Science and Technology Facilities Council

Driving the Clean Energy Revolution

How STFC is shaping the technological solutions to make the UK a clean energy superpower

April 2025

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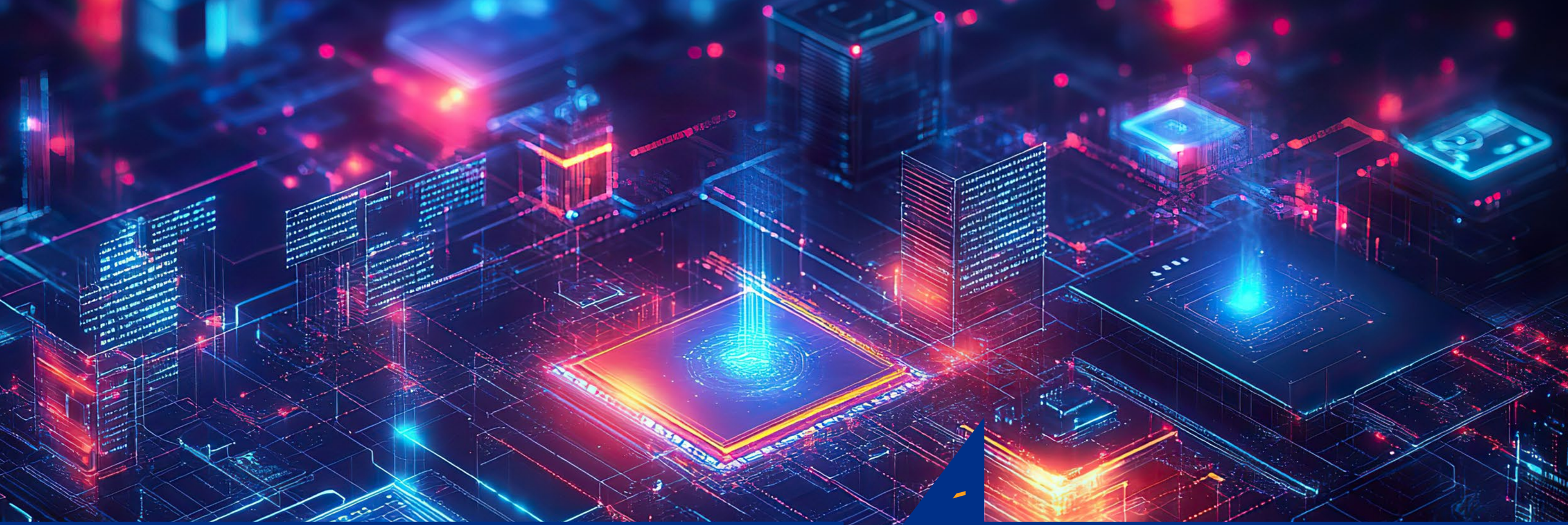


Research and innovation that shapes a more resilient future

As part of UK Research and Innovation (UKRI), the Science and Technology Facilities Council (STFC), through its world-class science facilities, technology capabilities and campus infrastructures, is addressing the most significant and critical global challenges. Top most of these is climate change and its associated challenges of sustainability, clean air and energy security.

STFC, with its combination of internationally-leading large-scale facilities, cutting-edge research, campus infrastructures, and national and international collaborations, is enabling the UK's transition to a low-carbon economy and shaping a cleaner, more resilient future.

A key focus of UKRI's corporate five-year strategy, Transforming Tomorrow Together, is Building a Green Future - accelerating the shift to a secure, low-carbon economy. Key to this is collaboration. By focusing on fostering public-private partnerships and working closely with government, UKRI is supporting the UK government Clean Energy Action Plan and addressing the challenges of decarbonisation.

Over the past three years, UKRI has invested approximately £1 billion in energy research. From these investments, spin-out companies generated UK revenues of £28.9 million in 2019, creating 180 jobs in the process. Through cutting-edge research and collaboration, we support the UK's transition to a low-carbon economy, shaping a cleaner, more resilient future.

As the UK moves towards a low-carbon future, electricity demand will surge, making it vital to scale up clean power. The UK government has set ambitious targets to reach net zero by 2050—the fastest emissions reduction commitment of any major economy. A key national mission is to "Make Britain a Clean Energy Superpower," delivering 95% clean electricity by 2030. To achieve these 2050 targets alongside clean power commitments by 2030, we need to increase the pace of research into the technological solutions. This is a pivotal moment for energy security, affordability, and emissions reduction—and STFC has a significant role to play.

The UK government Clean Energy Action Plan outlines a bold, urgent roadmap, scaling up low-carbon, flexible technologies to ensure a reliable, future-ready energy system. With mass electrification and rapid clean energy growth essential through the 2030s and 2040s, the challenge ahead is immense.

Image source: STFC Daresbury Laboratory

STFC is helping to mobilise cutting-edge research that tackles the UK's biggest energy challenges and builds resilience. With world-class expertise and facilities, we are delivering breakthrough technologies that will shape the future energy system and make the UK a clean energy superpower. Every day, our researchers and engineers turn clean energy ambition into reality—pushing the boundaries of innovation for a sustainable future. We don't just fund clean energy and net zero science—we deliver it.

As the energy transition accelerates, STFC is a hub for collaboration. By working with government, industry, and the wider scientific community, we provide access to cutting-edge research, helping to build the low-carbon systems that will power the future. At STFC we are driving innovation and increasing the opportunities for the adoption of technologies from AI to clean energy and net zero research. We are delivering excellence in science and innovation to ensure our world-class research translates into commercial success, and playing a crucial role in delivering the government's Clean Energy Superpower Mission and Economic Growth Mission.

This report showcases breakthroughs in net zero technologies, AI, and smart energy systems—where research is driving real change. STFC is where innovation meets impact, bringing together science, engineering, and technology to solve the most pressing challenges of our time.

Foreword

At STFC, our mission is to discover the secrets of the Universe by pushing the boundaries of research and innovation and developing cutting-edge technologies that solve real-world challenges. Our world-class research and innovation facilities develop breakthrough solutions that contribute significantly to the fight against the climate crisis.

Across our organisation, we are leveraging our expertise to support the UK government Clean Energy Mission in becoming a Clean Energy Superpower. From harnessing clean energy that advances low carbon technologies to upskilling our workforce in green tech roles, our research and innovations are accelerating progress towards the Clean Energy target and shaping a resilient future.

I am proud to share this report which highlights the impactful ways our research is making a positive contribution to the clean energy and net zero challenge. By unlocking new opportunities and uniting forces across our industry and beyond, we are delivering the solutions that will help advance the UK's transition to net zero.

Michele Dougherty
Executive Chair, STFC

Image source: RAL

We recognise the urgency in developing breakthrough technologies for this once-in-a-generation transition to clean energy. Through the world-class research and innovation conducted by our scientists, technicians, and partners, we remain steadfast in our commitment to accelerating progress towards net zero.

At STFC, we recognise the power of partnership and are continuing at pace to collaborate across industry, academia, and government to position the UK at the forefront of the global low-carbon revolution. In this report, we showcase our collective pioneering work that supports the UK government to become a Clean Energy Superpower. Across STFC we are unlocking clean energy solutions, advancing energy storage, and harnessing AI to enhance grid security.

We are proud of our impact and the significant role we play in this clean power sprint but remain aware that there is still more to be done. Looking ahead, I am confident that we will continue to go from strength to strength in our partnerships and push discoveries even further than ever before.

Dave Newbold
Executive Director, STFC National Laboratories: Science and Technologies

Image source: STFC Chilbolton Observatory

Our National Laboratories and large-scale facilities are world-class centres of excellence in multi-disciplinary science, engineering, and technology. Working with our extensive user communities and by harnessing the talent and skills of our people alongside the capabilities of our leading facilities, we are advancing clean energy solutions that bring worldwide benefits.

Our commitment extends beyond the boundaries of our own organisation to supporting the UK government Clean Energy Mission. Within this mission, we recognise that, to ensure a resilient future, we must advance the development of new technologies and, through our forward thinking approach, we are actively supporting the transition to net zero.

Our expertise positions the UK at the forefront of the global shift to a low-carbon future. Our multidisciplinary facilities provide the UK research community with world-leading capabilities to address global challenges like climate change. In this report we explore the key areas of focus where we are combining our world-class facilities and expertise with cutting-edge research. This is an exciting moment for our organisation, and I encourage you to read on to discover how our breakthroughs are translating into real-world impact.

Roger Eccleston
Executive Director, STFC National Laboratories: Large Scale Facilities

Energy storage

The UK's energy system faces growing pressure from ageing grid infrastructure, rising demand, and reliance on imported fossil fuels. While renewables like wind and solar are key to decarbonisation, their variability disrupts the balance between supply and demand. Modernising the grid is critical to ensuring a stable, secure, and affordable energy future.

Researching AI and digital technologies that optimise distribution, manage peak demand, and boost efficiency is a top priority. Energy storage is equally vital to stabilise the system, capturing surplus power during low-demand periods and deploying it when needed. It also enables consistent energy transfer between regions, improving reliability and unlocking the full potential of renewables.

STFC and industry partners are driving advances in energy storage to meet these challenges. Innovations such as sodium-ion batteries – an abundant, cost-effective alternative to lithium-ion - and efficient on demand ammonia generation from electrolysed water and air, which stores and transports energy as a chemical fuel, are being developed to create a secure, flexible, and low-carbon system. By prioritising storage solutions, the UK can accelerate its path to net zero and build a resilient, sustainable energy future.

Image source: ASTeC and STFC Daresbury Laboratory

Pioneering next-generation batteries

- **Testing and optimisation:** STFC provides cutting-edge characterisation and imaging data, developing simulations and digital twin to model battery performance, test variables, and accelerate innovation.
- **A game-changer for sustainable energy storage:** Operating similarly to lithium-ion batteries but using more abundant materials, sodium-ion batteries reduce reliance on scarce resources like cobalt and copper. STFC researchers are working to commercialise their world-leading positive-electrode technology as a UK-patented product, positioning sodium-ion as a key alternative for sustainable energy storage.

Connecting researchers to drive innovation

Collaboration accelerates breakthroughs. Dr James Le Houx, jointly funded by the ISIS Neutron and Muon Source (ISIS) and the Faraday Institution, is leading efforts to integrate STFC and Diamond Light Source expertise into a unified strategy – reducing resource consumption, improving battery performance, and supporting global energy efficiency efforts.

Spotlight on:

Green ammonia

Ammonia has all the technological attributes to be a game-changer for large-scale energy storage and transport. With high energy density, easy storage, and an existing global infrastructure, it can serve as a renewable energy carrier, converting surplus electricity into a storable, transportable fuel. The global ammonia infrastructure is already capable of substituting for fossil fuel energy provision and storage at a significant scale. For it to be truly sustainable however, ammonia must be produced using green methods rather than fossil fuels.

Pioneering green ammonia innovation

STFC's Energy Research Unit is driving innovation to make green ammonia a viable energy source through several pioneering projects. The Energy Research Unit specialises in performing and enabling innovative research on new and renewable energy technologies.

- **Ammonia Synthesis Plant using Intermittent Renewable Energy (ASPIRE) project:** Developing a demonstrator plant that efficiently produces ammonia from intermittent electricity sources using novel chemical processes. This scalable approach could replace fossil-fuel-based production and enable on-demand electricity generation.

- **Renewable Energy Ammonia Charging (REACH) project:** Exploring ammonia-powered fuel cells, bridging the gap between ammonia storage and electric vehicle technology, thereby decarbonising transport. Ammonia-fuelled fuel cells also represent a possible option for the decarbonisation of off-grid, temporary, or emergency power systems.

- **High-Pressure Ammonia Cracker (HPAC) project:** Converting ammonia into hydrogen for internal combustion engines, providing a zero-emission alternative to conventional fuels. An application of this could be in shipping and transport where heavy fuel oil engines that produce a large amount of carbon dioxide would be replaced or retrofitted.

STFC researchers are also optimising catalysts, improving hydrogen extraction, and minimising environmental risks such as spill pollution. Recent breakthroughs include:

- Two patents for ammonia decomposition catalysts.

- New synthesis catalysts operating at lower temperatures and pressures for greater efficiency.

- Replacing costly ruthenium with earth-abundant metals, making ammonia production more practical and scalable.

These innovations position ammonia as a key clean energy solution for hard-to-decarbonise sectors and highlight how STFC is helping to accelerate the UK's transition to a sustainable energy future.

Driving the clean energy revolution

The Intergovernmental Panel on Climate Change (IPCC) warns that without immediate emissions cuts, global warming will exceed 1.5°C, intensifying climate risks. Yet, the Climate Change Committee (CCC) reports that progress is too slow, hindered by regulatory delays and infrastructure bottlenecks. To achieve net zero, we must rapidly deploy low-carbon backup generation, and advance energy storage and AI-driven optimisation to build a resilient energy system.

Technology is key. The National Energy System Operator's (NESO) Clean Power 2030 report highlights the critical role of AI and digital solutions in balancing supply and demand, integrating renewables, and maximising efficiency. From AI-driven energy management to next-generation fusion and fission, breakthroughs in clean energy technology will be key to securing a low-carbon future. STFC is currently conducting exciting research utilising digital and AI technologies that supports resilience and flexibility of the national grid.

Image source: STFC Hartree Centre

STFC: Powering the future of clean energy

At STFC, we are unlocking next-generation energy solutions, advancing:

- fusion reactor designs,
- next-generation fission technologies,
- innovative energy storage, including green ammonia, and
- AI-driven optimisation for grid stability and demand prediction.

Under the Hartree National Centre for Digital Innovation (HNCDI) programme, a collaboration between STFC's Hartree Centre and IBM Research, we have developed advanced automated decision-making algorithms to reduce energy consumption in data centres have been developed. As major data companies increasingly invest in power plants for their facilities, the significance of this work continues to expand.

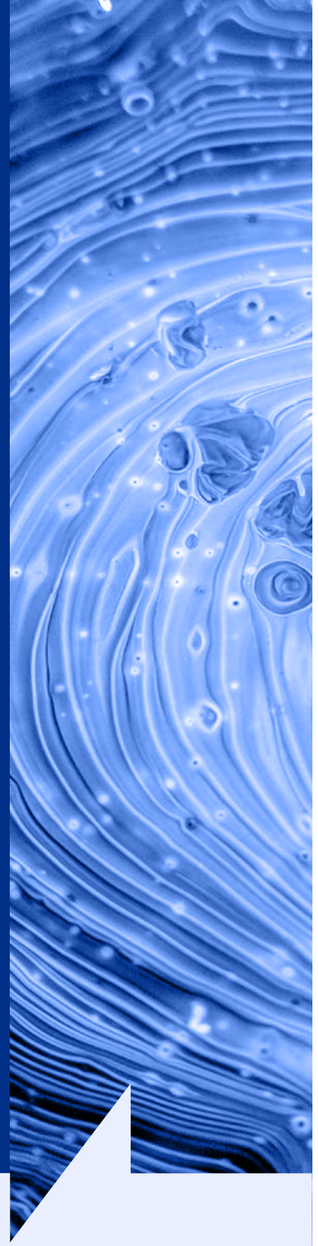
By combining world-class facilities with cutting-edge research, STFC is tackling infrastructure challenges and strengthening UK energy security, ensuring breakthroughs translate into real-world impact. Our expertise positions the UK at the forefront of the global shift to a low-carbon future, delivering the technologies needed for a net zero energy system.

Fusion: From experiment to reality

STFC, in collaboration with UK Atomic Energy Authority (UKAEA) and the Fusion Futures initiative, is pioneering Inertial Confinement Fusion (ICF)—a promising approach to limitless, clean energy. Through the UPLIFT project, funded by Department for Energy Security and Net Zero (DESNZ), we are also working with the National Ignition Facility (NIF) in the US to enhance Fusion Laser Containment (FLC) technology. This work aims to improve efficiency and accelerate the transition from experimental fusion to a viable energy source through:

- **Advanced lasers:** Developing more powerful, efficient lasers to optimise the fusion process.
- **Fusion fuel targets:** Enhancing fuel capsule designs for higher ignition success rates.
- **AI-driven fusion simulations:** Using advanced computational models to accelerate fusion energy development.

By tackling these challenges, STFC is positioning the UK at the forefront of the global fusion race, driving the transition from experimental fusion to viable power generation.



Advancing Fission: Technology and skills for a net zero future

STFC works closely with the UK's Engineering and Physical Sciences Research Council (EPSRC), advancing nuclear science to support the fission industry:

- **Skills & training:** STFC trains early-career scientists, supplying expertise to the nuclear sector.
- **Technology innovation:** Advances in detector and instrumentation development enhance nuclear safety and infrastructure.

Accelerating AI for clean energy

The Hartree Centre and UK Atomic Energy Authority (UKAEA) are collaborating on a five-year project, Fusion Computing Lab, to fast-track fusion energy development. Together, they've established a Centre of Excellence that uses powerful supercomputers and AI to address the challenges of making commercial fusion energy a reality. By creating advanced computer models, scientists can refine fusion technology without the need for costly physical prototypes.

The team are also doing exciting work combining AI and other digital technologies to support clean energy development:

- **AI-designed carbon capture materials:** Scientists have developed an AI tool to design highly efficient carbon capture materials, such as Metal-Organic Frameworks (MOFs). These ultra-porous materials could one day capture a football field's worth of CO_2 with a material the size of a teaspoon, revolutionising carbon removal.
- **AI for fusion reactor design:** In the Fusion Computing Lab project, AI is optimising reactor designs, thereby reducing the need for costly physical prototypes and accelerating fusion development. AI is also aiding the selection of the most informative simulations to run on high-performance computing hardware. The use of AI streamlines problem-solving and enhances fusion efficiency, bringing commercial fusion power closer to reality.

Image source: ASTeC

Spotlight on:

Tokamak digital twin

The Hartree Centre, in collaboration with the UK Atomic Energy Authority (UKAEA), are developing a digital twin of the UK's Tokamak—a machine designed to produce fusion energy. This highly detailed virtual model allows scientists to test ideas, predict performance, and prevent issues before they arise, accelerating fusion research.

By integrating AI, advanced computing, and physics expertise, the digital twin enhances design precision and operational planning, reducing reliance on costly physical trials. Developed alongside the Tokamak's construction, it will streamline experiments and optimise performance, ensuring the Tokamak components talk to each other seamlessly. It will also fast-track the UK's path to increasing resilience of power generation via the use of commercial fusion energy.

This project is part of a global collaboration, ensuring the UK remains a leader in fusion innovation and advancing fusion as a practical, scalable clean energy source.

The common impact across these efforts is the use of digital models to replicate and study real-world phenomena, providing researchers with powerful tools to deepen their understanding. By enabling virtual experimentation and analysis, these models are helping to drive advancements in technologies critical to reducing emissions and supporting the transition to a sustainable future.

> **What is great about this collaboration between STFC and UKAEA is that our teams are very well integrated and are working together very efficiently. We are sharing our knowledge and skills by combining the Hartree Centre's computing capabilities with UKAEA's expertise in fusion science to help make fusion energy a reality. The future of this collaboration will support the growth of the fusion energy capabilities and community in the UK and develop a network with the right expertise to prepare the industry to adopt advanced fusion technologies.**
>
> Vassil Alexandrov, Chief Science Officer, Hartree Centre

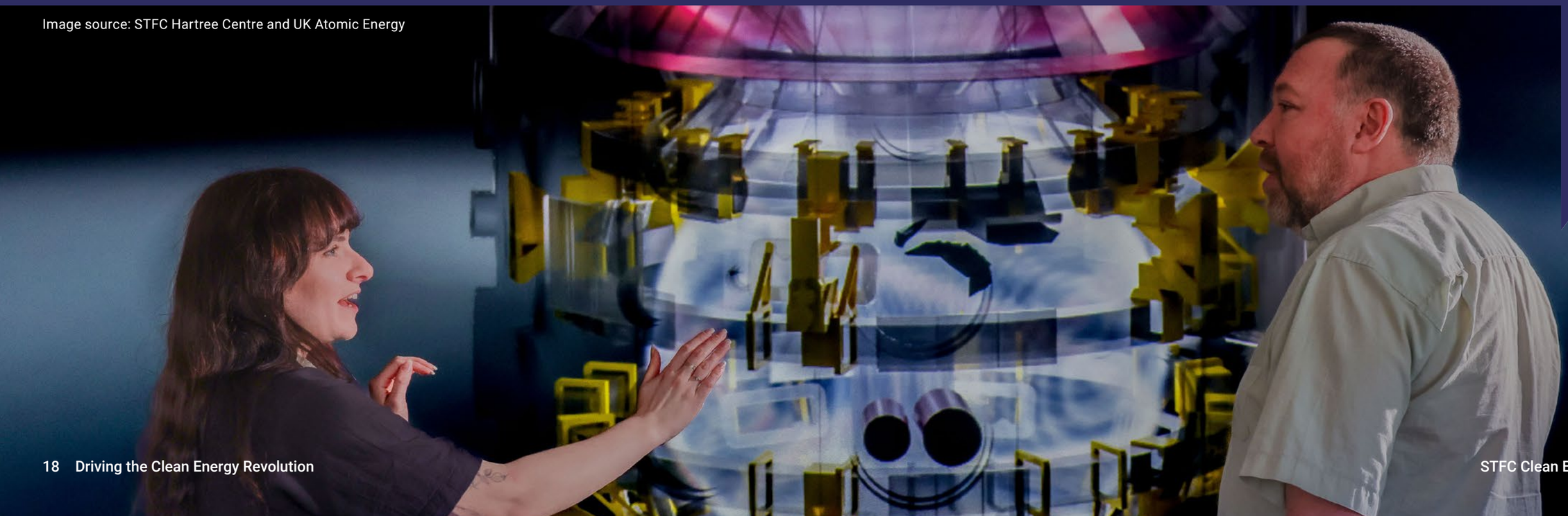


Image source: STFC Hartree Centre and UK Atomic Energy

Energy research and skills

A highly skilled workforce is as critical as technological innovation in delivering a secure, decarbonised power system. However, reports from the Climate Change Committee (CCC) and the National Energy System Operator (NESO) warn that skills shortages and slow technology deployment are major barriers to scaling up energy storage, grid flexibility, and low-carbon power. Demand for specialists in energy, engineering, and digital infrastructure is outpacing supply, threatening progress towards net zero.

The UK government Clean Power 2030 Action Plan emphasises the importance of reskilling workforces with the strong potential for the transfer of skills between the oil and gas workforce and the offshore renewables sector. With the risk of training gaps and limited investment, workforce shortages could stall clean energy progress.

At STFC, we are tackling this challenge head-on—training the next generation of energy scientists and engineers while advancing research in catalysis, fuel cells, battery technology, climate data analysis, and nuclear science. Our world-class facilities provide hands-on experience, equipping early-career researchers with the expertise needed for the energy sector.

By collaborating with industry, academia, and government, we ensure cutting-edge research leads to real-world solutions.

Advancing catalyst research

Industrial chemistry is a major emissions source, both directly through chemical reactions and indirectly via inefficiencies. Catalyst research is key to reducing this impact by enhancing reaction efficiency and sustainability.

STFC supports catalysis research by funding university projects and providing access to STFC ISIS Neutron and Muon Source (ISIS) instruments for catalytic analysis. A key focus is clean air and carbon sequestration, advancing technologies that lower emissions, absorb carbon, and improve air quality. In collaboration with universities, STFC uses advanced neutron imaging and a new infrared spectroscopy technique, amongst other sophisticated techniques, to study catalyst structures and reaction mechanisms to develop more effective catalysts.

UK Catalysis Hub III

The UK Catalysis Hub, in partnership with the STFC's Central Laser Facility (CLF), is a national research hub uniting researchers from 46 universities to advance research in net zero and sustainable chemistry. The UK Catalysis Hub III tackles challenges like developing catalysts to convert waste, such as plastics and CO_2, into valuable raw materials. Its labs at the Research Complex at Harwell, supported by STFC facilities, provide nationwide access to cutting-edge expertise and instruments.

Image source: Research Complex at Harwell. Photographer: David Fisher

Building the UK's nuclear talent pipeline

STFC's Technology Department's Nuclear Physics Group strengthens the UK's nuclear sector by developing highly skilled professionals through research and university partnerships. While much of this work supports the broader nuclear industry, it is crucial for knowledge transfer and workforce development. By training early-career researchers, the group ensures a pipeline of expertise in clean energy solutions, indirectly contributing to net zero.

STFC's latest exciting collaboration with UK Atomic Energy Authority (UKAEA) is the QuEST-FuSED (Quantum Enabling Skills Training – Fusion Skills Education Development) project which will deliver in-house engineering skills programme to apprentices. The programme was announced at the 2024 National Quantum Technologies Showcase and aims to better equip participants with the fundamental skills required to thrive in their placements on-site.

Image source: ISIS Neutron and Muon Source

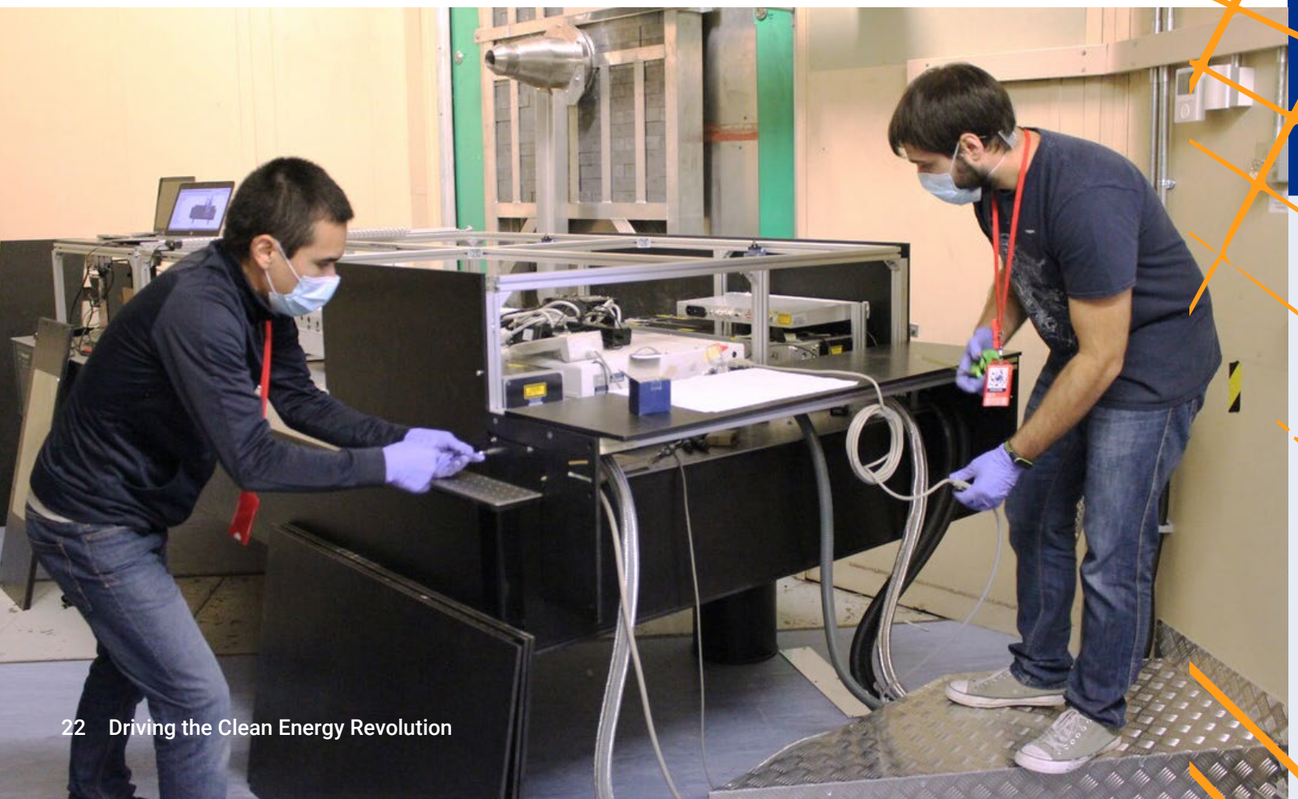


Image source: JASMIN

Powering global climate research

JASMIN is a globally unique data analysis facility. It provides storage and computer facilities to enable data-intensive environmental science. This supports UK and international efforts to tackle climate change, making climate data accessible to researchers worldwide exploring topics from climate change and oceanography to air pollution, earthquake deformation and wildlife populations.

JASMIN is managed jointly by STFC Scientific Computing and the Centre for Environmental Data Analysis (CEDA), part of STFC RAL Space. CEDA helps scientists maximise the impact of this data by offering specialised tools and expertise. By strengthening global climate research, CEDA supports more informed decision-making in climate policy and adaptation strategies.

Fuel cells and battery innovation

STFC is driving fuel cell advancements through its Lasers for Science programme, providing researchers with state-of-the-art tools to explore fuel cell chemistry. This work improves energy efficiency and accelerates the development of clean energy technologies.

To further battery research, STFC hosts seminars and 'Meet the Beamline Scientist' sessions, helping researchers leverage STFC's facilities for battery innovation. By fostering knowledge exchange, STFC is accelerating progress in energy storage and sustainable power solutions.

Spotlight on:

Harwell Energy Tech Cluster

STFC co-owns and manages the Harwell Science and Innovation Campus, where it runs the Harwell Energy Tech Cluster, fostering collaboration between over 90 organisations to address the UK's energy challenges. It unites companies, research institutions, and government organisations to accelerate clean energy innovation. By combining expertise in nuclear fusion, hydrogen, battery technology, and AI-driven energy solutions, the cluster drives the UK's net zero ambitions and the transition to a low-carbon energy system.

As a bridge between STFC, industry, and researchers, the cluster provides access to world-class facilities and expertise, turning research into real-world impact. While not all projects are solely focused on net zero, most advance a more efficient and sustainable energy sector through cleaner technologies, efficiency improvements, and emission reductions. At STFC, we are driving innovation and increasing the opportunities for the commercialisation and adoption of AI and clean energy technologies. This supports both the UK government Clean Energy Superpower Mission and Economic Growth Mission.

A key role of the cluster is seed funding for projects that integrate STFC's research capabilities with industry, accelerating technology development and commercialisation. Current priorities include:

- **Energy storage:** Advancing battery and grid solutions for stability.
- **Modular nuclear reactors:** Driving safe, scalable nuclear innovation.
- **Process efficiency:** Reducing energy waste and emissions across industries.

The Harwell Net Zero Living Laboratory allows testing of prototypes to move technologies rapidly through the technology readiness levels. Recent examples include:

- a novel heat pump technology at DiSH (the restaurant at Harwell Campus),
- a demonstrator for nitrous oxide removal using clean hydrogen-based catalysis, and
- the testing of an advanced renewable technology on lampposts that is capable of converting movement to electricity.

> **"The Harwell Energy Tech Cluster is where innovation meets sustainability, driving the future of clean energy through collaboration, cutting-edge research, and breakthrough technologies. This has provided an interface for STFC to work with key stakeholders, building technical collaboration, skills and supporting the Clean Energy Mission.**
>
> Emma Southwell Sanders, Harwell Energy Tech Cluster

Image source: Harwell Energy Tech Cluster

Committed to long-term operational environmental sustainability

UKRI's Environmental Sustainability Strategy ensures responsible investment and operations, embeds sustainability principles into research, and reduces environmental impact, aligning with the UK's net zero targets. As a Wellcome Concordat signatory, UKRI champions open research, collaboration, and ethical practices, ensuring transparency and accountability.

Aligned with UKRI's vision and strategic ambitions, STFC is committed to responsible science and environmental sustainability. Both STFC's Strategic Delivery Plan and STFC's Environmental Sustainability Strategy drive transformative energy technologies while reducing the carbon footprint of our research and operations.

At STFC, our environmental sustainability vision is to use our world-leading expertise to responsibly deliver and enable innovative science, research and technology and embed environmental sustainability in everything we do, to have a positive, lasting impact on our planet.

Creating environmentally sustainable technological solutions for big science

Particle accelerators are important in many aspects of physics, as they uncover a hidden world much smaller than our eyes can see. However, their high-power consumption poses a significant environmental challenge. Experts at STFC have been developing a sustainable alternative. The Zero Power Tuneable Optics (ZEPTO) magnet is a novel way for accelerators to reduce both running costs and carbon footprint. It marks an exciting step towards more sustainable particle accelerator technologies and could transform how these powerful machines are designed and built in the future. This project is just one of STFC's initiatives towards doing our big science differently by reducing its impact on the planet.

The UK is at a turning point in its journey towards net zero, and STFC is at the heart of delivering the scientific and technological advancements that will shape a sustainable future. By investing in pioneering research, world-class facilities, and strategic partnerships, STFC is driving solutions to the most pressing energy and climate challenges.

Our expertise in energy storage, clean power, and advanced climate technologies ensures the UK remains resilient and a global leader in decarbonisation. Whether through collaboration, investment, or policy support, stakeholders across industry, academia, and government have a vital role to play. Now is the time to work together to accelerate the transition and unlock the full potential of a clean energy future.

We invite governments, businesses, and researchers to partner with us in shaping the next generation of sustainable solutions. With the right investment and collaboration, we can build a future that is cleaner, more resilient, and technologically advanced.

About STFC

The Science and Technology Facilities Council (STFC) supports research in astronomy, physics and space science, and operates world-class research facilities for the UK. STFC's goal is to deliver economic, societal, scientific and international benefits to the UK and its people – and more broadly to the world.

World Class Scientific Facilities

Our large-scale scientific facilities in the UK and Europe are used by more than 3,500 users each year, carrying out more than 2,000 experiments and generating around 900 publications. The facilities provide a range of research techniques using neutrons, muons, lasers and X-rays, and high performance computing and complex analysis of large data sets.

National campuses

We work with partners to build National Science and Innovation Campuses based around our National Laboratories to promote academic and industrial collaboration and the translation of our research to market through direct interaction with industry. Our two campuses are based around our Rutherford Appleton Laboratory at Harwell in Oxfordshire, and our Daresbury Laboratory in Cheshire.

Universities

We support university-based research, innovation and skills development in astronomy, particle physics, nuclear physics, space, environment, and energy science.

Find out more

If you are interested in any of the case studies and would like to find out more about the impacts of STFC's research and innovation contact: **cleanenergyresearch@stfc.ac.uk**

www.ukri.org/councils/stfc

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/ScienceAndTechnologyFacilitiesCouncil

/bigscience_stfc

Acknowledgements

We extend our gratitude to all our colleagues across STFC who have been involved in the creation of this report. Your insights and expertise have been instrumental in shaping the direction and content. A special thanks goes to all the STFC colleagues whose commitment and hard work is accelerating the delivery of innovative solutions to meet the energy and climate challenges we face.

UKRI Science and Technology Facilities Council