Department for
Business, Energy
& Industrial Strategy

Translational Energy Research Centre

Translational Energy Research Centre Capability Overview

BEIS Grant Determination Number CS369

March 2022

Any enquiries regarding this publication should be sent to us at:
enquiries@beis.gov.uk

Contents

Welcome to the Translational Energy Research Centre

One of the largest and best-equipped low-carbon energy solution R&D facilities in Europe.

The Translational Energy Research Centre is a unique, national pilot-scale testing facility based at the University of Sheffield. We are working to discover, demonstrate and integrate low carbon and renewable energy generation solutions from across the energy spectrum to work towards secure, affordable and sustainable energy systems for the future.

Our state-of-the-art, first-of-its-kind equipment and world-leading academic excellence combined with a whole energy system, plug-and-play approach gives you access to faster, more effective and better value research and development.

Everything you need for commercially-focused R&D

In order to expand the existing experimental research facilities for zero-carbon energy research in the UK, the Translational Energy Research Centre features a large number of pilot-scale energy test rigs on one fully-integrated site, offering significant flexibility.

The centre focuses on low carbon energy research at a technology readiness level (TRL) of three to six. By offering the chance to carry out relevant, pilot-scale tests in an industrial setting, results can be scaled confidently and see a faster transition to market.

More than thirty permanent rigs – and capacity for more.

Available at the Translational Energy Research Centre is a comprehensive range of state-of-the-art equipment for research into:

- Carbon capture, utilisation and storage
- Sustainable aviation and transport fuels
- Hydrogen
- Bioenergy
- Renewable energy
- Energy storage
- Smart grids and energy control and monitoring systems

The various rigs and facilities, together with the extensive range of online and laboratory analytical equipment, can be integrated for a ‘whole energy system’ approach, using a smart energy management module and low-carbon heat management system, with optimal synergy between the rigs and processes.

£25.8 million

The £25.8 million centre is part-funded by £12.8 million from the European Regional Development Fund (ERDF) and £7 million from the UK government’s Department for Business, Energy and Industrial Strategy (BEIS) and £6 million from the University of Sheffield.

A new centre for innovation, research, and development on a national and global scale

The Translational Energy Research Centre offers:

- A fast-track to turning early stage research into proven, sustainable, low-carbon products and services which are ready for deployment in the UK and beyond
- Large-scale facilities to research areas with significant growth potential
- Enhanced capacity, flexibility and collaboration space
- A large number of test days and an increased scope of testing for researchers, technicians and industrial partners
- A plug-and-play approach, allowing visiting researchers and industrial partners to join their equipment with our facilities to enhance testing and research

Together, we aim to:

- Become a global leader in energy research, with world-leading innovations alongside academic excellence
- Increase the speed that new technologies can transition to market
- Remove the financial risk of large-scale industrial pilot trials
- Find solutions to some of the most complex energy demand and supply challenges
- Help the UK meet its target of net-zero emissions by 2050

We work with:

- Global companies of all sizes, from start-ups to multi-national partners, who need capacity to research new technology and innovations to decarbonise, or support to develop and test new low-carbon technologies.
- Academic research teams and research centres wishing to access advanced testing facilities and the opportunity to collaborate.
- Regional enterprises of all sizes, and in particular SMEs. We work closely with local partners to assess how to reduce the cost of energy for their business and to find solutions to operational energy loss issues.

Delivering industrial decarbonisation & net-zero emissions

Sustainable Aviation Fuels Innovation Centre

The Translational Energy Research Centre is closely aligned with the neighbouring Sustainable Aviation Fuels Innovation Centre (SAF-IC). The first centre of its kind in the UK, SAF-IC is an exciting new research facility to develop, test, validate and certify new zero carbon and sustainable aviation fuels.

Part-funded by the European Regional Development Fund, SAF-IC will act like a clearing house, with ASTM D4054 standard analytical and testing equipment to take sustainable fuels through the entire approval process. SAF-IC will work in combination with the TERC facility to support state-of-the-art research and provide much-needed testing capabilities to help ready sustainable aviation fuels for commercial use.

Together, TERC and SAF-IC will be the first in the UK to capture CO2, produce green hydrogen, convert them into sustainable aviation fuels and analyse their performance and technical sustainability in one location.

This new facility will enable the development of practical solutions to the challenge of making vital jet travel more sustainable for the industry and our planet, thanks to the decades of expertise and world-class knowledge of its key research academics.

Part of something bigger

The University of Sheffield Energy Institute

The Translational Energy Research Centre is part of the University of Sheffield's Energy Institute. The Energy Institute brings together pioneering researchers who are passionate about changing the world and transforming lives through innovative, interdisciplinary research.

As part of the Energy Institute, the Translational Energy Research Centre has access to over 300 of the best minds in energy research. The combination of the work of the Translational Energy Research Centre and the access enabled by the Energy Institute will ensure we can align early stage research with current and future commercial goals.

The Translational Energy Research Centre in the region and beyond.

The Translational Energy Research Centre and the Sustainable Aviation Fuels Innovation Centre are located in the heart of the University of Sheffield Innovation District, adjacent to South Yorkshire's Advanced Manufacturing Innovation District, alongside some of the UK's most exciting research centres. These include the world-leading Advanced Manufacturing Research Centre (AMRC) and the Nuclear Advanced Manufacturing Research Centre (NAMRC).

The facility and its neighbouring research centres will combine the work of the Translational Energy Research Centre and other Northern energy centres to improve the regional economy, enhance innovation and work towards reaching net-zero emissions in the North of England and beyond.

Some of the largest and most exciting equipment in Europe

Some of the largest and most exciting equipment in Europe

Green hydrogen production via Electrolysis

- Green hydrogen is produced on-site via electrolysis. This is currently done using an a fully-automated alkaline-based hydrogen electrolyser which can generate up to 32m3/h of pressurised hydrogen, with a purity of 99.999%
- This electrolyser is designed in a fail-safe mode with remote control and monitoring features, and can operate with as low as -10°C ambient temperatures
- A PEM-based electrolyser will be installed to increase the total production capacity to 150 m3/h
- Hydrogen production is combined with a specialised compressor which brings up the pressure of the generated hydrogen to 200 bar for storage
- Currently there is storage capacity of more than 35 kg (>450 Nm^3), to be increased to up to 1500 Nm3.

Polymer Electrolyte Membrane (PEM) fuel cell system

- Generates a power that could be used by the end user or returned to the national grid
- Provided with an internal bridge power system that enables instantaneous power generation from cold start
- Equipped with frost protection integrated utility that allows for operation at sub-freezing temperatures
- Operates at a wide range of pressure (2.7 to 10 bar) and relative humidity (5 to 100%)
- Has an integrated control and monitoring system
- Real-time monitoring of hydrogen consumption, electricity generation, fuel cell stack voltage and current, and capacity for more.

Molten Carbonate Fuel Cell (MCFC): Next generation CCUS technology

- Next generation technology to capture CO2 and produce electrical energy simultaneously
- Could lead to an increase in output power of up to 80% and could eliminate up to 70% of NOx emissions as the operating temperature is lower than that of combustion

- Supports extensive current and future research into low carbon energy generation, integrated energy systems and hydrogen economy
- Integrated with a hydrogen separation and purification unit, enabling the rig to produce hydrogen as a co-product of the energy generation. This is followed by the removal of impurities to achieve more than 99% purity hydrogen.

Grate-fired biomass with WtE and BECCS

- The 240 kWth moving grate fired WtE boiler is capable of burning a range of virgin biomass and waste fuels
- To combine the combustion of biomass and waste derived fuels with carbon capture research, the flue gas train is fully integrated with the on-site Amine solvent-based capture plant and can provide flue glasses produced by a wide range of fuels.
- Fuel capabilities include:

– Virgin biomass fuels, including woodchip and pellets

– Recycled untreated wood products (e.g. shipping pallets, cable reels)

– Biomass waste from agriculture or forestry

– Vegetable waste from the food processing industry

- The combustion chamber was built according to a direct pass principle for drying, gasification and combustion of the fuel, and the subsequent removal of ash from the combustion chamber
- The boiler was specifically designed for research purposes and is fitted with a wide range of ports at key locations of interest within the combustion chamber and flue gas passage to allow the detailed characterisation of these zones.
- Example experimental capabilities include the following analytical probes:

– Flame imaging camera probe

– Suction pyrometer

– Gas sampling probes

– Ellipsoidal radiometer

– Particle collection probe

– Deposition probes

– Corrosion probes to fit metal coupons made from materials used for the manufacturing of specialised boiler tubes

- Gas analysis can be carried out using:

– a stack gas analyser system (O2, CO2, CO, NOx, THC)

– a Gasmet FTIR

– an ETG syngas analyser (H2, CO2, CO, O2, NOx, CmHn)

– a Spectro-Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) analyser for online simultaneous multi metal emissions detection (e.g. K, Na, Hg, Cr, Cd, Pb, V, Zn, etc)

- High combustion temperatures, as well as a long residence time of the combustion gases, guarantee a clean burning process. Furthermore, particulate removal is achieved in two distinct steps using a multi cyclone followed by an electrostatic precipitator (ESP) to adhere to the strict emissions limits of the Medium Combustion Plant Directive (MCPD)

Solvent-based post-combustion CO2 capture plant

- Fully instrumented, 1 tonne/day pilot-scale conventional solvent-based CO2 capture plant with two absorber columns and solvent redistribution at each of the four packed beds
- Integrated with Gas Mixing Facility, 250kW Air Combustion Plant, 240kW waste to energy boiler, 300kW Gas Turbine and the Fischer-Tropsch plant to enable CCUS research on liquid fuel production from natural gas, biomass and biowastes
- Enables the development, evaluation and optimisation of a variety of solvents for energy performance, degradation studies and counter-measures
- Provisions for corrosion coupons and alternative materials test sites, and trace gas injection capability for capturing carbon from any synthesized flue gas compositions
- Integrated with rotating packed bed CO2 capture plant for performance assessment of individual units (absorber/stripper)
- Includes CO2 desulphurisation capabilities, which will be used to recover high purity (food-grade) carbon dioxide from the pilot plant. Enables carbon utilisation and feedstock flexibility, creating high quality aviation fuels and also increasing durability of the MCFC.

Rotating Packed Bed CO2 capture plant

- Next-generation pilot scale, process-intensified solvent-based CO2 capture plant with a rotating packed bed absorber and stripper, designed to remove up to 1 tonne /day of CO2 (based on MEA (monoethanolamine) from an equivalent of approximately 150kW conventional coal combustion flue gas
- Improved energy performance thanks to enhanced mass transfer
- Integrated with the Fischer Tropsch plant for CCUS research on liquid hydrocarbon production from captured CO2
- Integrated with 250kW Air Combustion Plant, 240kW waste to energy boiler and two 300kW Gas Turbines, enabling post-combustion capture research from real flue gases from natural gas power plants as well as pulverised, pelletised and chipped fuel combustion plants including coal, biomass, co-firing and wastes

- Integrated with dedicated gas mixing and trace gas injection facilities enabling carbon capture from any synthesised flue gas compositions, including industrial effluent gas mixtures
- Integrated with conventional CO2 capture plant for performance assessment of individual units (absorber/stripper)
- Develop, evaluate and optimise a variety of solvents for post-combustion capture and related technologies, and investigate solvent energy performance, degradation studies and counter measures
- Provisions for corrosion coupons and alternative materials test sites

Sustainable Aviation Fuel (SAF) pilot plant

- A state-of-the-art, fully automatic, first-of-its-kind world class plug and play pilot scale research facility with full solid to liquid and gas to liquid cycle capable of producing liquid fuels from biomass and gas, with a production capacity of 36 litres of fuel per day
- Equipped with novel Reverse Water Gas Shift (RWGS) and Fischer-Tropsch (FT) reactors, it offers the ability to synthesise sustainable alternatives to current petroleum distillates, enabling research into sustainable aviation fuels production from captured CO2 and green H2, or syngas
- Capability to test different reactor designs and catalysts in both RWGS and FT reactors at a wide range of operational conditions
- Able to separate and recycle excess/unreacted gases to enhance conversion efficiency
- Includes a polishing step for CO2 to remove SOx and NOx to a level which does not hinder the FT catalyst
- Online analysis available to monitor the feed and product gas streams at various locations
- Ability to fractionate FT product into different grades (petrol, diesel, kerosene and heavy oil)
- Additional pilot plant to enable direct captured CO2 conversion when combined with green hydrogen produced on site, accelerating innovation into next generation, low cost catalyst and reactor technologies

Gas Turbine

- Two Turbec micro gas turbines, highly instrumented. fueled by natural gas/ biogas with electrical output:100kW, thermal output: 165kW
- Humidified turbine cycles : steam injections to simulate the operation of a humidified turbine cycle
- Exhaust gas recycle (EGR & Selective EGR): CO2 injections to examine exhaust gas recirculation
- Post-combustion CO2 capture research from turbine systems.

- Modified design to include steam injections to simulate the operation of a humidified air turbine and CO2 injections to examine exhaust gas recirculation
- Fuel flexibility research including hydrogen blending and sustainable alternative fuels

Additional capability to convert the turbine with a hydrogen fired combustor + hydrogen fuel handling system for natural gas and H2 blends, which will provide burner component plug-and-play capabilities and access to testing of new engine component designs

Hydrogen Combustion Research Facility (HCRF)

- Undertake a wide range of analytical functions, including near burner analysis, heat transfer to load and furnace analysis, emissions analysis and burner design and performance analysis, as well as many other functions.
- The HCRF is tailored for R&D activities. With 200-300kWth input and turndown to 50kWth and max. operating temp. of 1500°C; sized appropriately for industrial long flame burners (~3.5-4m).
- The HCRF supports fundamental and applied research on hydrogen combustion and cofiring with other fuels (primarily natural gas) in air as well as capability for oxy firing or oxygen enrichment; flame, heat transfer, and emissions characterisation; burner development; corrosion, deposition and materials research and other aspects of combustion research.

Biodiesel Engine Generator

- A CHP unit capable of green power generation using a range of biofuels and operational conditions
- Equipped with extensive emissions monitoring facilities, and it is fully integrated with the on-site CO2 capture and utilisation facilities
- It has 188kW grid synchronised green electrical generation capacity, and 352kW thermal output to supply the space heating needs of the whole facility and potentially the surrounding facilities

Combined Heat and Power (CHP) Biomass Gasifier

- A combined biomass CHP unit with precise control for the gasification process, enabling users to achieve clean syngas production for power generation from biomass fuels
- Integration of the syngas produced and the onsite Fischer-Tropsch plant for liquid biofuel production, especially jet-fuels
- Extensive analytical facilities for research and development on the syn-gas quality. The flue gas output is fully integrated with the on-site CO2 capture and utilisation facilities

High Pressure High Temperature Shock Tube facilities

- A unique high pressure (up to 100 bar) single pulse shock tube with extended drivers
- State of the art laser diagnostic facilities
- Used for chemical kinetics measurement of sustainable alternative fuels
- Investigation into the chemistry which takes place during pyrolysis and oxidation of sustainable fuels
- Kinetics of branched chain reactions to define ignition

High pressure heat exchanger (HPHE) test bed with supercritical CO2 loops

- A high-pressure, high temperature Heat Exchanger (HEX) test bed with fully instrumented fail safe operation
- Includes two supercritical CO2 loops with operating pressures of up to 350 and 100 bars respectively
- Able to test two heat exchangers at the same time
- Supports research and development in high-efficiency power conversion cycles and their global applications in power and industrial sectors
- Provides performance data for the supercritical CO2 cycle to model and evaluate designs, for example in fluid passages
- Suitable for a wide range of applications including supercritical CO2 for oxy-fired gas cycles (Allam cycle) and, nuclear
- Also suitable for studying heat transfer, pressure drop, thermal stresses, impact of phase changes, impurities, fouling, corrosion and for materials research in heat exchangers using a range of fluids

Energy storage batteries

- 120kWh, 50Kw Lithium battery with DC and AC interfaces
- The battery can be connected to the AC grid for grid-connected research, or to a dedicated DC bus along with other assets to provide a flexible test bed to facilitate both grid-connected and ‘behind the meter’ energy optimisation

Smart energy system

- Real-time monitoring, control and coordination of the available energy resources
- Flexible design of intelligent energy management system in a centralised, decentralised or distributed manner
- Hardware-in-the-loop capabilities for future energy resources, paving the way towards system ‘scale-up’

A full list of the equipment and services available at the Translational Energy Research Centre

There will be more than 30 pilot-scale permanent test rigs available at the Translational Energy Research Centre, as well as further capability.

Low-carbon power and heat generation:

- Biodiesel engine generator
- CHP biomass gasifier
- Organic Rankine Cycle system
- Biomass grate boiler including bioenergy with capture and storage (BECCS) capability
- Gas turbines – with modifications for integration of molten carbonate fuel cell (MCFC)
- CHP engine for multi-sustainable fuel configuration
- Energy-from-waste boiler
- Fuel cell based micro-CHP

Oxy-fuel and high-pressure supercritical CO2 (sCO2) technology:

- High pressure heat exchanger test bed
- Shock tube test facility
- 250kW of biomass air/oxy-fired combustion test facility (CTF) with capability to use coal/biomass/clean wood waste fuels

CO2 capture and utilisation (CCU) technology:

- Amine CO2 capture plant – modified for integration with the flue gas and co-product gas manifold systems
- CO2 capture rotating packed bed
- Molten carbonate fuel cell (MCFC) and gas infrastructure for co-generation & next generation CO2 capture technology
- Fischer-Tropsch and fuels plant, and product gas infrastructure for utilisation of CO2
- Gas mixing facility – synthetic/model flue/process gas

Hydrogen production:

- Hydrogen electrolyser
- Reforming in MCFC
- Biomass gasification
- Hydrogen Fuel Cell Heating system
- Hydrogen Combustion Test Rig

Clean, renewable electricity generation and storage:

- Electrical energy storage (batteries)
- Solar PV panels
- Polymer electrolyte membrane fuel cell (PEMFC)

Integration:

- Smart energy management (SEM) module
- Low-carbon heat management system

CFD modelling and simulation:

- A complementary validating system including advanced computational modelling, experimental testing and detailed imaging
- Multiple modelling stations pre-loaded with relevant software including CAD Drawing, Ansys Fluent, Aspen, Chemical Kinetic, Matlab/Simulink
- Ensures a credible output and in-depth understanding and control of the impact of energy system characteristics and integration, critical reaction kinetics, emissions and combustion processes.

Multi-parameter fuel cell test station:

- The Multi-parameter fuel cell test station will investigate the impact of the operating conditions (i.e. the temperature, pressure, gas composition and humidity) on single fuel cell or small fuel cell stacks.
- It will be also used to investigate the effect of the new materials and/or designs on the fuel cell performance.
- It will enable a Multi-range electronic load with a maximum load power of 50 W. A current resolution ≤ 10 mA. A mass flow controller for anode: ≥ 2 SLPM. A mass flow controller for cathode: ≥ 2 SLPM. Temperature-controlled humidifiers for the

reactant gases. A fuel cell software for computer-controlled cell operation and experimentation. measurement for the real-time cell resistance.

Analytical and measurement capabilities:

- Gas analysis and measurement facilities
- Particle, P, and aerosol measurement facilities
- Unique Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) facilities
- Hydrogen analyser, monitoring and control equipment
- Signal stack gas analyser system (O2, CO2, CO, NOx, THC)
- Gasmet FTIRs for flue gas analysis (O2, CO2, CO, NOx, SO2, HCs, HCL, HF) and emissions from the CO2 capture process (NH3, CH2O, amines, etc)
- ETG syngas analyser (H2, CH4, CO2, CO, O2, THC)
- Portable Servomex analyzers (O2, CO2)
- DMS500 submicron aerosol analyser
- Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) for online multi-metal emissions detection (including K, Na, Hg, Cr, Cd, Pb, V, Zn; as well as Ag, Al, B, Br, Ca, Co, Cu, Fe, I, Li, Mg, Mn, Ni, P, S, Sb, Sc, Ti, Si, Sn)
- Analytical probes: Ellipsoidal radiometer, flame imaging camera probe, suction pyrometer, gas sampling probes, particle collection probe, corrosion and deposition probes

Additional capability:

- High pressure heat exchanger test bed
- Shock tube test facility
- Composite 3D printer for energy equipment design and construction
- Both AC and DC electrical infrastructures
- Grid-tied to enable excess clean and renewable energy to be exported
- The entire facility and its various equipment and systems will be controlled by a smart energy management system, enabling research into integrated grid technologies and enabling a ‘whole energy system’ approach
- Plug-and-play facilities to enable visiting researchers to bring their own equipment and connect it to our infrastructure to enhance research and testing abilities
- A heat rejection network to provide permanent and visiting equipment with cooling water. Captured heat will be distributed to the building itself, as well as adjacent buildings connected via a district heating network across the Sheffield Innovation District in the future.

- Additional capability added for Direct Air Capture (DAC), for which the CO2 capture capacity of the plant will be 600kg/day and will be powered by renewable electricity generated from solar panels located onsite

This publication is available from: www.gov.uk/beis

If you need a version of this document in a more accessible format, please email enquiries@beis.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.