Techno-economic modelling of sustainable data centre integration in the European energy system

Supervisors: Dr Hongyu Zhang, University of Southampton, hongyu.zhang@soton.ac.uk, co-supervisor(s) TBD
Application deadline: 27 January 2026
Application website: https://sustai.info/apply/
Funded by The UKRI AI Centre for Doctoral Training in AI for Sustainability.

Data centres are rapidly becoming one of the most energy-intensive infrastructures in Europe. With growing demand for cloud services, AI, and digitalisation, their electricity consumption and cooling needs pose significant challenges to the energy system. At the same time, data centres can also provide flexibility to the grid through demand response, waste heat utilisation, and co-location with renewable energy sources.

This PhD project will further develop an optimisation model to analyse the sustainable integration of data centres into the European energy system. The project will investigate trade-offs between energy demand, system flexibility, emissions, and cost-effectiveness under different policy, market, and technology scenarios.

The successful candidate will:

- Further develop a long-term energy system model to capture the role of large-scale data centres in Europe's net-zero transition.
- Analyse the interaction between data centres and renewable integration, including grid balancing, flexibility services, and storage.
- Explore sustainable cooling solutions and waste heat recovery for district heating and industrial use.
- Conduct scenario-based techno-economic assessments, evaluating the impact of data centre growth on investment and operational decisions in generation, transmission, and storage.
- Provide policy-relevant insights for European decarbonisation strategies.

The student will join the University of Southampton's School of Mathematical Sciences, working at the intersection of optimisation, energy modelling, and sustainability analysis. There will be opportunities to collaborate internationally with leading research groups in energy systems.

We are seeking highly motivated candidates with a strong background in one or more of the following:

- Energy systems modelling and optimisation
- Techno-economic analysis or operations research
- Data science or applied mathematics
- Strong programming skills (Python, Julia, or similar).

Quantum computing for large-scale stochastic optimisation in energy system planning

Supervisors: Dr Hongyu Zhang, University of Southampton, hongyu.zhang@soton.ac.uk
Dr David Bernal Neira, Purdue University
Application deadline: 27 January 2026 (International students must apply before 31 March)
Application website: https://www.southampton.ac.uk/study/postgraduate-research/projects/quantum-computing-optimisation-for-large-scale-energy-system#about
Funded by The EPSRC Centre for Doctoral Training in Quantum Technology Engineering.

This PhD project explores how quantum computing can transform energy system planning for a net-zero Europe. By integrating quantum and classical optimisation methods, it will address uncertainty in renewable generation and develop scalable algorithms for large-scale stochastic models, advancing both optimisation theory and practical tools for the energy transition.

Achieving a net-zero European energy system by 2050 requires effective long-term planning that accounts for uncertainty in renewable generation. Stochastic optimisation is widely used to support such planning under uncertainty, but these models often become computationally intractable as system complexity grows.

The rapid development of Noisy Intermediate-Scale Quantum (NISQ) devices offers new opportunities to develop quantum-based algorithms capable of tackling these large-scale challenges. However, significant gaps remain in understanding how quantum computing can be applied to real-world stochastic optimisation problems.

This project aims to: (1) harness the inherent uncertainty of quantum computing—arising from superposition, entanglement, and probabilistic measurement outcomes—for stochastic optimisation; (2) integrate Variational Quantum Algorithms (VQAs), such as the Quantum Approximate Optimisation Algorithm (QAOA), with classical decomposition algorithms to create a hybrid quantum–classical solution framework; and (3) apply these techniques to large-scale energy system planning models, benchmarking their performance against state-of-the-art classical solvers to assess potential quantum advantages.

By leveraging advances in both quantum computing and classical optimisation, the project will contribute to the development of hybrid quantum–classical paradigms for energy system modelling, supporting Europe's transition to a sustainable, low-carbon energy future.

The successful candidate will collaborate with experts in quantum computing, stochastic and computational optimisation, and energy systems. Opportunities include a research stay and an industry placement.

Machine learning and optimisation for climate modelling and energy system integration

Supervisors: Dr Hongyu Zhang, University of Southampton, hongyu.zhang@soton.ac.uk
Dr Calvin Tsay, Imperial College London
Application deadline: second round 11 January 2026, final round 8 March 2026
Application website: https://www.mfccdt.ac.uk/university-of-southampton/
Funded by The EPSRC Centre for Doctoral Training in the Mathematics for our Future Climate: Theory, Data and Simulation.

This PhD project will develop machine learning and optimisation methods to improve climate modelling and integrate climate models with energy system models. The project will leverage GPU programming and provide decision-support tools for sustainable planning under climate uncertainty, contributing directly to Europe's energy transition and net-zero targets.

Climate change poses unprecedented challenges to energy system planning and operation. Long-term uncertainties in climate patterns affect renewable energy availability, energy demand, and system resilience. This project aims to bridge climate modelling and energy system modelling through advanced machine learning (ML) and optimisation.

The PhD student will develop ML techniques to extract key features from climate models and construct scenario representations that can be integrated into long-term energy system planning models. Optimisation algorithms will then be designed to handle these large-scale, stochastic problems efficiently, balancing cost, resilience, and sustainability. For example, optimal decisions could account for potential new energy technologies and robustness to extreme climate scenarios. Emphasis will be placed on using ML methods to generate computationally tractable, yet informative scenarios, and algorithms to solve the underlying energy models accounting for climate-driven uncertainty at both short-term and long-term horizons. Algorithms will be designed to be scalable (e.g., GPU parallelisable) at both steps.

The student will work at the interface of applied mathematics, computer science, and climate/energy policy, joining a growing network of researchers at Southampton and Imperial College. There will be opportunities to collaborate internationally and contribute to cutting-edge research on sustainable energy transitions.

The project offers the chance to contribute to the global net-zero agenda by providing innovative computational tools for climate-resilient energy system planning

Essential skills required:

- Strong programming skills (GPU programming, Python, Julia, or similar).
- Solid mathematical background in optimisation and machine learning.
- Ability to handle large datasets and computational models.

Machine learning and stochastic optimisation for maritime anomaly behaviour identification

Supervisors: Dr Hongyu Zhang, University of Southampton, hongyu.zhang@soton.ac.uk, Professor Peter Schütz, Norwegian School of Economics, and Dr Wissam Albukhanajer, Roke
Application deadline: 20 April 2026
Application website: https://www.southampton.ac.uk/study/postgraduate-research/projects/machine-learning-stochastic-optimisation-for-maritime-anomaly
Funded by The EPSRC and MOD Centre for Doctoral Training in Complex Integrated Systems for Defence and Security.

This PhD project will develop advanced machine learning and stochastic optimisation methods to identify anomalous behaviours in maritime traffic using Automatic Identification System (AIS) data. It will enhance maritime situational awareness and security while addressing uncertainty and complexity in vessel behaviour modelling.

The maritime domain is critical for global trade and economic stability, yet faces threats from anomalous behaviours such as illegal fishing, smuggling, and piracy. Automatic Identification System (AIS) data offers a rich source of real-time vessel movement information. However, detecting anomalies within such high-dimensional, noisy, and incomplete datasets remains a challenge.

This PhD project aims to bridge machine learning (ML) and stochastic programming for robust maritime anomaly detection. The student will:

- Develop ML-based models (deep learning, unsupervised clustering, probabilistic models) to classify and predict vessel behaviours from AIS data.
- Formulate stochastic optimisation models to address uncertainty and incomplete data, enabling decision-support for anomaly identification.
- Explore hybrid ML–optimisation approaches to enhance detection accuracy, interpretability, and scalability.
- Validate methods on real-world AIS datasets, benchmarking against existing anomaly detection methods, and collaborate with maritime stakeholders.

The project will contribute to complex integrated systems research, providing a robust framework for maritime domain awareness, supporting sustainable shipping, and enhancing global maritime security.

The student will also benefit from international collaborations and engagement with industrial partners in maritime technology and security.