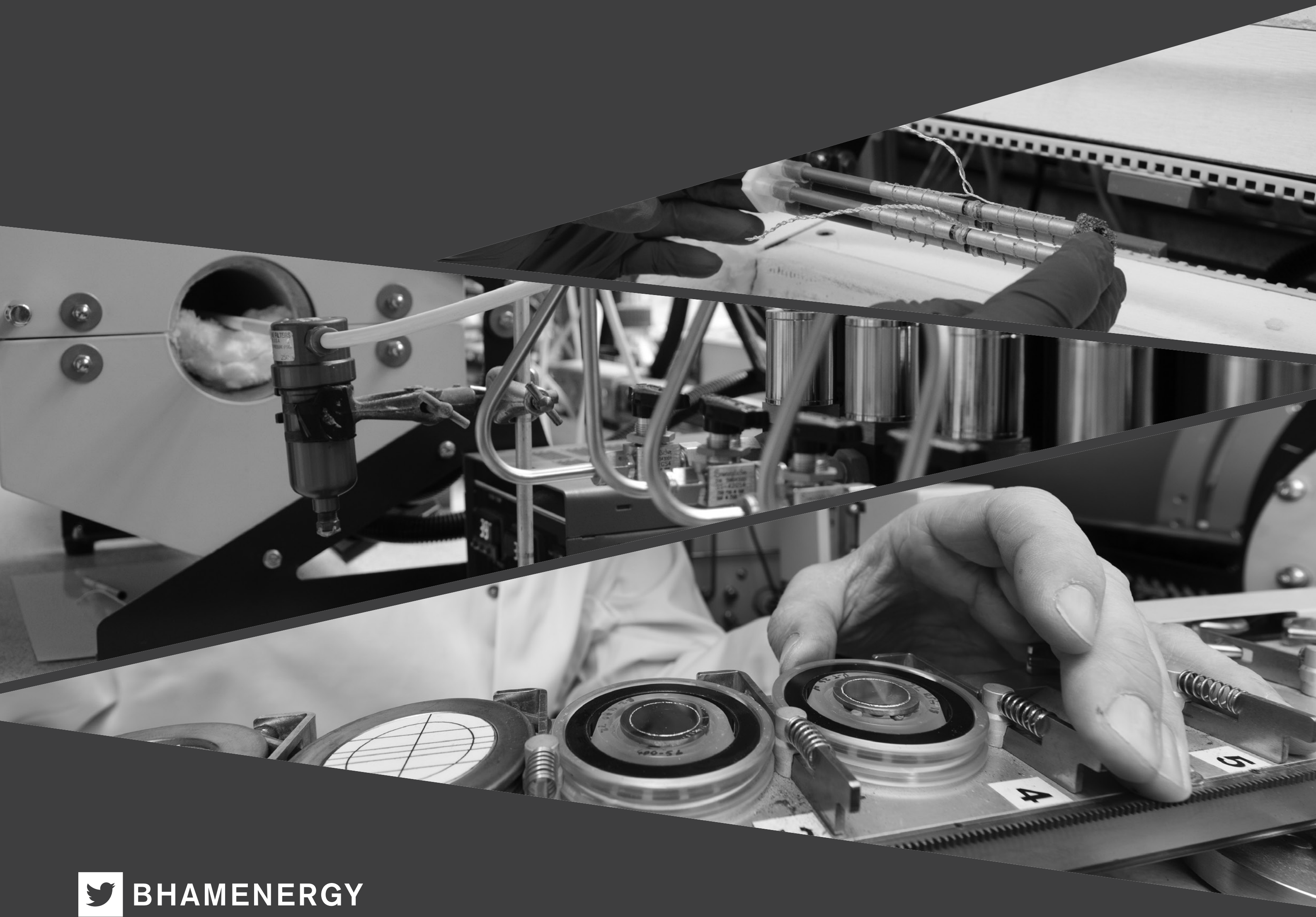
UNIVERSITY OF BIRMINGHAM | BIRMINGHAM ENERGY INSTITUTE

BIRMINGHAM CENTRE FOR FUEL CELL AND HYDROGEN RESEARCH



BHAMENERGY

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BIRMINGHAM CENTRE FOR FUEL CELL AND HYDROGEN RESEARCH

The University of Birmingham is the only research institution in the UK to have integrated research work across all aspects of fuel cells and their fuels. With an internationally recognised programme of research into hydrogen as a future energy vector and the development of key technologies, from sustainable production and hydrogen storage to commercial utilisation, as well as the efficient provision of electricity and heat from fuel cells.

The Birmingham Centre for Fuel Cell and Hydrogen Research is nationally and internationally recognised for its expertise in fuel cell technologies. The Centre focuses on research and development, applications and demonstrations of fuel cell and hydrogen systems and technologies.

Our research is driving both the technology and thinking required to solve some of the challenges facing the UK, as it seeks to develop sustainable solutions to the designing of future cities, energy and transportation. It is the ability to combine the practical with the radical, which has placed Birmingham at the forefront of this endeavour.

The Birmingham Energy Institute is the focal point for the University, and its national and international partners, to create change in the way we deliver, consume and think about energy. The Institute harnesses expertise from the fundamental sciences and engineering, through to business and economics to deliver co-ordinated research, education, and the development of global partnerships. By creating technology and guiding policy today, we aim to help shape energy solutions tomorrow.

A FLEET OF HYDROGEN FUEL CELL CARS CAN BE SEEN OPERATING AROUND OUR CAMPUS. WE OPENED THE UK'S FIRST HYDROGEN VEHICLE REFUELLING STATION ON CAMPUS IN 2008, UNDER THE BIRMINGHAM SCIENCE CITY PROGRAMME.

Challenge-Led Research

The Birmingham Centre for Fuel Cell and Hydrogen Research focuses on research and development, applications and demonstrations of fuel cell and hydrogen systems and technologies. Our activities cover a wide range of areas from developing polymer electrolyte fuel cells (PEFC), solid oxide fuel cells (SOFC) and low-cost electrolysers through to full-scale hydrogen fuel cell demonstrators, such as hydrogen fuel cell hybrid cars, scooters and combined heat and power units. Birmingham is also home to England's first public hydrogen filling station.

CENTRE FOR DOCTORAL TRAINING

BY EXPLORING GLOBAL ENERGY PROBLEMS, OUR AIM IS TO TRAIN A NEW GENERATION OF SCIENTISTS AND ENGINEERS TO ADDRESS INTERDISCIPLINARY CHALLENGES INVOLVED IN THE TRANSITION TO A SUSTAINABLE ENERGY FUTURE. TO ACHIEVE THIS, WE ARE INVESTIGATING THE WIDE RANGE OF FUELS USED IN FUEL CELLS TODAY. THIS INCLUDES DIRECT USE OF NATURAL GAS, ETHANOL, GASIFICATION SYN-GAS AND OTHER BIOMASS PRODUCTS IN ADDITION TO HYDROGEN.

Biomass to Power

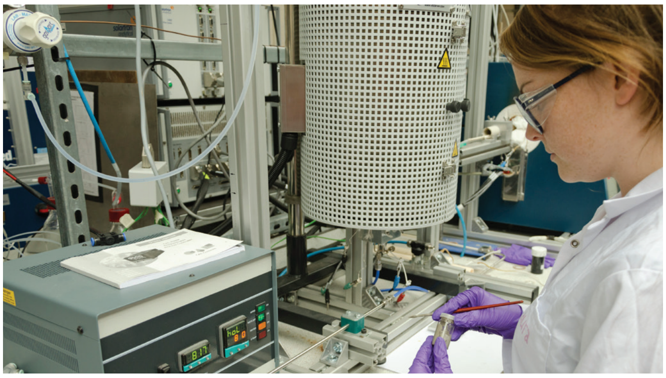
The utilisation of biomass is entirely green. It reduces greenhouse gas emissions, therefore, reduces the global warming effect. Additionally, power generated energy sourced from biomass encourages the decentralised power production, which can significantly reduce the transmission losses caused in centralised power generation. Produced energy can even be fed back to the national grid (either in electricity or natural gas form) improving the stability and security of our power supply.

At the Birmingham Centre for Fuel Cell and Hydrogen Research, we are currently working closely with partners around the globe to develop strategies for turning waste into energy at a high efficiency through innovative methods:

- Thermodynamic modelling
- Gas cleaning and sulphur removal
- Gas Liquefaction
- Combined steam and dry reforming of hydrocarbon fuels
- Hydrogen purification
- Solid oxide fuel cell operation on hydrocarbon fuels
- Anode off-gas recirculation
- New anode materials

SUPERGEN

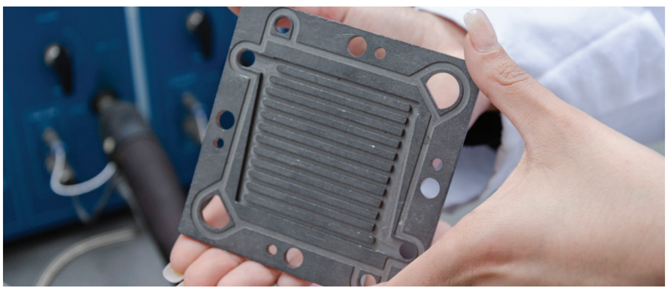
THE UNIVERSITY OF BIRMINGHAM IS A MEMBER OF THE RESEARCH COUNCIL FUNDED HYDROGEN AND FUEL CELLS SUPERGEN HUB PROJECT, A COLLABORATIVE ENDEAVOUR BETWEEN LEADING UK RESEARCH UNIVERSITIES TO DEVELOP THE NEXT-GENERATION OF FUEL CELL TECHNOLOGIES.



Low Temperature Fuel Cells

Fuel cells have great potential to help fight carbon dioxide emissions, to reduce dependence on hydrocarbons and to contribute to economic growth. Low temperature fuel cells, benefiting from a low operating temperature, high-speed start-up and shut down, have shown high potential in micro-CHP, transport and portable applications.

Low temperature fuel cell research at the University of Birmingham covers electrodes, single cells and stacks of Polymer electrolyte fuel cells and Direct methanol fuel cells, working to bridge the gap between the pure material research and the high-performance fuel cell systems for power generation and transport applications. Researchers at the University are leading the way in developing Polymer Electrolyte Fuel Cell (PEFC), operating at temperatures in the range (100–120°C). The technology is being developed for the automotive industry, focusing on the reduction of cost and manufacturability.



Solid Oxide Fuel Cell (SOFC) Systems Development

The Birmingham Centre for Fuel Cell and Hydrogen Research, in collaboration with industry partners, are looking into the research, development and demonstration of SOFC power systems.

The work focuses on will see the development of stacks and systems that can operate with either syngas or natural gas; focusing on the production of the fuel cells, the scale-up of stacks, hardware development and commercialisation of the technology.

Our portfolio of SOFC projects concentrate on innovative concepts. These projects conduct bench-scale R&D on SOFC stack technologies. Leveraging improvements in lower-cost materials, innovative manufacturing methods, and alternative architectures that have the potential to decrease the cost of SOFC power systems.

Modelling Accelerated Ageing of Solid Oxide Fuel Cells

In addition to physical testing, we also have advanced computing facilities for modelling the physical processes that take place within fuel cells. The EPSRC-DST project MAAD-SOFC aims to develop a new mathematical model to describe the degradation process seen in SOFC when fuelled with biogas. The long-term aim is to develop new durable materials to incorporate into a stack. With our sophisticated laboratory facilities, these models can be compared against observed phenomena. We are investigating new sulphur and carbon tolerant anodes to improve the lifetime of SOFC's when used with biogas.

Hydrogen Separation Membranes

Hydrogen produced from natural gas reformers and from biomass sources, usually contains small amounts of impurity gases, such as carbon monoxide, and sulphur. A polymer electrolyte fuel cell (PEFC) converts hydrogen and oxygen gases into electricity; however, even very small amounts of impurities can reduce the operating life of the fuel cell. The Hydrogen Materials Group within the University of Birmingham is investigating how metallic diffusion membranes can be used to purify hydrogen with certain palladium based alloys that will allow only hydrogen gas to pass through (the impurity gas molecules are too large), resulting in parts-per-billion level pure hydrogen. However, these materials are currently expensive and delicate so Birmingham academics are investigating how the cost of these membranes can be reduced and robustness increased.

FUEL CELLS CONVERT HYDROGEN AND OXYGEN GASES INTO ELECTRICITY

Interdisciplinary approach to fuel cell materials

Our research underpins a range of industrially important areas, including new materials for energy technologies. Efficient energy storage and production is a huge challenge facing our society, and to meet it requires innovation and a change in direction. The Birmingham Energy Institute draws together a significant concentration of research, targeted at developing the next generation of materials for fuel cells and hydrogen storage across the schools of the University.

The Hydrogen Storage Group in the School of Chemistry at the University of Birmingham has an extensive programme dedicated to the discovery and synthesis of hydrogen storage materials. One application of these materials is for hydrogen storage in fuel cell vehicles, enabling the cleaner mobility solutions and the next generation of zero-emission vehicles.

Our Hydrogen Materials Group in the School of Metallurgy and Materials has over 35 years' experience in the investigation and exploitation of hydrogen interactions with materials. The laboratory has state of the art equipment, with one of the most comprehensive ranges of techniques in the world for the characterisation of hydrogen storage materials. Research spans the use of lightweight metal powders that are able to efficiently store large amounts of hydrogen to membranes that can separate gases to give ultra-pure hydrogen.

Academics in the School of Chemistry and Chemical Engineering are also collaborating in the development of new materials for fuel cell electrodes and solid oxide fuel cell electrolytes. For both groups, an important aim is the development of a new reversible hydrogen storage material that could greatly extend the driving range of a hydrogen fuel cell vehicle.

EDUCATION AND TRAINING

THE RESEARCH UNDERTAKEN AT THE UNIVERSITY OF BIRMINGHAM PROVIDES THE LEADING-EDGE KNOWLEDGE THAT UNDERPINS OUR TEACHING.

Embedded within a context of rich partnerships with industry and commerce, our students are exposed to training opportunities which fuse practical experience with teaching informed by the latest advances in the field. Our aim is to nurture the next generation of research pioneers and leaders in industry. The EPSRC Centre for Doctoral Training (CDT) for Fuel Cells and their Fuels builds on the success of the Hydrogen, Fuel Cells and their Applications Centre, which was established in 2009, in collaboration with the Midlands Energy Consortium (MTC). Drawing upon expertise and research facilities at the Universities of Birmingham, Loughborough, Nottingham, Imperial College London and University College London, the CDT is flagship collaboration undertaking research in a breadth of fuel cell-related fields.

By exploring global energy problems, our aim is to train a new generation of scientists and engineers to address interdisciplinary challenges involved in the transition to a sustainable energy future. To achieve this, within the CDT, we are investigating the wide range of fuels used in fuel cells today. This includes direct use of natural gas, ethanol, gasification syn-gas and other biomass products in addition to hydrogen.

KNOWHY

KnowHy is a three- year European FP7-project, funded by the European Commission (EC) and coordinated by the Fuel Cell and Hydrogen Joint Undertaking (FCH-JU), that aims to develop an innovative, online, hands-on educational programme for technicians working with hydrogen and fuel cell systems. Courses will be supported in E-learning format and will be available in multiple countries and in seven languages.

The collaborative consortium is organised by Delft University of Technology and includes partners in FC&H2 technology at the University of Birmingham, Instituto Superior Tecnico, FAST, Munich Technical University, Fundación para el desarollo de las nuevas tecnologias del hidrogeno en Aragon, Environment Park, and McPhy Energy.

Fuel Cell Passenger Vehicle Demonstration Projects

Hydrogen cars cut carbon emissions through the use of fuel cell technology, which converts hydrogen's chemical energy into electricity through a chemical reaction. They only emit water into the atmosphere, and can already be competitive with petrol or diesel models. Replacing fossil fuels with alternative energy sources is important if we are to cut carbon emissions. But powering vehicles, as well as domestic heating, lighting systems, and electrical devices, with the likes of hydrogen and methanol, will become a reality – only if they can be proven to be reliable, robust and cost-effective. We are working on the design and production of fuel cell equipment for various mobile and portable applications replacing batteries. We manufacture our own fuel cells and test and optimise them in our laboratories. Our five-strong fleet of hydrogen cars has gone through a series of improvements and the next generation will soon be trialled on the streets of the West Midlands.

Quieter, cleaner, zippier and cheaper to run, hydrogen-fuelled cars, for example the one Birmingham has co-developed in conjunction with Microcab, are set to revolutionise the motor industry. And it's not only cars; we are also developing fuel cell systems for trains, planes, ships and rail buses. In fact, we are the only UK research centre looking at all aspects of how hydrogen can be harnessed to create a greener future.
The Centre is also part of a group of which 17 partners undertaking the project 'Small 4-Wheel Fuel Cell Passenger Vehicle Applications in Regional and Municipal Transport' (SWARM). This project aims to optimise and build 100 low-cost Fuel Cell Hybrid Vehicles. There are five industrial partners: Air Liquide, Microcab, Riversimple, H2O e-mobile, and TUV.

The project also aims to deploy the infrastructure to support this fleet of small, efficient vehicles. Two 200kg/day hydrogen refuelling stations are planned. This will support demonstration sites in North West Germany and in Brussels.

Hydrogen canal boat

Engineers have also developed a zero-emission canal boat, powered by an electric motor, polymer electrolyte fuel cell (PEFC), and metal hydride storage technology. The project was in collaboration with British Waterways and is used to demonstrate and raise awareness of the practical applications of hydrogen.

Hydrogen train

Currently, the energy to move trains is either provided by electricity that is provided via wayside infrastructure or through the combustion of diesel on-board the train. Electrification of railway lines requires large initial investment in infrastructure and is only economically viable on routes that have a high density of traffic. The railway industry is committed to increase the amount of electrified lines, which will mean that the number of electric trains will increase further. However there will still be a requirement for autonomously powered trains which serve the non-electrified lines. A cross-disciplinary venture between a number of Birmingham Energy Institute academics in the School of Chemical Engineering, School of Metallurgy and Materials, and Birmingham Centre for Railway Research and Education, developed, designed, and constructed the UK's first practical hydrogen-powered locomotive.

Energy Balancing via Hydrogen Cycle

The fluctuation in renewable energy generation and the deviation from the power demand can be balanced through the integration of hydrogen technologies within a smart micro grid. An energy management strategy (EMS) is required to control the power flow from a generation side to match that for the demand, and enhance power supply reliability. Researchers at the University of Birmingham are using hydrogen technologies to move closer towards a renewable energy based grid.

Techno-economic and social aspects of hydrogen and fuel cells

Fuel cells and hydrogen technologies are now in a stage of development where they can be offered to customers. Due to the massive scalability of fuel cells, customers range from people who use consumer electronics to grid power suppliers who need to balance renewable energy supply with demand. Fuel cells have been able to achieve notable sales volumes, with some companies selling many thousands of units.

However, they have yet to reach mass markets; one reason for this is because they have not been targeted toward markets where they are able to outcompete both incumbent and innovative competing technologies.

The techno-economic and social research team at the University of Birmingham assesses the technical, economic and social viability for fuel cells. This divided approach allows technically feasible and economically viable markets to be identified. The social research assesses the attitudes and preferences of potential customers ensuring fuel cells and hydrogen technologies are placed in markets where a need for them exists.

Mission possible: using fuel cell power systems to extend the flying time of drones

Unmanned aerial vehicles (UAVs) are increasingly being used for a wide range of industrial and commercial purposes, from power line surveillance to documentary filmmaking, as a way to boost efficiency and safety and cut labour costs.

As the demand for civilian-use drones continues to take off, so will the demand for lengthier flight times of UAVs.

And that's where we come in. The four-and-a-half-year SUAV project to dramatically extend the mission duration of mini-UAVs is cruising ahead.

Using a microtubular solid oxide fuel cell (µSOFC) power system, we are working towards considerably increasing the flight duration of small drones – thus reducing mission costs.

In collaboration with ten companies and universities from seven European countries, SUAV – the first of its kind in Europe – will, quite literally, take to the skies in late 2015: we aim to get our first SOFC-powered drone in the air during November.

Working with Dutch company HyGear and with SURVEY Copter, a subsidiary of our industry partner Airbus Group, we have taken the existing battery pack from its mini-UAV and swapped it for a fuel cell unit. Whereas the majority of systems are based on polymer electrolyte fuel cells (PEFCs), using SOFC allows us to use more readily available fuels such as propane.

With more than €3 millon of funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), we are designing, optimising and building a 350W µSOFC stack, designing and building a fuel processor to convert propane into suitable SOFC fuel, and integrating these components into a mini-UAV platform.

We are confident of the success of the SUAV project, and intend that it will open up new opportunities in other weight-limited and man-portable applications.

WE ARE BUILDING A FUEL CELL STACK THAT WILL POWER UAV MORE EFFICIENTLY

COMMERCIAL CASE STUDIES

That's cool: on the road to a greener future with new truck refrigeration system

Refrigerated transportation plays a vital role in carrying goods from manufacturing sites to primary storage centres and, from there, to retail stores and other secondary distribution points.

But current refrigerated trucks run on vapour compression systems, powered by a separate auxiliary diesel engine or the main diesel engine itself. Vehicles with internal combustion engines are noisy and emit a considerable amount of greenhouse gases. Even when trucks are stationary, they have to keep their engines idling, which uses up diesel.

Fuel cell technology promises to solve these problems, which is why we are working on a way to apply fuel cells to power truck refrigeration systems.

In conjunction with Unilever, we are running a research project called 'fuel cell integration for refrigeration applications', which focuses on how to use fuel cell technology in a refrigerated truck(with a gross weight of seven tonnes and above). A solid oxide fuel cell (SOFC) provides the energy to allow the refrigeration system to be on all the time – even when a truck's engine is switched off. This means no noise and no emissions. In addition to these environmental benefits, the SOFC system will reduce wear-and-tear on vehicles and cut diesel consumption.

Besides electricity, a solid oxide fuel cell (SOFC) provides heat, producing temperatures of 650–700°C. Rather than wasting the heat, it can be used to run a thermally driven refrigeration system. What is more; because the SOFC provides a constant source of heat, it allows the refrigeration system to be on all the time, even when a truck's engine is switched off. This means that in addition to environmental benefits, the SOFC system will reduce wear-and-tear on vehicles and cut diesel consumption.

The work is currently expanded to include application such as combined heat, cool and power generation for commercial buildings and hospitals.

We are confident we can demonstrate that using fuel cells in trucks can significantly improve and 'green up' the transportation of foodstuffs and other perishable goods.

JOIN US

We would be delighted to discuss your requirements with you for research, consultancy, education or partnerships through the Birmingham Energy Institute.

CONTACT US

To learn more about the detail and impact of our research:

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