



**Sustainable
Hydrogen**

CENTRE FOR DOCTORAL TRAINING

Annual Report 2020



**University of
Nottingham**
UK | CHINA | MALAYSIA



**Loughborough
University**



**UNIVERSITY OF
BIRMINGHAM**

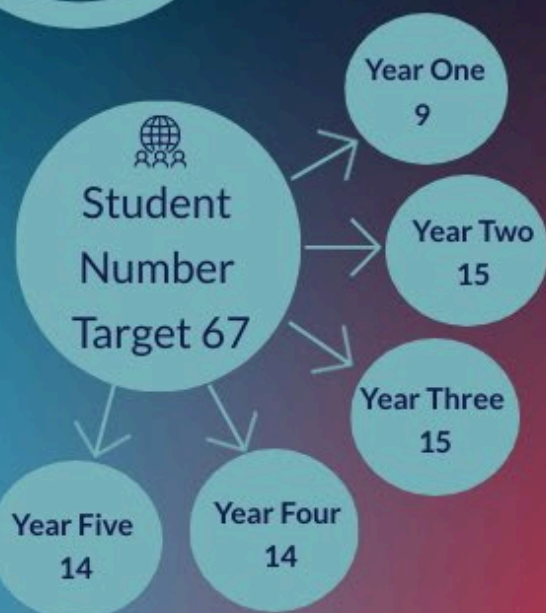


**Engineering and
Physical Sciences
Research Council**

Sustainable Hydrogen CDT



Student Training 
8,226 Hours



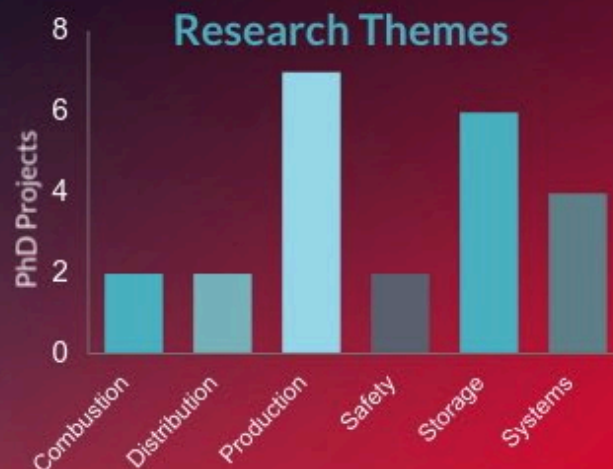
OVER THE PAST YEAR

564
Applications

25% Female Students
2021 Target 50%



International Collaborations
Five



Presentations and Publications
6

Where our Students are From



 **Two International Students**

84
Stakeholder Interactions

The Year in Numbers



Our Vision

Our vision

Moving beyond 2030 – hydrogen facilitated deep-decarbonisation.

Our objectives

- Deliver high quality transdisciplinary training, covering fundamental science, applied engineering, and systems issues and build an appreciation of societal barriers to innovation.
- Through innovation opportunities, build initiative and stimulate an entrepreneurial mindset.
- Deliver “industry ready” doctorates who have a comprehensive skill set and experiences.
- Co-create research ideas and undertake in partnership with our stakeholders, cutting edge investigations of hydrogen-based solutions to deep decarbonisation of the energy system.



Director's Report

The past year has been an exciting time for the sustainable hydrogen field, with many advances in the use of hydrogen for renewable energy, heat and transport sectors. For example the launch of large scale electrolyser facility in the Humber region providing energy storage for offshore wind and recently in the news of hydrogen planes, trains and automobiles (respectively: Airbus, University of Birmingham train and a number of bus and refuse truck projects in the UK). These initiatives are all supported by government announcements of hydrogen storage need alongside a rapid four-fold expansion in off-shore wind generation and for hydrogen to deliver zero-emission medium/heavy duty vehicles.

For SusHy CDT, this has been a successful year despite the major disruption to the universities because of the pandemic. Our first cohort of nine students have just successfully completed their first year. The first year is focussed on training, with 120 credits of taught modules. The move to online training went well and all modules were completed, with favourable reviews being received from the cohort. However, the start of experimental work has been hampered by the lockdown, but is now slowly picking up.

The recruitment for our second cohort was very successful and we used the move to online interviews to speed-up our recruitment processes as it was easier to convene interview panels. This did not impede on the quality of the recruitment procedure and I'm pleased to welcome cohort 2 to the CDT this month, 15 talented individuals from diverse backgrounds who will make significant contributions to our growing vibrant sustainable hydrogen community.

There were some teething problems at the start of the CDT, since late spring we have had a full operations team and the CDT is going from strength to strength. Opportunities for 2021 include stakeholder involvement with our existing PhD projects, offering stakeholder challenges for cohort 1 to tackle, or collaborating on PhD projects for the recruitment of our third cohort, a further 15 PhD students. Recruitment for 2021 will start towards the end of the year and we have two ambitions, to increase the number of stakeholder collaborations and to improve the gender balance of our research project portfolio. The SusHy Management Board are also keen to improve the supportive environment of the CDT for both the student cohort and our early career researchers (new lecturers and research fellows) so that everyone feels equally valued and no one is impeded from achieving their full potential. Challenges will remain, providing support for students if access to research facilities is disrupted and maintaining cohort building activities whilst physical contact is limited, but I am confident in the SusHy community in meeting these challenges as we progress into 2021.

A handwritten signature in blue ink, appearing to read 'G. Walker'.

Professor Gavin Walker
Director, Sustainable Hydrogen CDT



CDT Team Members



Prof Gavin Walker
Director

gavin.walker@nottingham.ac.uk



Dr Kandavel Manickam
Program Manager

manickam.kandavel@nottingham.ac.uk



Mrs Kelly Malcolm
Administrator

kelly.malcolm@nottingham.ac.uk



Mrs Lorraine Hammond
Marketing Manager

lorraine.hammond@nottingham.ac.uk



Equality, Diversity and Inclusivity

Why diversity matters

At the SusHy CDT we appreciate that diverse teams are more successful which is why Equality, Diversity and Inclusivity (EDI) are at the heart of our operations. The positive evidence for this is all around: companies with diverse workforce are more productive and those with diverse boards are more profitable. Ignoring diversity has negative impacts: some products fail certain sections of the customer base; a result of innovation teams not listening to diverse voices.

The SusHy programme aims to train the energy leaders needed to meet the net-zero global challenge, which will require leading successful innovation teams informed by diverse perspectives.

What SusHy is doing

SusHy has recruited amazing individuals from a diverse talent pool who are contributing to the success of the CDT. Our recruitment is guided by EDI best practice (from the wording of adverts through to anonymised shortlisting). The CDT has an EDI training framework for everyone—students through to supervisors—and supports students, early career academics and those returning after a career break. Some examples include providing a space where concerns and issues can be raised, being responsive to care responsibilities outside of work and an EDI fund to assist students with mobility issues to participate in CDT activities or events.

Challenges for SusHy

SusHy is always seeking to improve and aims to strengthen the supportive environment so that everyone feels equally valued and no one is impeded from achieving their full potential. The recruitment stretch-objective is to have a cohort which reflects the diversity of the UK. This has been achieved for ethnic minority groups, but the gender balance, although improving, has yet to achieve parity. A refreshed recruitment drive for 2021, guided by Diversity by Design, will strive for a better-balanced cohort.



Management Board



Prof. Gavin Walker
University of
Nottingham



Prof. Upul Wijayantha
Loughborough
University



Prof. David Book
University of
Birmingham



Prof. Vladimir
Molkov
Ulster University



Prof. Elena Besley
University of
Nottingham



Prof. David Saal
Loughborough
University



Prof. Lynne Macaskie
University of
Birmingham



Dr. Dmitriy
Makarov
Ulster University



Prof. Monica Giuliatti
Loughborough
University



Dr. Rafael Orozco
University of
Birmingham

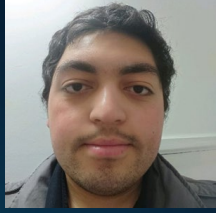


Our Students

Combustion



Distribution



Production



Safety



Storage



Systems



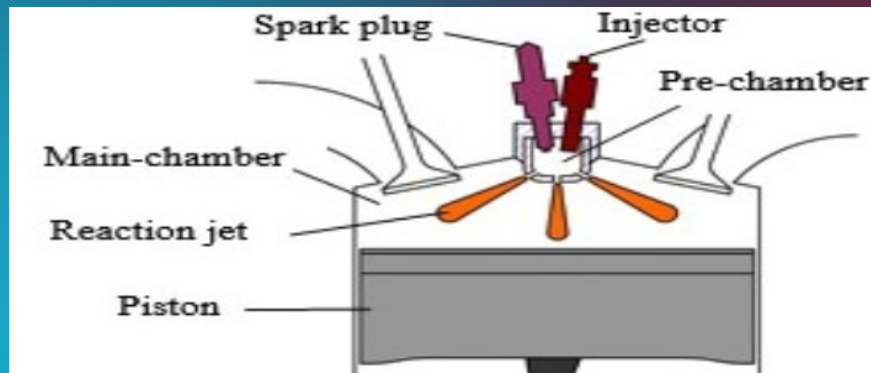
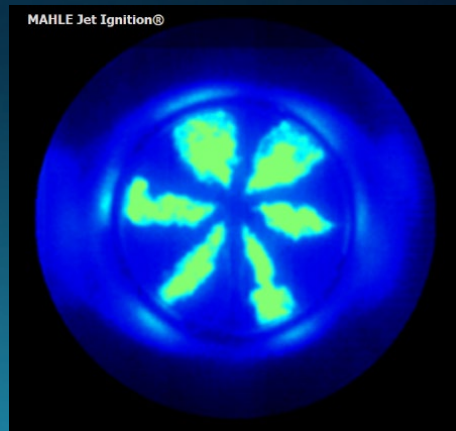
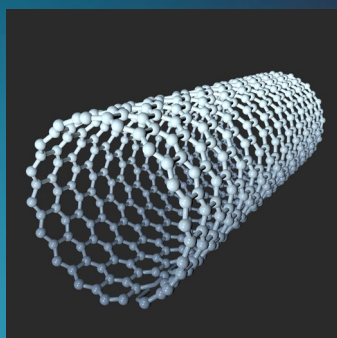
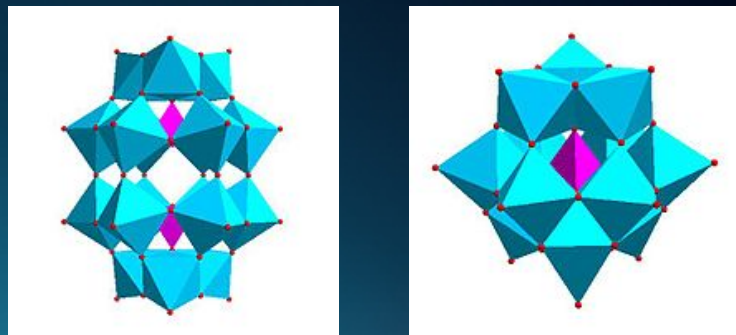


Image: MAHLE Powertrain

High efficiency internal combustion engines

Will undertakes research in Turbulent Jet Ignition technology enabling the use of Ammonia as a fuel. Specific interests surround producing a zero carbon internal combustion engine platform that gives similar efficiencies to a larger fuel cell vehicle.

Supervisors – Prof Alasdair Cairns, Dr Antonio La Rocca,
Dr Richard Jefferson-Loveday



Sustainable electrocatalysts for H₂ generation

Jack carries out research into the development and use of polyoxometalates (POMs) as electrocatalysts that facilitate both the oxygen and the hydrogen evolution reactions during electrolytic water splitting. He is particularly interested in the development of POM-carbon nanotube composites.

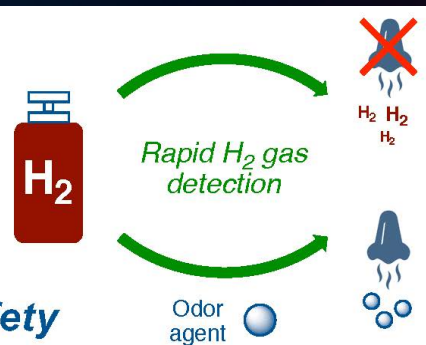
Supervisors – Dr Darren Walsh, Dr Graham Newton,
Dr Ming Li



Odor additives for H₂

- Rationale design
- Chemical synthesis
- Benchmarking

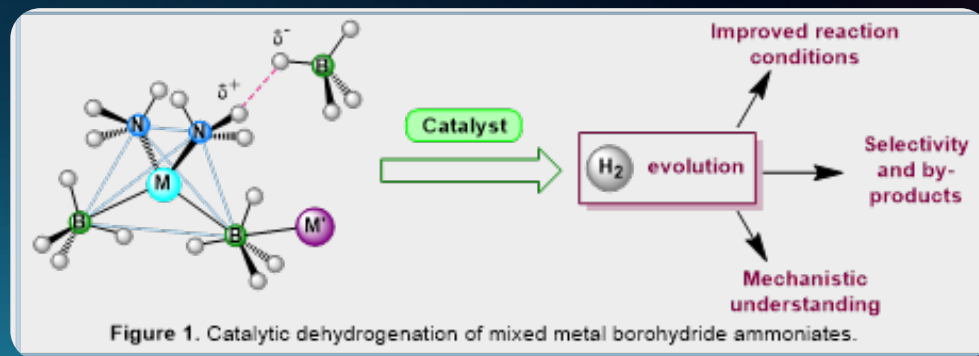
Leading to Improved H₂ safety



Development of odour additives for use in H₂ technology

The remit of the project involves the design and synthesis of new odour additives for hydrogen storage, and then benchmark them against the current industry standard(s).

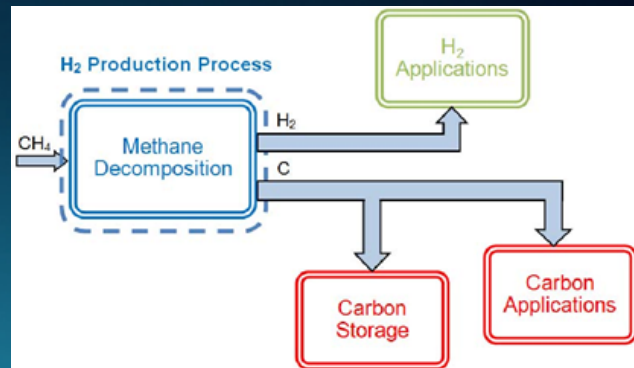
Supervisors – Dr Marc Kimber, Dr Gareth Pritchard



Dehydrogenation catalysis of mixed metal borohydride ammoniates

Antonia is developing novel catalysts for the dehydrogenation of mixed metal borohydride ammoniates and seeks to elucidate the mechanisms involved in order to improve reaction conditions and selectivity.

Supervisors – Prof Deborah Kays, Prof Gavin Walker



Hydrogen enrichment of natural gas by thermo-catalytic decomposition of methane

The gas network currently supplies natural gas to consumers but, could instead supply low carbon gases, such as hydrogen, in the future. Thermo-catalytic decomposition of methane allows enrichment of natural gas with hydrogen, a carbon free fuel. However, for this technology to reduce GHG emissions the source of heat used in the process must be low CO₂ emitting, for example electricity generated from renewable energy such as offshore wind. In this context, further development and early deployment of low CO₂ emitting thermo-catalytic decomposition of methane technology is exigent.

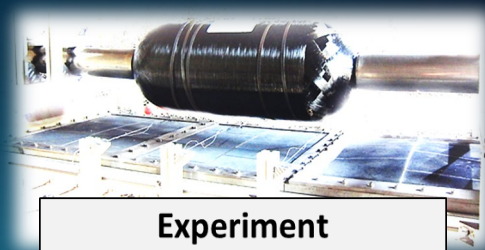


Business cases for green hydrogen

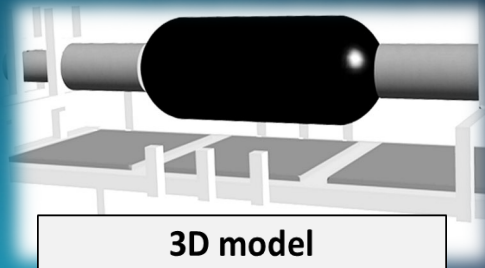
This work will be looking into how green hydrogen can be costed so that it is better compatible with today's energy system. This includes analysing business cases, high-value applications, externalities, and options to sell 'greened' products based on green hydrogen application.

Supervisors - Prof Robert Steinberger-Wilckens, Dr Christoph Biehl, Prof Jan Bebbington

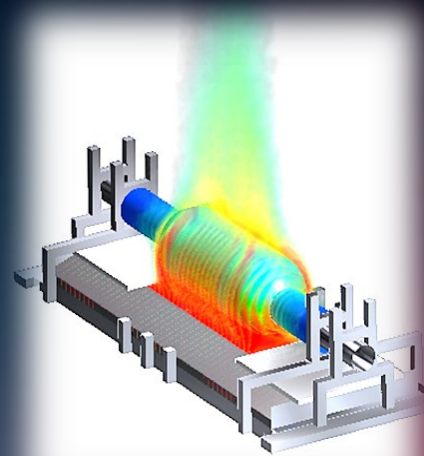
Hazir Ebne-Abbasi
Belfast School of Architecture and
the Built Environment (BSABE)
Ulster University



Experiment



3D model

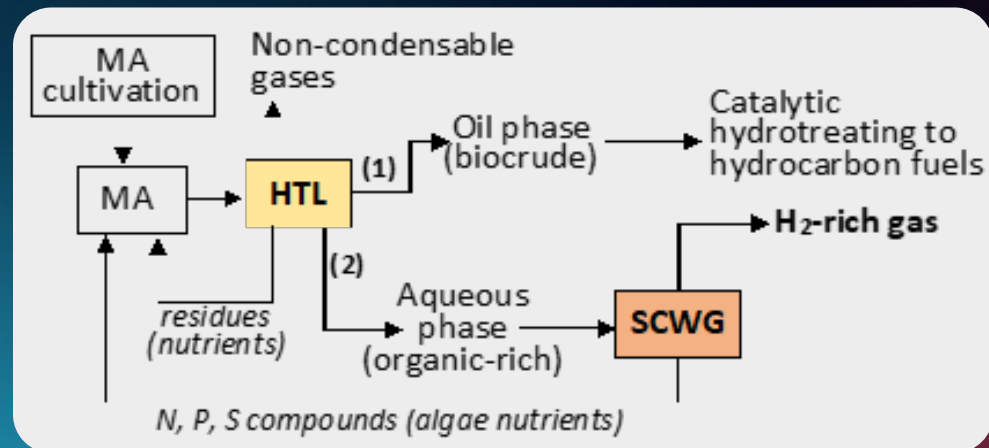


Fire test simulation

Assessment and mitigation of hydrogen-fuelled vehicle hazards

The project aims to close knowledge gaps associated with safety of high-pressure hydrogen storage relevant to hydrogen-fuelled transport and to develop novel engineering models for such areas as predicting thermal condition of tank structure, safe fuelling and defueling of onboard tanks, prevention of tank rupture in a fire, etc.

Supervisors - Dr Dmitriy Makarov, Prof Vladamir Molkov,
Dr Volodymyr Shentsov



Algal biomass to hydrogen: a circular approach for green sustainable processing with enhanced efficiency and minimal waste

The project investigates hydrothermal conversion of algal biomass to H₂-rich gas in a sustainable circular approach.

Supervisors – Dr Bushra Al-Duri, Dr Rafael Orozco, Prof Lynn Macaskie

Edward Jones
Department of Chemistry
Loughborough University

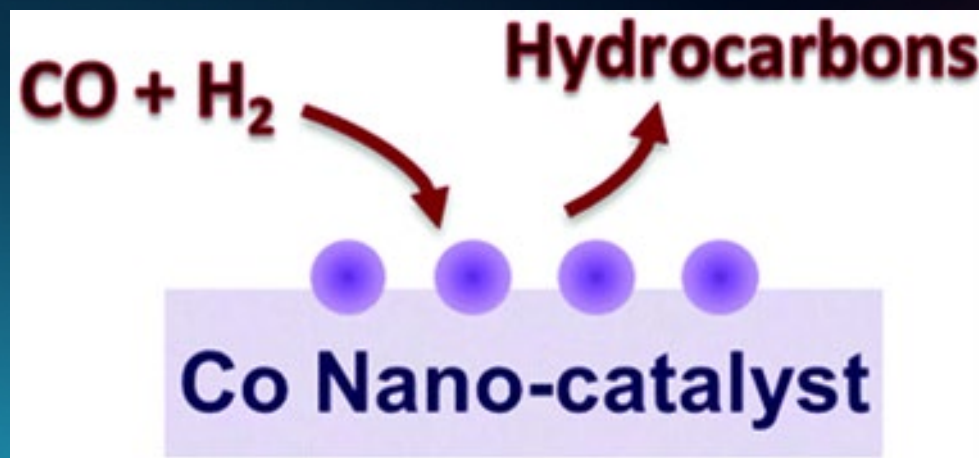


Figure: Recent developments in the application of nanomaterials to understanding molecular level processes in cobalt catalysed Fischer-Tropsch synthesis", *Phys. Chem.*, 2014, 16, 5034-5043 DOI:10.1039/C3CP55030C

Neutron spectroscopy of surface intermediates on nanoporous metal catalysts for H₂ storage technologies

Ed is using neutron spectroscopy to study reaction intermediate speciation and diffusional properties of cobalt catalysed CO/CO₂ hydrogenation and borohydride decomposition for hydrogen storage

Supervisors - Dr Simon Kondrat, Prof Sandie Dann, Prof Ian Silverwood

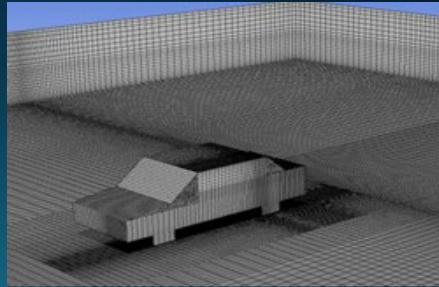


Figure 1: Hexahedral mesh of car in carpark

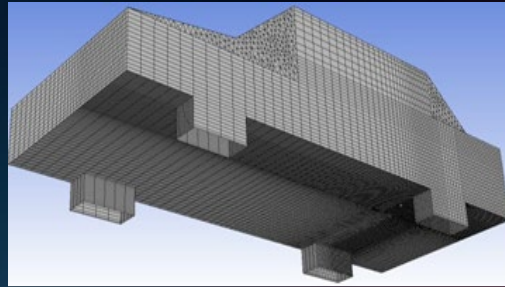


Figure 2: Meshed car

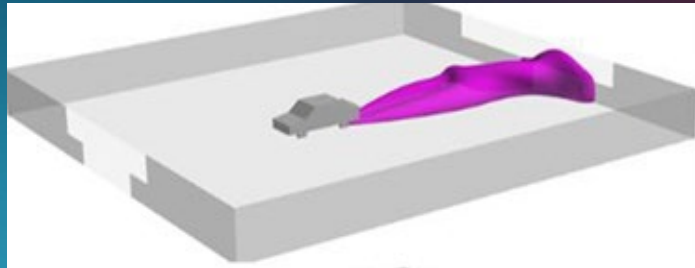


Figure 3: An Iso-surface plot showing 4% vol of hydrogen mole fraction for an unignited release 5s through a 2 mm gap at a 45° angle downward release

Hazards and mitigation of hydrogen releases in underground parking

The scope of this doctoral study includes the identification and prioritisation of relevant knowledge gaps; performing analytical and numerical studies to close identified knowledge gaps; development of innovative safety strategies and engineering solutions to prevent and mitigate accidents with hydrogen powered vehicles in confined infrastructures, specifically car parks.

Supervisors – Dr Sile Brennan, Dr Dmitriy Makarov,
Prof Vladamir Molkov

Stephen Marr
Department of Chemistry
Loughborough University



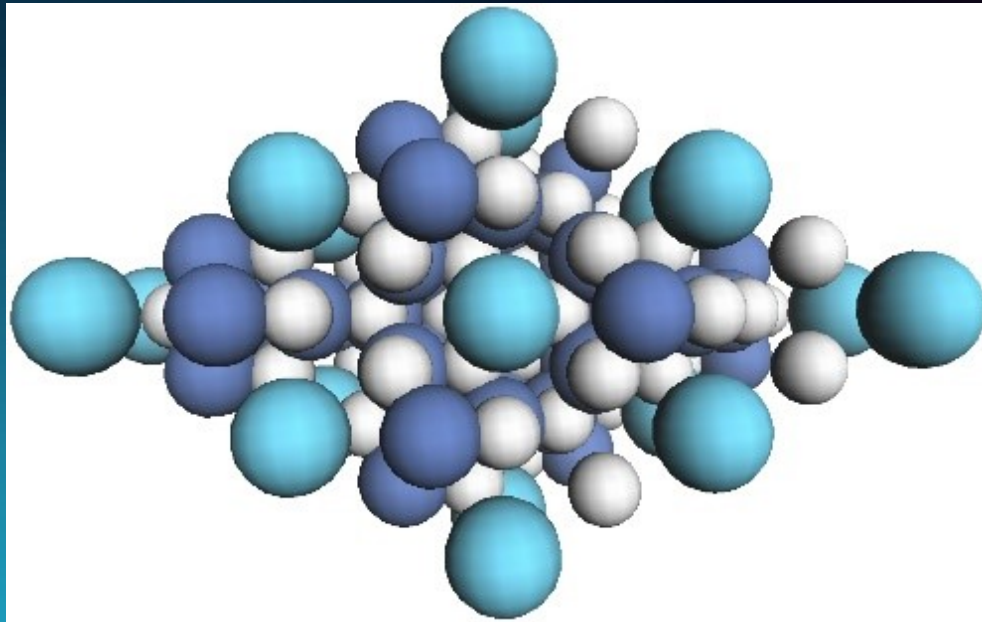
Image: Gavin Walker

Development of techniques and methods for sampling, calibration and testing of hydrogen purity for fuel cell vehicles

Measurement challenges for hydrogen fuel cells are preventing the overall sector from growing and this project aims to develop a cylinder passivation technology providing temporal stability data for the 14 trace contaminants outlined in ISO 14687-2.

Supervisors – Dr Ben Buckley, Prof Upal Wijayantha,
Prof Paul Holland

Alex McGrath
Faculty of Engineering
University of Nottingham



Synthesis and characterisation of metal alloys for hydrogen storage and related applications

This project aims to experimentally synthesize new metal alloys shortlisted by computational screening, and characterise their physical, chemical and structural nature along with their thermodynamic and kinetic properties during hydrogenation and de-hydrogenation.

Supervisors – Prof David Grant, Prof Gavin Walker,
Dr Sanliang Ling, Dr Kandavel Manickam



Adam McKinley
Department of Chemical Engineering
Loughborough University



Catalyst development for low-cost large-scale sustainable hydrogen production from seawater and renewable energy

Adam undertakes research for the oxygen evolution and hydrogen production via seawater splitting, driven by renewable energy. He is particularly interested in the production and utilisation of low-cost, highly efficient and highly selective catalysts for the process.

Supervisors - Prof Wen-Feng Lin, Prof Jin Xuan,
Dr Darren Walsh

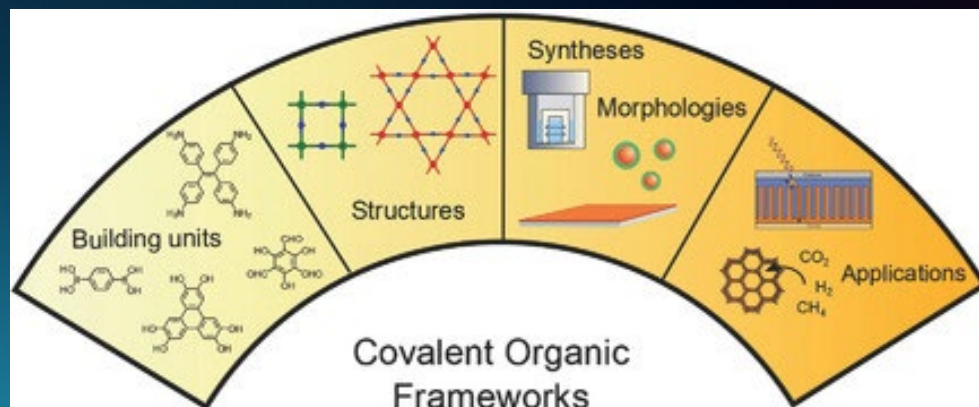


Figure: Adv. Funct. Mater. 2018, 28, 1705553.

Photocatalytic covalent organic frameworks for hydrogen production and storage

Jai undertakes research into the use of covalent organic frameworks (COFs) for hydrogen production and storage as apposed to the popular MOF alternative. The project involves the synthesis of new molecules which can be functionalised onto the surface of covalent frameworks (COFs) creating photocatalytic and size-specific channels which will permit hydrogen production from water and selective ingress, storage and egress.

Supervisors – Dr Iain Wright, Dr Simon Kondrat

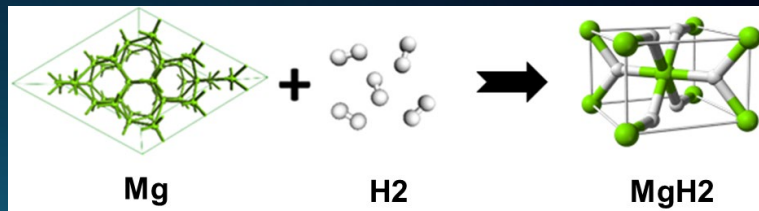


Figure 1: A visualisation of hydrogenation. Hydrogen gas has a low density. Hydrogen can be stored within metal through hydrogenation, which greatly increases its density.

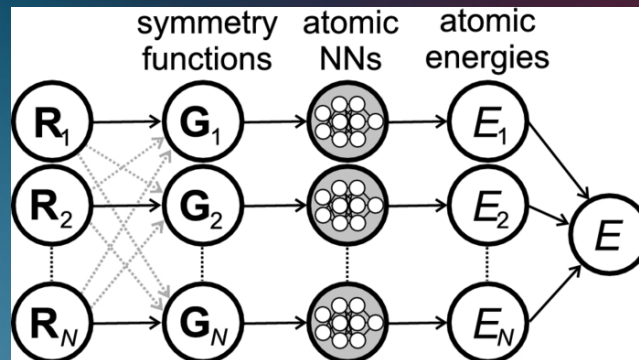


Figure 2: Visualisation of a machine learning model used in Oliver's research.

Hydrogenation of storage materials

Oliver undertakes research in applying machine learning models to run accurate molecular dynamic simulations, with an emphasis on understanding the (de)hydrogenation reactions in metal hydrides.

A more detailed understanding of these reactions will inform the selection of improved hydrogen storage materials.

Supervisors – Dr Sanliang Ling, Prof Gavin Walker,
Prof David Grant

Una O'Hara
School of Metallurgy and Materials
University of Birmingham



Development of high-performance complex hydrides

Here Una is investigating boron-based and nitrogen-based complex hydrides which will be synthesized by chemical and mechanochemical routes (or sourced) and their hydrogen storage, electrical, and thermal properties will be assessed in detail.

Supervisors – Dr Daniel Reed, Prof David Book

Zoe Pallis
School of Psychology
University of Nottingham

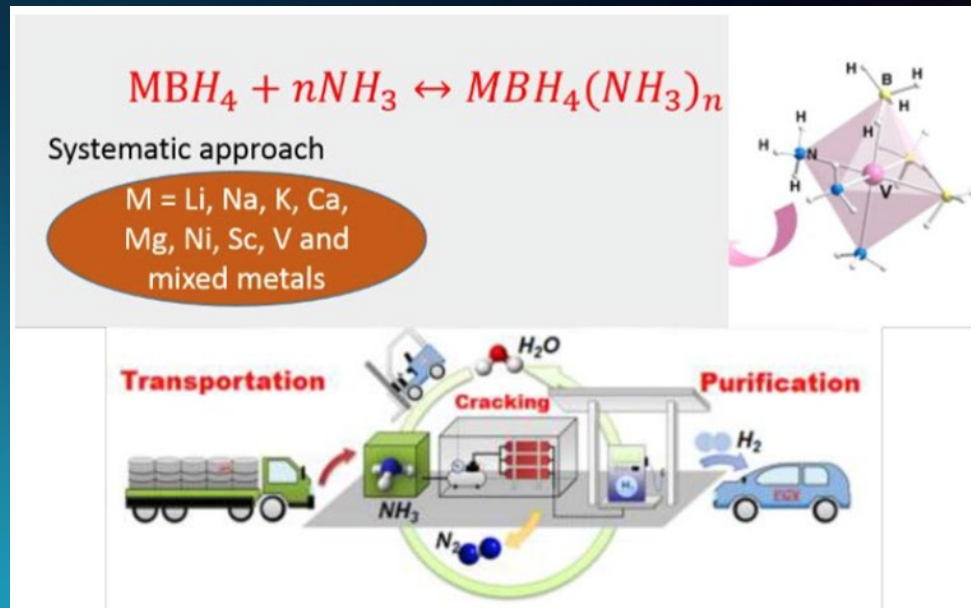


Image: [Jake Melara](#) on [Unsplash](#)

Public values for a hydrogen energy system

Here Zoe's research uses a mixed methodology using both qualitative and quantitative approaches to examine perceptions towards likely future Hydrogen technology scenarios.

Supervisors – Dr Alexa Spence, Prof Gavin Walker



High capacity mixed metal borohydrides ammoniates for hydrogen energy storage applications

Jacob undertakes research into mixed metal borohydride ammoniates (MMBAs) as alternative hydrogen storage materials. He is particularly interested in the synthesis of novel MMBAs, elucidating the reaction mechanisms responsible for the decomposition process and investigating catalysts to accelerate the release of hydrogen from these materials.

Supervisors – Prof Gavin Walker, Prof David Grant,
Dr Kandavel Manickam

Courtney Quinn
School of Chemistry
University of Nottingham



Image: engin akyurt on [Unsplash](#)

Sustainable hydrogen evolution catalysts

The development of composite systems based on molecular metal oxide nanoclusters and ionic liquids will be undertaken. The ionic liquids will allow the stabilisation of the molecular catalysts into thin films, membranes and 3D-printed superstructures. Then research will be undertaken to explore the stability and efficiency of these systems during prolonged electrolysis.

Supervisors – Dr Graham Newton, Dr Darren Walsh,
Dr Lee Johnson

Chris Ryder
School of Physics & Astronomy
University of Nottingham

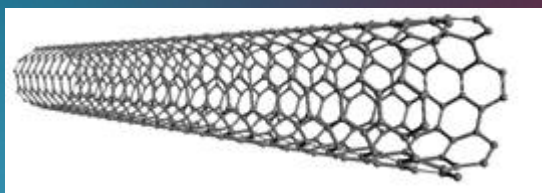
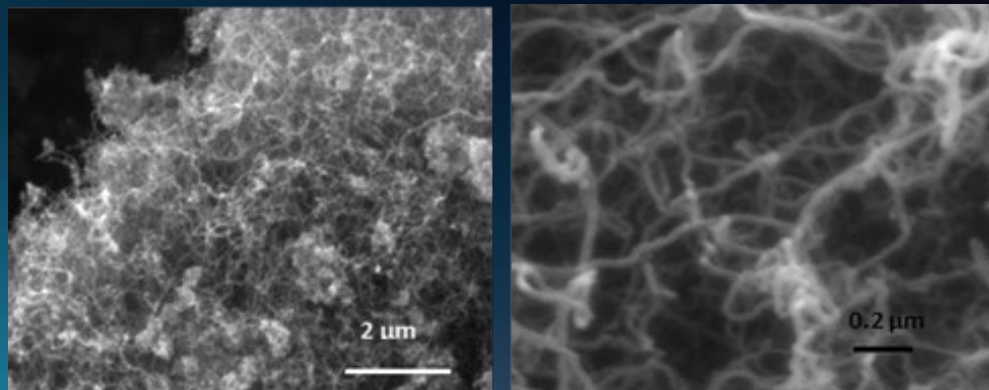


High-throughput cycling coupled XPS of hydrogen storage materials

Chris undertakes research into the application of X-ray photoelectron spectroscopy (XPS) to samples in high-pressure environments. He is particularly interested in developing a method which extends XPS to pressures compatible with hydrogen storage.

Supervisors - Dr James O'Shea, Prof Gavin Walker,
Prof David Grant

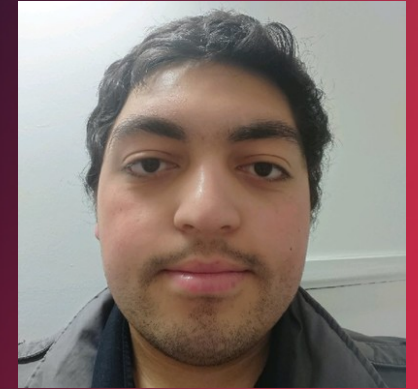
Jack Shacklock
Department of Chemistry
Loughborough University



Lowering the H₂ cost in methane cracking technology by using solid carbon as an energy storage material.

The research Jack is undertaking is designed to investigate the systematic alteration of process conditions to obtain value-added solid carbon specifically for energy storage whilst still maintaining a high yield of hydrogen.

Supervisors – Prof Upul Wijayantha, Dr Niladri Banjeree



Hydrogen for a sustainable built environment

This research builds upon significant existing investment that created a unique hydrogen research facility at the Creative Energy Homes. The project will produce a working demonstrator including control for hydrogen as a Novel Multi-Energy Vector for Hydrogen Energy Generation-Storage-Use in the built environment

Supervisors – Prof Mark Gillott, Prof Gavin Walker

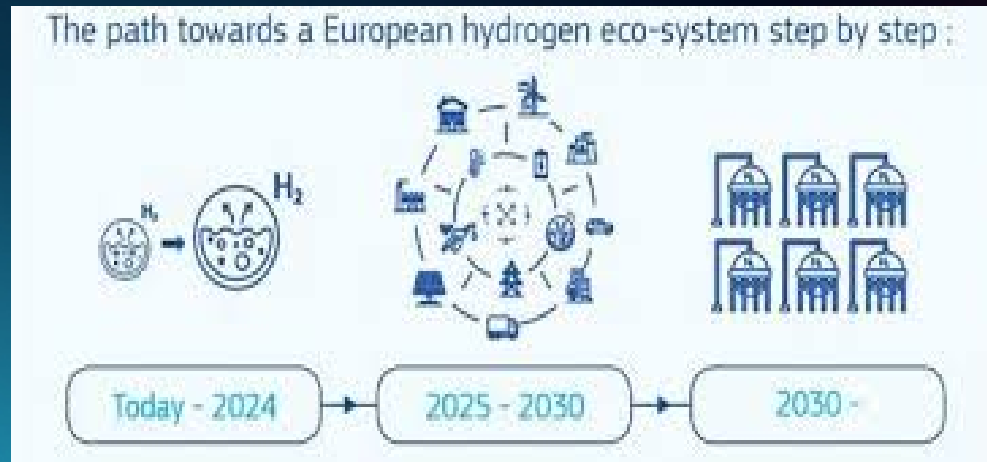


Figure: European commission energy webpages

Understanding the potential of hydrogen technology adoption in a complex challenging energy system

This project characterises the existing energy system and potential hydrogen technologies on economic, technological, and engineering grounds so as to evaluate their potential for successful adoption. It will provide detailed analysis with regard to how the existing energy system supports and or hinders the development of the analysed technologies, and give an understanding of how engineering, managerial, regulatory, technological factors would need to change in order to foster stronger adoption of hydrogen technologies.

Supervisors – Prof Monica Guiletti, Prof David Saal,
Prof Upal Wijayantha

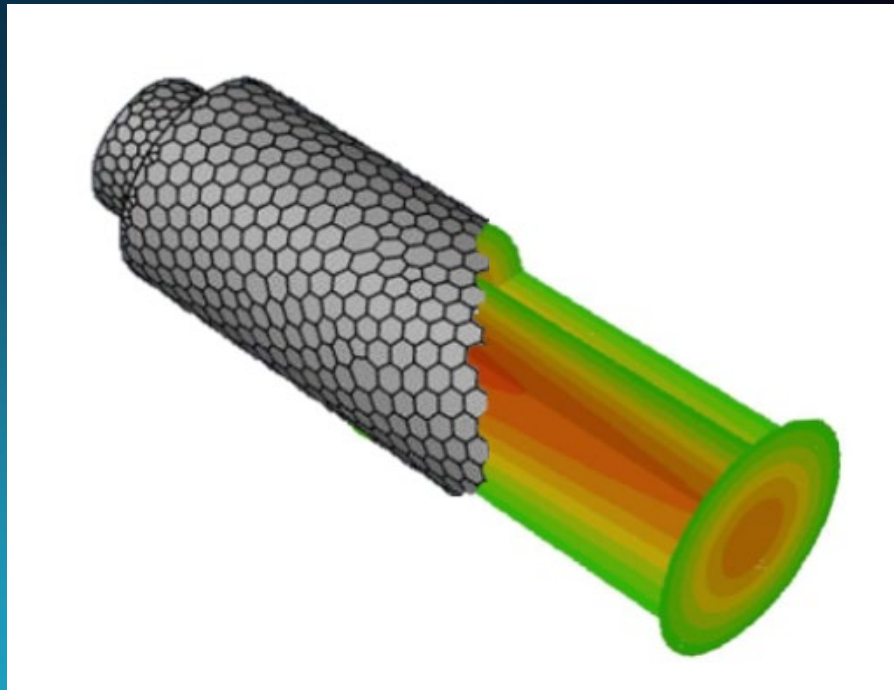


Figure: Temperature profiles in a CFD model of a micro-hydrogen partial premixed bluff body burner (PPBB burner)

To a 100% hydrogen domestic boiler

This project seeks to redesign the domestic boiler so that hydrogen can be used as a network fuel. At the moment because methane which is currently used burns quite differently from hydrogen our current domestic boilers cannot be used.

Supervisors – Dr Donald Giddings, Prof David Grant, Prof Robin Irons



Want to get involved?

We'd love to hear from you

e: beinspired@sustainablehydrogen-cdt.ac.uk

w: sustainablehydrogen-cdt.ac.uk

