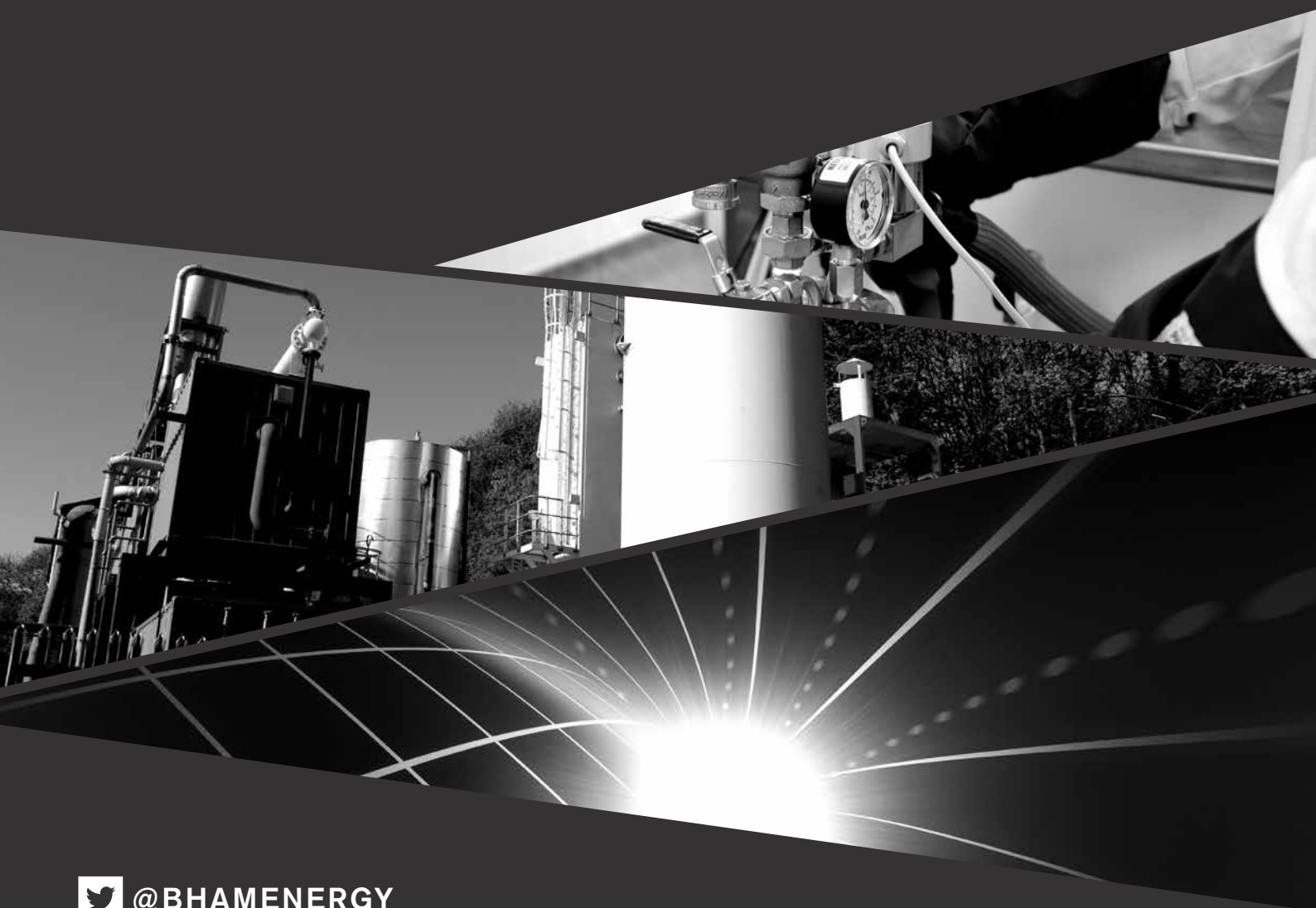
UNIVERSITY OF BIRMINGHAM

BIRMINGHAM ENERGY INSTITUTE

BIRMINGHAM CENTRE FOR ENERGY STORAGE



@BHAMENERGY

WWW.BIRMINGHAM.AC.UK/ENERGYSTORAGE

BIRMINGHAM CENTRE FOR ENERGY STORAGE

The Birmingham Centre for Energy Storage (BCES) brings together research expertise from across the University to drive innovation from the lab to the market. The BCES was established in 2013 with a £12 million investment by UK industry and the Engineering and Physical Sciences Research Council under its Eight Great Technologies Capital Programme. The BCES consists of two components: the Birmingham Centre for Thermal Energy Storage, and the Birmingham Centre for Cryogenic Energy Storage, both of which draw on capability in materials, thermodynamic processes, application development, smart grid and policy economics.

The BCES recognises how energy storage, particularly thermal and cryogenic energy based technologies, coupled with appropriate policy, could play an important role in delivering an integrated energy system. The service that could be provided range from enhancing power quality and reliability, transmission network stability and frequency regulation, to dealing with intermittency of renewables and improving infrastructure utilisation, along with effective and efficient utilisation of industrial waste energy. Energy systems will need to become more flexible and resilient to respond to greater variability in supply and demand. Our researchers are providing flexibility and robustness by developing new low carbon technologies that allow us to shift energy from one place or time to another, and to turn highly fluctuating energy sources to stable ones.

'NEW STORAGE TECHNOLOGIES COULD TRANSFORM HOW ENERGY IS SUPPLIED AND USED, HELPING TO MAKE FUTURE ENERGY SYSTEMS MORE EFFICIENT AND RELIABLE, LOWER CARBON AND MORE AFFORDABLE. HOWEVER, INNOVATION IN TECHNOLOGY AND POLICY IS NEEDED TO RELEASE ITS VALUE. THE CENTRE INTEGRATES THE FULL RESEARCH AGENDA TO ACCELERATE THE DEVELOPMENT AND DEPLOYMENT OF THE ENERGY STORAGE TECHNOLOGIES'
PROFESSOR YULONG DING, DIRECTOR OF THE BIRMINGHAM CENTRE FOR ENERGY STORAGE

ABOUT THE BIRMINGHAM ENERGY INSTITUTE

BIRMINGHAM ENERGY INSTITUTE

The Birmingham Energy Institute is a 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.

More than 140 academics from 4 colleges are engaged in energy and energy related research and development, with over £75 million external research investment. The Birmingham Energy Institute's strength comes not only from the concentration of expertise in specialised centres, but also the breadth of knowledge and facilities that it can draw upon through interdepartmental and interdisciplinary working across the University.

WE HAVE OVER 140 ACADEMICS ENGAGED IN ENERGY AND ENERGY RELATED RESEARCH AND DEVELOPMENT

£75 MILLION

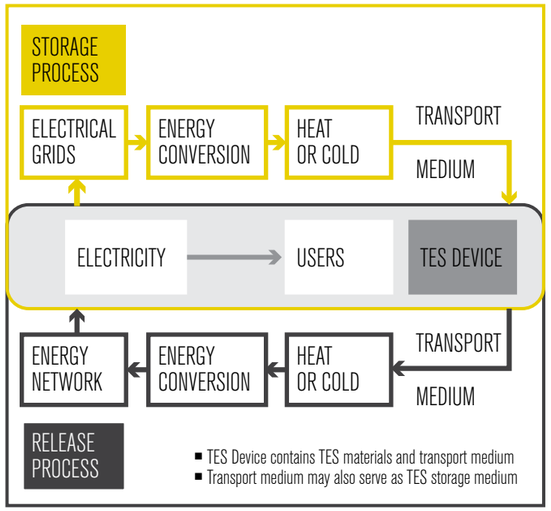
AWARDED FROM EXTERNAL PROJECT FUNDING RELATED TO ENERGY

Around 90% of the global energy budget centres around the conversion, storage, and transmission of thermal energy. Fossil fuel and nuclear power generation are thermally based systems and emits a huge amount of low-grade waste heat; effective and efficient utilisation of such thermal energy represents one of the key challenging areas that becs is working on.

THERMAL ENERGY STORAGE

WHAT IS THERMAL ENERGY STORAGE?

Thermal Energy Storage (TES) refers to the family of technologies that store excess energy in the form of heat and uses the stored heat either directly or indirectly through energy conversion processes when needed. TES is based on heating a storage medium so the thermal energy in the system can be used at a later time. Our research helps to provide a balance between the energy demand and supply, and utilise waste heat generated in various applications including energy production, conversion processes and in the process industry. produced from energy generation or industrial processes.



TES increases system efficiency and reduces CO2 emissions by making use of waste heat. The integration of TES in fossil fuel and nuclear power plants can also increase their peak shaving capability. Additionally, TES can play a pivotal role in large scale solar thermal power generation.

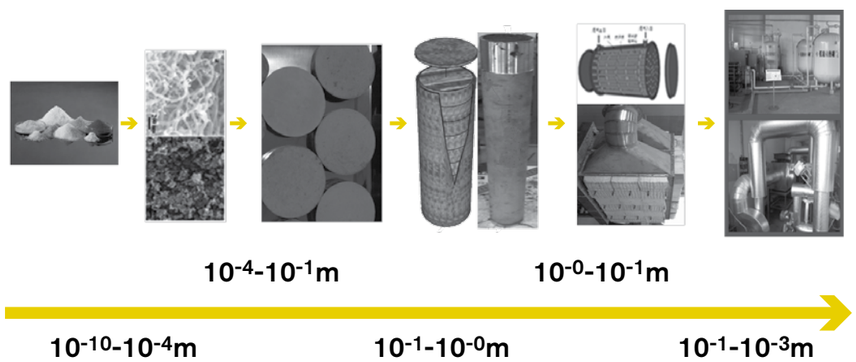
THE BIRMINGHAM CENTRE FOR THERMAL ENERGY STORAGE (BCTES) WAS ESTABLISHED UNDER THE SUPPORT OF THE UK ENGINEERING AND PHYSICAL SCIENCES RESEARCH COUNCIL, ALONG WITH A NUMBER OF RESEARCH GRANTS ON ENERGY STORAGE. IT COMPRISES NEW LABORATORIES, STATE-OF-THE-ART EQUIPMENT, AND A PILOT MANUFACTURING LINE FOR THERMAL ENERGY STORAGE MATERIALS, COMPONENTS AND DEVICES.

THERMAL ENERGY STORAGE RESEARCH

BCES focuses on the following research activities:

- Phase change based microstructured composite materials for applications between approximately the room temperature and 1500 °C;
- Novel nano-pore based insulation materials for elevated temperature applications;
- Components and devices using the composite materials;
- Applications through integration and optimisation with energy networks and industrial processes;
- Advanced manufacture technologies for materials, components and devices, including scale-up;
- Economic analyses and policy.

The first five research areas are interconnected, covering tens of orders of magnitude.



Our materials research stretches from the nanoscale up to full-size demonstration

CRYOGENIC ENERGY STORAGE

THE BIRMINGHAM CENTRE FOR CRYOGENIC ENERGY STORAGE (BCCES) IS THE FIRST IN THE UK TO HAVE A RESEARCH FACILITY FOR ENERGY STORAGE USING CRYOGENIC LIQUIDS, COMPRISING NEW LABORATORIES, STATE- OF-THE-ART EQUIPMENT, AND A MAJOR DEMONSTRATION FACILITY.

WHAT IS CRYOGENIC ENERGY STORAGE?

Thermal energy storage is often commonly thought of in terms of heating and high temperatures. Energy can be stored more effectively and with a higher energy density by cooling materials. A cryogenic energy storage (CES) technology uses off-peak electricity to liquefy a gas such as air and carbon dioxide, and store the liquefied gas in a storage tank (energy is stored). At peak hours, liquefied gas is pumped and heated by the ambient heat, expands many times (over 700 times for air) to generate electricity (energy is released). The CES technology helps to address the 'wrong time wrong place' energy generation and supply problem, such as excess wind power generated at night when demand is low. The system can also be applied to low-grade waste heat recovery from power stations, industrial processes, or renewable sources, such as solar and geothermal. CES can also be built alongside liquefied natural gas terminals to recover cold energy and does not require scarce resource, and is not limited by geography or geology.

Cryogenic liquids can be used to power engines, which are often called cryogenic engines although the engine operation is not at cryogenic temperatures. Diesel generators are routinely used as a reserve capacity for the National Grid but emit large amounts of waste heat and carbon dioxide that induce climate change and particulates that are harmful to health. In contrast, cryogenic engines are zero emission and can be used in transport, small to medium scale power generation, and as a back-up power supply. By combining the cryogenic engine with a traditional internal combustion (IC) engine, the efficiency can be improved significantly by capturing waste heat from the IC engine exhaust'; Our researchers are looking at ways to use cryogenic liquids for more efficient and effective alternatives to air conditioning technology to meet the growing demand for cooling systems in food transport and data centres.

CRYOGENIC ENERGY STORAGE RESEARCH

BCES focuses on the following research activities:

- **Novel cold storage materials** with an aim to further increase energy storage density and life-span, improve charge-discharge kinetic performance and reduce costs. These materials can help further reduce the footprint of CES plants and tank size of cryogenic liquid fuelled vehicles.
- **New thermodynamic cycles and processes** with an aim of developing more efficient cycles and processes. These cycles and processes can help improve energy efficiency of gas liquefaction plants – one of the largest electricity consumers. The work can also help develop novel cooling and refrigeration technologies.
- **Systems integration, control and optimization** with an aim to develop tools for designing new technologies through integration of CES with energy networks and industrial processes, and for assessing and optimising the performance of integrated technologies under current and future energy scenarios.
- **Pilot-scale liquid air energy storage facility testing** with an aim to carry out detailed study for both component and system level performance improvement, to validate our work on integration and optimisation, and to provide an education and training base for undergraduate and postgraduate students and engineers working in the area.
- **Cold economy** with an aim to investigate the societal and economic impacts of the cold chain for the UK and abroad, and thus providing a guideline to the scientific and technological research.

The broad range of expertise across the centre and University ensure that our approaches are truly multidisciplinary and innovative.

COLD AND POWER

AROUND 14% OF BRITAIN'S ELECTRICITY AND £5.2 BILLION EACH YEAR IS SPENT ON ENERGY FOR COLD ACROSS THE GRID AND TRANSPORT. THESE FIGURES WILL BE SIGNIFICANTLY HIGHER IN WARMER COUNTRIES, WHILE IN RAPIDLY DEVELOPING NATIONS SUCH AS CHINA AND INDIA INVESTMENT IN COOLING IS STARTING TO BOOM.

The world needs cooling in many forms – for thermal comfort, industrial processes, medical uses and a 'cold' chain of refrigerated food storage and transport. India, for example, needs to make substantial investment into its cold chain over the next five years; and China is on track to increase its refrigerated storage capacity 20-fold by 2017. The US, Europe and UK are all still seeing significant growth in cold transport. In fact, it is estimated that projected growth in global cooling demand to 2030 could equate to as much as three times the current power output of Brazil.

Almost every country has energy policies covering power, transport and heat, but cold currently receives far less attention. However, if soaring cold demand is satisfied using current technologies and fuels, the impacts on climate, air quality and cost will be substantial. So, it is vital that the primary energy required should not grow as fast as the demand for cold services.

'WE ARE LOOKING AT THE CHALLENGES FOR MEETING THE FUTURE DEMANDS TO PROVIDE COLD AND POWER IN BOTH AN ENVIRONMENTALLY AND ECONOMICALLY SUSTAINABLE WAY, FROM THE PURE SCIENCE TO THE LOGISTICS AROUND SCALE AND POLICY IMPLICATIONS. DRAWING ON OUR OWN EXPERTISE AND BY WORKING IN PARTNERSHIP WITH OTHER HIGHER EDUCATION INSTITUTIONS AND WITH INDUSTRY, WE ARE BECOMING RECOGNISED AS A CENTRE FOR EXCELLENCE AND A CENTRE FOR ENERGY SOLUTIONS.' PROFESSOR MARTIN FREER, DIRECTOR OF BIRMINGHAM ENERGY INSTITUTE

COLD AND POWER RESEARCH

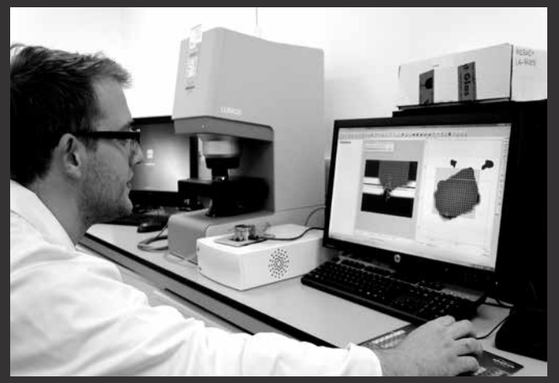
BCES focuses on the following research activities:

- **Storing cold and power** is an important part of how we can make best use of the resource, and also allows the storage of 'wrong-time' renewable energy to use in grid and transport cooling applications.This includes novel materials and methods for storing cold and power, efficient insulation materials and methods, and advanced materials manufacturing technologies.
- **Hybrid engines:** we are working to delivering a prototype transport auxiliary power and cooling system, funded by Innovate UK and in partnership with the Dearman Engine Company, and Hubbard Refrigeration Products. AuxPac will reduce COƋ emissions from refrigerated trucks and air-conditioned buses. The Dearman Engine Company is developing a piston engine that runs on liquid air delivering both power and cold, and which can serve as an efficient and zero-emission transport refrigeration unit (TRU).
- **Economy and policy study** forms an integral part of the research at BCES on cold and power. This will provide guideline for the scientific and technological research, and also provide evidence for government, industry and funding agents for their decision making processes.

SMART GRIDS AND INTEGRATION

Advanced and unique facilities based at the University of Birmingham, funded by Advantage West Midlands and the European Regional Development Fund, as part of the Birmingham Science City initiative, are being used to further the understanding of the operation, control and management of smart grid systems powered by energy from distributed sources.

Large scale integration of renewable distributed generation into the power grid has significant potential to both reduce carbon dioxide emissions and provide secure and resilient power. The current UK grid is largely a one-way system with power generated in large power stations. These are distributed through transmission and distribution lines, with no storage capability. The current system requires power generators to provide excess generation capacity to meet peak demands. The alternative is to develop smart grid systems which integrate power generation and storage through an intelligent communication system.



OUTSTANDING FACILITIES

The University houses facilities for the following research activity:

- A smart power grid and real-time simulator that provides the capability to realistically simulate smart power grids with the integration of distributed power generation including wind, wave and fuel cell generation systems;
- Monitoring and control capability as well as real-time information integration, monitoring, protection and closed-loop control functions;
- Novel VSC HVDC simulations and control.

The Power & Control Group at BCES have been working with companies such as National Grid, Western Power Distribution, E.ON, and ALSTOM Grid.

'THE THIRD ENERGY INDUSTRY REVOLUTION IS TAKING PLACE WHERE THE KEY IS THE DEVELOPMENT OF ELECTRICAL POWER GRIDS IN THE CONTEXTS OF SMART GRIDS. SMART GRIDS ARE PLAYING A PIVOTAL ROLE IN THE DEVELOPMENT OF A SUSTAINABLE ENERGY SUPPLY, ENABLING RENEWABLE ENERGY GENERATION AND ELECTRIFYING TRANSPORTATION IN TERMS OF ELECTRIC VEHICLES IN PARTICULAR. THERE ARE HUGE CHALLENGES FOR DESIGNING, OPERATING, CONTROLLING AND THE ECONOMIC ANALYSIS OF SMART GRIDS. THESE CHALLENGES NECESSITATE THE REVOLUTIONARY CHANGES TO ENERGY GENERATION, ENERGY DISTRIBUTION AND ENERGY CONSUMPTION AS WELL AS ENERGY STORAGE.' PROFESSOR XIAO-PING ZHANG, PROFESSOR OF ELECTRICAL POWER SYSTEMS AT THE BIRMINGHAM CENTRE FOR ENERGY STORAGE

SMART GRIDS AND INTEGRATION RESEARCH

BCES focuses on the following research activities:

- Technologies for smart grids
- Application of power electronics such as FACTS (Flexible AC Transmission System)
- HVDC in transmission and distribution systems
- Integration of PHEVs into power grids
- Super AC/DC power grids for large scale renewable energy delivery
- Protection and control of distribution networks with distributed generation
- Micro-Vgeneration and Micro-grid
- Smart metering and wide area monitoring and awareness
- Power system economics
- Large scale power system optimisation and planning
- Analysis and control of power system stability
- Power quality and harmonics
- Energy Union
- Global Power & Energy Internet

EDUCATION AND TRAINING

Globally there is a shortage of skilled engineers for designing, operating and controlling future electricity networks and heat/cold networks. These systems are playing a pivotal role in the development of a sustainable energy supply and enabling renewable energy generation.

We have developed a portfolio of courses which will equip engineers to meet the demands of future energy challenges.

OUR UNDERGRADUATE PROGRAMMES

- BEng / MEng Energy and Engineering

OUR POSTGRADUATE PROGRAMMES

- MRes Materials for Sustainable Energy Technologies
- MSc Electrical Power Systems

CONTACT US

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

Birmingham Energy Institute
University of Birmingham
Edgbaston B15 2TT
United Kingdom

+44 (0) 121 414 7031
www.birmingham.ac.uk/energystorage
energy@contacts.bham.ac.uk
@bhamenergy

POLICY AND ECONOMICS

The commercial deployment of energy storage technologies will be dependent on viable business cases being made. Studies show that energy storage can reduce the costs of the transition to a low-carbon energy system. The policy and regulatory environment is especially important for energy storage, as the value of energy storage is spread across different markets and it will rise as intermittent generation increases.

The Birmingham Centre for Energy Storage's activity analyses energy policies and markets to enable take-up of effective energy storage, considering UK and global cases. Work also assesses the techno-economic case for deploying energy storage in energy systems at national and local scales.

BUSINESS ENGAGEMENT

Working closely with industry ensures our research is aligned to real-life solutions and commercial, financial and policy environment in which they operate. We have important relationships with a number of industrial companies including China State Grid Smart Grid Research Institute, AnSteel Inc, Alstom, E.ON, EDF, GDF, Highview Power Storage, Economy Energy, Air Products and the Dearman Engine Company. We use our research to solve tomorrow's problems today. Whether you are a large corporate organisation or a small business you can tap into the world-class expertise at the Birmingham Energy Institute.

UNIVERSITY OF BIRMINGHAM
Birmingham Energy Institute
Edgbaston, Birmingham,
B15 2TT, United Kingdom
www.birmingham.ac.uk