IMPERIAL

Project title: Integrated energy, carbon and water management for sustainable data centres across diverse environments

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Project Description:

The rapid growth of artificial intelligence and digital services is increasing demand for data-centre capacity, electricity and cooling. Nearly all electrical energy used by computing is eventually released as heat, while heat removal can consume additional energy and water. Conventional indicators such as power usage effectiveness provide only a partial view: a design with low cooling power may still increase water stress, rely on carbon-intensive electricity or reject heat to a sensitive environment. Sustainable data centres therefore require coupled management of energy, carbon, water and heat from computing hardware to the final heat sink.

This PhD project will develop an engineering framework for designing and operating data centres as integrated computation-thermal-resource systems. It will ask how cooling technologies should be matched to local constraints, when waste heat can become a useful resource, and how energy, carbon and water performance can improve together without transferring impacts. Conventional terrestrial data centres will provide the reference architecture. Desert, offshore or underwater, and space-based systems will be contrasting scenarios with fundamentally different water availability, heat sinks and maintenance requirements.

Work package 1 - Unified modelling and sustainability metrics (Months 1-12). The student will construct a validated chip-to-heat-sink model linking computing load, cooling architecture, coolant temperature, heat capture and final rejection. The framework will combine power and energy-reuse indicators with carbon and water accounting, life-cycle assessment and techno-economic analysis, enabling designs to be compared under consistent service, climate, electricity-mix and lifetime assumptions.

Work package 2 - Scenario-responsive thermal management and optimisation (Months 10-28). The student will evaluate representative air, liquid or immersion, dry or evaporative, seawater-based and radiative cooling pathways. Multiphysics and system models will quantify trade-offs among electricity, water, carbon, heat quality, reliability and infrastructure. Optimisation and uncertainty analysis will identify operating envelopes and design rules, including how workload, ambient conditions, grid carbon intensity and water stress should influence cooling and recovery decisions.

Work package 3 - Waste heat to useful resources (Months 22-42). District heating, sorption-based carbon capture, water purification or production, cooling and thermal storage will be screened against heat temperature, availability, location, demand and value. One primary recovery pathway will then be selected for detailed integration, optimisation and targeted proof-of-concept validation. The work will

retain safe full-load heat rejection when recovery is unavailable, ensuring that resource recovery does not compromise resilience.

The project is deliberately scoped for one PhD researcher to complete within 3.5-4 years. The environments will be addressed through a common model and focused case studies, rather than separate experimental programmes. After the Year 1 baseline, one principal cooling and recovery architecture will be selected for detailed investigation. The final phase will integrate models, validation and sustainability assessment into an open decision-support framework and transferable design principles.

The research will suit a candidate in mechanical, energy, chemical, environmental or related engineering. Experience in thermofluids, numerical modelling, optimisation, sustainability assessment or experimental thermal systems would be valuable. The balance between modelling and experiments can be tailored to the student's strengths.

The student will join the LIGHT Lab at Imperial College London and contribute to its research on engineering physical systems for a sustainable future. They will also engage in the associated PhD training and activities of the Grantham Institute - Climate Change and the Environment and the Department of Mechanical Engineering.

Funding: The Grantham funded studentship will provide funding for tuition fees at the level of Home (UK) students and a tax-free stipend at the standard UKRI London rate (£23,805 pa for 2026/27. The funding can also be used to partially support an international student, combined with other scholarships, although such scholarships have strict deadlines and tend to be extremely competitive.

How to apply:

Please email Xiangkun (Elvis) Cao (mailto:elvis.cao@imperial.ac.uk) and include in your application:

- Statement of Purpose
- Your CV
- At least two references to be sent directly to Xiangkun (Elvis) Cao from the referees.

Informal enquiries are welcomed and should be sent to Xiangkun (Elvis) Cao (mailto:elvis.cao@imperial.ac.uk).