage patterns for forecasting demand loads to anticipate energy consumption. • These behaviour insights and user behaviour data could provide decision-making parameters to assist in Data Centre Infrastructure Management (DCIM), to provide a holistic view of the data centre, and to enable operators to manage energy usage and improve efficiencies from one central control interface. • User interface and human-computer interaction design of such control systems in relation to occupant behaviours and preferences, with the potential goal of addressing pertinent questions, namely (i) how buildings' control systems for energy and comfort interact with and adapt to occupants' comfort and preferences, (ii) how robust would a control system need to be before failing to track occupant behaviours, and (iii) the manner that decision-making tools could be designed to be more relevant for achieving occupants' preferred environments without compromising on efficiency and sustainability.

Please note that the above are potential research areas. For more information, please reach out to

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