Applicant: **McDermott, Christopher Ian**
Organisation: **the University of Edinburgh**
Funding Sought: **£2,776,751.00**

CiET2021\28

Low Carbon Heat from Urban Multi-user Sustainable GEOthermal BATTERYs (Ed-GeoBattery)

Near surface (2m – 800m) Low Enthalpy Geothermal (LEG) heat is being increasingly explored as a resource which could lead to the UK cutting over 50% of its energy requirements for space heating, and contribute significantly to 2050 zero carbon ambitions.

Ed-GeoBattery addresses the over-simplistic current practise of LEG heat mining and aims to demonstrate a sustainably managed commercially viable regional scale geo-heat battery south of Edinburgh. The fundamental principle is that heat extraction must be balanced against heat recharge to achieve a long term sustainable system. Overoptimistic estimates of solar heat recharge at the surface, and false assumptions that the temperature of the near subsurface remains constant are leading to a non-sustainable groundsource heat extraction “race”. With the drive towards zero carbon emissions by 2050, and the proposed legislation that no fossil fuel heating be installed from 2025, there will be a move towards increasing the spatial density of groundsource heat pumps and minewater technology to supply domestic and commercial heating requirements. Where groundsource heat pump technology is installed, the LEG heat is being mined at 20+ times the heat recharge rates. Ofgem reports that the standard medium sized house in the UK requires circa 12000kW/h, most of this is for space heating. The geothermal heat flux in the UK is ~65mW/m2, so this heat demand equates to every house accessing ~5 acres of land.

Through continually depleting the LEG heat, stored over thousands of years, we will rapidly “flatten the battery”. Without sustainable management, the LEG heat resource will be exhausted (10-15+ years). Long enough for the initial installers to have moved on from liabilities, and short enough for the technology to fall into disrepute, ruining the social acceptance of this potentially globally impacting low carbon heat technology and leaving cold spots causing long term environmental and social impacts.

Ed-GeoBattery demonstrates how LEG heat can be strategically recharged using industrial//commercial and domestic sources where there is recyclable heat, e.g. from data centres, waste incineration etc., or domestic//community scale solar heat harvesting technology. Extensive legacy mine workings will be used to distribute heat from surface sources (initially addressing the cooling requirements of a national computer facility) to enhance LEG. This heat will be available to multiple domestic and larger scale community and commercial users via heat pump technology.

Specifically the project will
- Construct a multi megawatt capacity heat storage plant utilising legacy mine workings.
- By creating a virtual model of the Ed-GeoBattery, manage the balanced heat storage and extraction, simulating multi-user heat extraction, recharge and environmental risk.
-Ensure knowledge exchange through a path finder//road map, or best practise style publication facilitating the development of this technology under UK planning, permitting and legislation for multiple scales from local community to regional applications.
-Create a field site for further research into hydrogeology, heat storage and extraction technology in urban environments with legacy mine workings.
-Formulate and demonstrate investor ready business models using LEG heat for domestic and commercial applications.

-Provide a platform for training next generation low carbon heating technology technicians.
-Facilitate widespread international dissemination of the Ed-GeoBattery achievements with UK wide diffusion of technology.

The Ed-GeoBattery program comprises three phases, the completion of each phase representing a key milestone in the project progression.

Phase 1 Proof of technology (4 years): facilitate a demonstrator heat storage plant for 2MW of cooling for the Advanced Computer Facility, Easter Bush, and strategically store this heat in extensive interconnected legacy mine workings, equivalent to the heat demand of 1300 homes, with a net value of ~£600/house per year (1MW storage ~ £0.4M/year). Address commercial questions of heat ownership and provide realistic business models for heat users and providers.

Phase 2 Sustainable heat supply (3 years): expand to 10MW heat storage and create a virtual GeoBattery software platform (GIST) managing the heat resource assessment, hydrogeological characterisation, environmental risk. Integrate a smart monitoring and community integrated participatory approach.

Phase 3 Regional GeoBattery (3 years): expand to a stable 20MW+ heat storage plant, with a district wide uptake of the heat battery concept of heat recharge and extraction under the control of GIST, establishment of district business models and clear economic benefits.

Ed-Geobattery will reduce UK energy poverty, CO_2 emissions and climate impact.

LEAD APPLICANT DETAILS

Title	Dr
Name	Christopher Ian
Surname	McDermott
Organisation	the University of Edinburgh

Section 1 - Applicant Details & university details

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Title	Dr
Name	Christopher Ian
Surname	McDermott
Organisation	the University of Edinburgh

GMS ORGANISATION

Type	**UK University**
Name	the University of Edinburgh

Country of residence:
Please state your country of residence at the time of making this application.

United Kingdom

Section 2 - Project details and person specification

Project Title
Your project title should not be longer than 10 words and understandable to a non-specialist reader. The essence of the research should be captured in the title and should be as informative as possible.

Low Carbon Heat from Urban Multi-user Sustainable GEOthermal BATTERYs (Ed-GeoBattery)

Project Start Date
All projects must start on 1 October 2020.

01 October 2020

Project End Date
All projects must end on 30 September 2030.

30 September 2030

Subject area
Select one field from the dropdown list below that most closely matches the general subject area of your project.

Civil

Subject
To help identify expert reviewers, please add keywords to further define the area of your project.

Geotechnical Engineering, Hydrogeology, Heat Storage and Extraction, Environmental Impact Assessment, Numerical Modelling, Smart Networks, Groundsource Heat Pumps, Legacy Coal Mines

Declare Conflicts of Interest

Please list reviewers who would have a conflict of interest and therefore would not be able to review this application. Listing should be made in the following format:
Dr John Xyz [ABC University], Prof. Jane Abc [XYZ University].

Professor Jon Gluyas, University of Durham, (external member of project team)

Synopsis
Describe the programme and its expected outcomes in terms that can be understood and evaluated by a reviewer with extensive engineering and technology innovation expertise, but not necessarily any familiarity with the particular field of the proposal.
Please refer to the guidance notes for further details.

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Ed-Geobattery will reduce UK energy poverty, CO2 emissions and climate impact.

Challenge areas related to your proposal
Please list any specific challenge area(s) where long-term impact could arise as a result of your project being awarded such as the four Grand Challenges**,** Eight Great Technologies**,** Sustainable Development Goals **and the areas highlighted in the** Industrial Strategy Challenge Fund**.**

Clean Growth
Energy
Affordable and Clean Energy
Sustainable cities and Communities
Climate Action
No Poverty
Prospering from the Energy Revolution

Applicant's CV
The format and content of your CV is left to your discretion. You do not need to include contact details here again as these are included earlier in the application. Please include the following in your CV: Your research track record, list of key publications and conference presentations, PhD students supervised, awards and prizes received, and details of grant income secured. The CV should be uploaded as a PDF but the file size should be less than 5MB.

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pdf 1.15 MB

Applicant's track record
Outline how your professional experience and academic track record makes you suitable of this award along with benchmarking your capabilities against peers and individuals and competitors in the same fields globally.

I am highly qualified to lead Ed-GeoBattery, having an excellent track record of initiating, coordinating, leading and managing complex international science projects and postgraduate teaching amongst my peers. I hold qualifications in Geology (BSc.hons), Engineering Geology (MSc.), Hydrogeology (post MSc. level), Applied Geoscience (PhD), Hydroinformatics (habilitation) and PGC in lecturing. I have worked both in academia and in civil engineering industry in geotechnics. I have been employed by the University of Edinburgh since 2007, and am currently a reader in hydrogeology and coupled processes modelling.

My leadership of the 14 partner international H2020 project, FracRisk (www.fracrisk.eu), 2014-2018, demonstrates my ability to coordinate complex international projects. FracRisk's aim was to provide a modelling based assessment to minimise the environmental footprint of shale gas extraction and to address public concerns. The output of the project has been >32 peer reviewed papers, >44 conference presentations and multiple public and outreach activities. Consequently I was the organiser of the EU H2020 Dissemination Workshop for all H2020 Fracking Related Research Projects, Brussels, May 16th 2018.

Demonstrating my ability to lead the construction of new technology, I initiated and coordinated the GREAT (Geo-Reservoir Experimental Analogue Technology) cell project, at the University of Edinburgh with Heriot Watt University and with the University of Goettingen, Germany (2010 – ongoing). This project created world unique beyond the state of the art experimental facilities for investigating large samples of fractured geo-reservoir material (20cm diameter x 20cm length) under true triaxial stress conditions, fluid flow pressures and reservoir temperatures. The GREAT cell has already contributed to ~£9.2M funding, with a further €2.3M for construction of mark II in Germany.

Illustrating my ability to lead teaching and communication with the next generation of scientists and decision makers, from 1998 – 2002, I was responsible for the development of a new international Masters teaching program at the Eberhard Karls University of Tuebingen, Germany. This MSc course acted as a role model for the extensive international Masters courses now offered across Germany. This included coordinating some 200 different teaching elements, 50 different lecturers including 20 external//industry lecturers. As of 2019 the program is still running, educating multiple students world wide, and has an alumni of circa ~350 international graduates employed worldwide.

I have approximately 120 research outputs, 60 in peer reviewed journals, a number of which are directly related to geothermal energy. I have an H index of 15, with circa ~1400 citations (Google Scholar). As of January 2019 UoE staff co-authored 6,858 peer-reviewed papers with collaborators in Germany over 10 years, the biggest SciVal hits included myself, therefore I recently represented UoE for a visit of the President, Vice President and Director of the State Parliament of Lower Saxony.

I have worked with some 20 different public and private regulators, companies and international organisations in the context of knowledge exchange and dissemination. This is exemplified by the support of this grant application by RSK, the UK's largest privately-owned multi-disciplinary environmental consultancy and one of the fastest growing companies of its kind in Europe.

Section 3 - Case for support

Area of emerging technology and vision
Please expand upon your description of the area of emerging technology you wish to pursue and your vision for the long-term application of the technology. Please make a case for the timeliness of the case in the context of "emerging technology". Expand upon the case for the distinctive contribution you make towards realising that vision with sustained personal support over the ten year period of this award.

At least 50% of UK energy use is for space heating. The source of this heat is principally gas, then oil. Most of this heating could be replaced by using a balanced geothermal heat battery approach which includes

both local and district storage of heat in the subsurface and heat pump extraction of energy from the subsurface.

The challenge is not the demonstration of individual technologies, but the demonstration of an integrated balanced sustainably managed and commercially viable geothermal heat battery in Urban Environments within the UK. This could lead to the UK cutting over 50% of its energy requirements for space heating, and contribute significantly to the 2050 zero carbon ambitions.

Currently, in the UK, the use of the near subsurface to provide heat occurs through heat mining, i.e. heat extraction significantly exceeds any sustainable heat recharge. No thought is being giving to balancing heat extraction against heat storage.

A quarter of UK homes and businesses sit on former coalfields where the flooded underground workings provide a network of interconnected channels in the subsurface. This subsurface highly permeable network of former mines and collapsed layers can be strategically employed to recharge heat in the subsurface using waste heat, and manage the geothermal gradient, ensuring long term sustainability of the heat resource. The waste/recycled heat may come from a variety of sources, including data centres, commercial uses and even domestic heat recharge technology. The emerging technology challenge is to use the multiple sources of heat available, and store them seasonally to ensure long term as sustainable low carbon base load heat available to everyone.

The Ed-GeoBattery project will demonstrate the long term true sustainable use of heat in the subsurface. It will provide a road map for similar projects elsewhere within the UK, having gone through all the necessary science, social, environmental, regulatory and commercial aspects for the establishment of a heat battery and build on European experience, e.g. Herleen, Netherlands, https://www.mijnwater.com/?lang=en . It will provide the necessary heat assessment and system management software to manage the distribution of the heat resource and assess any environmental risks. It will provide a clear demonstration of the commercial viability of the project, and demonstrate successful business models for future growth.

I hold MSc level and beyond qualifications in Engineering Geology, Hydrogeology and Informatics, and have industry experience in geotechnical engineering. This allows me to relate the geology to the engineering challenges, and allows me to conceptualise software solutions and understand the data structures and coding required to facilitate integrated control systems. I have been responsible for the development and installation of complex engineering technology requiring input from multiple disciplines to create state of the art unique game changing experimental capacity. A significant amount of my work has focused on geothermal heat movement and use. Additionally my experience in managing large projects with a large number of multi-disciplines and different seniorities of scientists from different nationalities demonstrates my ability to deliver complex multifaceted scientific projects, e.g. I was PI on the multi-partner EU H2020 project FracRisk.

The longer term vision for the heat battery concept is to have multiple heat users and producers discharging or recharging a district scale heat battery. State of the art real time monitoring technology integrated into a control system rewards users for less heat use, and for heat storage in the system. Commercially, a number of ventures will be using low grade heat, and across the whole system there will be a better integration of anthropogenic use of the heat resource within the natural environmental constrains. Communities will be able to use local legacy mine workings (Coal, Clay, Oil Shale, Iron Stone, Limestone, etc.), which once established them, for the longer term well being of the citizens. The integrated system will lead to a more citizen participatory approach which in turn will increase pride in community being, belonging and link to industrial legacy. The integrated system will lead to a reduction in energy poverty, a reduction in CO2 emissions and a reduction in climate impact.

Significance of the emerging technology

You should make a case for its strategic significance, relationship between the emerging technology and wider UK technological priorities, and the potential for economic and social benefit to the UK. Particularly consider the potential for the UK to gain comparative advantage in disruptive or platform technologies, and the opportunity for the nation to capture greater value from these advances.

Providing low cost, low carbon energy is a key national technological priority. A pathway to zero carbon emissions by 2050 is strategically highly significant and a legal requirement for the UK. However, the practical steps to achieving this lag behind the political aspirations.

Storing energy in terms of recyclable heat and heat harvested at a community scale in the subsurface, and using state of the art computational science and data driven innovation to manage this on a regional scale will put the UK at the cutting edge of renewable energy provision. The demonstrable supply of low cost locally secure heat proposed here will reduce energy poverty and significantly increase economic power within the UK, particularly focussed around communities who most need this assistance. Developing this technology will provide long term sustainable access to an energy source which is local and resilient.

The technology will require complete rethink and redesign of
(1) the use of available technology to store heat in the subsurface
(2) the ability to holistically manage the urban environment as a battery
(3) regulation favouring the development of both heat storage and heat extraction, including the requirement to store heat in the ground at the scale of use, e.g. planning and building regulation changes to install not just heating technology but also storage technology, the requirement to encourage district heating schemes.
(4) regulation ensuring that at the development stage there a clear appreciation of the need to install technology which can support district scale heat networks

The involvement of both industry and regulatory authorities and the experience and knowhow gained in the implementation of the project will ensure a highly commercialiseable product for national and international export. The concept can lead to a significant world wide reduction in CO2 emissions and reduction in overall energy demand for space heating.

The creation of a field site for further research activities will ensure international collaboration and exposure of the technological innovation. At a local scale provision of technical training on low enthalpy heat systems will enhance a much needed skill base.

Goals and objectives
Please state the goals and objectives for the project, distinguishing those of highest priority.

Primary goals and objectives, given in order of priority.

(1) Development and implementation of a multi megawatt capacity groundwater // minewater cooling plant and the strategic storage and recycling of waste heat in legacy mine workings using heat from the Advanced Computer Facility at Easter Bush.

(2) Demonstration of an integrated balanced (heat storage, heat extraction) and commercially viable geothermal heat battery in Urban Environments within in the UK. Understanding the transport of heat in the subsurface mine workings and strategically recharging the subsurface heat using the 3D nature of the mine workings and the dynamics of fluid flow with different density and temperatures.

(3) The development and demonstrated operational use of GeoBattery Integrated Dynamic Management Software Technology, GIST, based on a virtual numerical GeoBattery simulating multi user heat extraction, recharge and hydrogeology risk management, calibrated to the actual Ed-GeoBattery use.

(4) Knowledge exchange in the form of a path finder, or best practise style publication ("How to create and Operate a Community GeoBattery") to facilitate the development of the technology under UK planning, permitting and legislation for multiple scales from local community to regional applications.

(5) Establishment of realistic business models to manage the heat battery, provide wide spread economic benefit and reduce energy poverty. Thereby demonstration of the reduction in energy poverty and community ownership.

(6) Establish a field site for further research into hydrogeology and heat storage and extraction technology in urban environments with legacy mine workings. This field site should be for the use of training students in different engineering and hydrogeological disciplines at BSc, MSc. and PhD level, and also enable training for technical installation staff for low enthalpy heating technology.

(7) Establishment of suitable building regulations and planning considerations to facilitate the uptake of low enthalpy heating technologies. All current law relevant to the delivery of the project will be reviewed and summarised, a legal route-map of actions and outcomes required for successful delivery of the project will be developed and the limitations of the law as it currently stands will be reviewed with respect to developments in the science and engineering of this and similar schemes; and recommendations will be made for improvements where they can be demonstrated to deliver a tangible benefit to society, the environment and investment in renewable energy development.

(8) Establishment of necessary novel smart real time monitoring technologies to balance heat extraction and storage. This includes furthering state of the art technology such noble gas as natural conservative tracers, and the use of DNA for characterising subsurface fluid flow.

(9) Widespread international dissemination of the project achievements with UK wide diffusion of technology.

Research programme, methodology and key deliverables
Describe the ten-year work programme, indicating the research to be undertaken and the methodology to be used in pursuit of the research. Outline specific deliverables anticipated.

Ed-GeoBattery envisages the near subsurface (to 800m depth) as a rechargeable geothermal heat battery and addresses the very specific problem of balancing and dynamically managing geothermal heat use by communities for space heating against both natural and managed man made recycled or harvested heat storage and recharge. An experience common to all is that a battery, when constantly used without recharging, eventually goes flat. It is the same with the subsurface heat when extraction rates exceed recharge rates. Simple calculations show that the heat use per household for space heating per year, if supplied from the subsurface, would exceed by a factor of 20 and above the natural recharge. According to Ofgem the typical annual heat requirement of a standard house is of the order of 12000kWh/year. This equates to a heat demand of ~1.4kW, the geothermal heat flux is 0.065W/m2, so the sustainable area for geothermal heat recharge is ~5 acres per house. Overoptimistic estimates of solar heat recharge at the surface, and false assumptions that the temperature of the earth remains constant are leading to a non-sustainable ground source heat extraction "race". With the drive towards zero carbon emissions by 2050, and the proposed legislation that no fossil fuel heating be installed from 2025, there will be a move towards increasing the spatial density of groundsource heat pumps to supply domestic and commercial heating requirements. Through continually relying and depleting the heat stored over thousands of years in the subsurface we will quickly flatten the battery. The consequence being the ground cools to such an extent (1-2C per year) that that technology no longer functions efficiently after 10+ years of use, with accompanying significant longer term environmental impacts.

Ed-GeoBattery provides an important demonstration of how heat storage in legacy mine workings can be used to strategically recharge the GeoBattery and produce a step change in geothermal heat delivery and sustainability.

The methodology to facilitate the longer term uptake of this game changing technology is divided into three phases, illustrated in Figure 1.

Phase 1 Proof of technology (4 years)
Create a demonstrator heat storage plant for 2MW of recycled heat from the Advanced Computer Facility (ACF) situated at Easter bush, South of Edinburgh, and storing this in extensive interconnected legacy mine workings. This involves satisfying all the environmental, social, planning and regulatory legislation. It will include a full hydrogeological site characterisation, environmental impact assessment and understanding of the heat resource with the creation of numerical models mapping the heat transport and distribution. At this stage we also start to address commercial and legal questions of heat ownership and provide realistic business models for heat users and providers. It can be shown that 1MW of heat supply has a gross value of approximately £0.4M/year).

Phase 2 Sustainable heat supply (3 years)
Create a virtual GeoBattery software platform (Geobattery Integrated dynamic management Software Technology GIST) integrating the heat resource assessment, the hydrogeological characterisation, the environmental risk assessment and provide a management software balancing heat storage against heat need coupled with a smart monitoring and community integrated participatory approach. Demonstrate the local social, economic and business benefit from the use of low carbon heat stored in the legacy mine workings, whilst continuing to expand the storage of heat to 10MW. Investigate further domestic and commercial local heat storage possibilities, and clearly expound “investor ready” business plans. Initiate the use of the GeoBattery as a field site, and a site for further technical training.

Phase 3 Regional GeoBattery (3 years)
Expand to a stable 20MW+ heat storage, with a district wide uptake of the heat battery concept under the demonstrable control of GIST. Establishment of district business models and clear economic benefits. Uptake of the approach in at least two further separate cities across the UK.

At the end of the project seven distinct deliverables will have been achieved

1. Development and implementation of a multi megawatt capacity groundwater // minewater cooling plant and the storage of the heat in legacy mine workings.
2. The development and demonstrated operational use of the GeoBattery Integrated dynamic management Software Technology, GIST, simulating multi-user heat extraction, recharge and hydrogeology risk management in a Virtual GeoBattery calibrated to the actual Ed-GeoBattery use.
3. Knowledge exchange in the form of a path finder, or best practise style publication (“How to create and Operate a GeoBattery”) to facilitate the development of the technology under UK planning, permitting and legislation for multiple scales from local community to regional applications.
4. A field site for further research into hydrogeology and heat storage and extraction technology in urban environments with legacy mine workings.
5. The demonstration of functional investor ready business models using the low grade heat for both domestic and commercial use.
6. A platform for training technicians and practical skills training course.
7. Widespread international dissemination of the project achievements with UK wide diffusion of technology.

To facilitate this development over ten years the project is divided into 12 workpackages. Each workpackage addresses an overarching themes and each workpackage comprises a number of associated

tasks. Figure 2 illustrates the different workpackages, and demonstrates how the different overarching themes combine to facilitate the development of the GeoBattery technology and the key deliverables.

A detailed breakdown of the tasks within each workpackage is given below, and the Gantt chart (Figure 3) expresses the relationship between the workpackages, key milestones, the timing, the staffing and the resources allocated to each task. Although the overall scientific coordination and direction of the project is undertaken by Dr. C.I.McDermott (applicant), each workpackage has been assigned an overall WP leader, and comprises a number of tasks. Summary CV's of the WP leaders are attached at the end of the applicants CV. The project includes input from external experts or specialised companies many providing matched funding in-kind for the work undertaken, a resume or description of the resource provider is given after the applicants CV. These include Midlothian Council, RSK (https://www.rsk.co.uk/), Sandown Ltd, Vattenfall (https://group.vattenfall.com/uk), Quintessa (https://www.quintessa.org/) and the regulator SEPA. The University of Durham (UoD) is also involved.

Each task within a workpackage (WP) will produce a task level deliverable report on the fulfilment of the task detailing methods, data and results. The WP lead is responsible for the assimilation of the task reports and ensuring that the WP deliverables are met. Additionally each workpackage will produce at least one peer reviewed publication, and contribute to at least one conference output. The direction of the overall project dissemination is managed by WP12.

WP1 Overall Project Management, (Lead Dr. C.I.McDermott)
Carry out scientific coordination, leadership, financial reporting and administrative management. Manage the collaboration and interaction with national and international partners; coordinate the scientific and industry advisory board (SIRAB) and ensure six monthly project meetings.
Task 1.1a Scientific Coordination
Task 1.1b Co-coordination
Task 1.2 Administrative Management
Task 1.3 Financial Reporting

WP2 Environmental and Geoscience Site Characterisation (Lead Dr. I.Molnar)
The aim of this workpackage is to characterise the main geological and hydrogeological features at a local and regional scale, identify and collect key baseline data about groundwater, minewater and surface water quality, determine ground gas distribution and concentration and determine the overall existing temperature profile within the GeoBattery. The key research question addressed in this workpackage is identifying which methodology is best suited for the holistic multiphysics geoscientific baseline characterisation of a generic future potential GeoBattery location.
Task 2.1 Local and Regional Hydrogeology
Task 2.2 Geomechanical Facies Description
Task 2.3 Baseline Aquatic Geochemistry
Task 2.4 Baseline Ground Gas (Methane and Nobel Gas) Characterisation
Task 2.5 Initial Heat Distribution in the GeoBattery
Task 2.6 Key Environmental Impact Assessment Vectors

WP3 The Dynamic System, (Lead Dr. K.Edlmann)
This workpackage will address the key research question "what dynamic changes can be expected within the GeoBattery system as a result of the extraction of mine water and heat, and the storage of heat and heated mine water in the subsurface?" This includes an assessment of the potential geochemical, biological community and groundwater alterations, the impact of thermal stress on the legacy mine workings and the coupled ground gas and groundwater fluid pressure changes.
Task 3.1 Geochemical Alterations Driven by Minewater Temperature Changes
Task 3.2 Groundwater // Aquatic Changes due to GeoBattery Operation
Task 3.3 Biological Changes due to Temperature Alterations

Task 3.4 Rock Mechanical Stress Impacts of Cyclical Heat Storage : Rock Weakening
Task 3.5 Ground Gas Changes due to Water Level and Temperature Changes.

WP4 Thermal Resource Assessment and Sustainable Management (Lead Dr. C.I.McDermott)
The fundamental research question addressed in this workpackage is how to evaluate how much sustainable heat is present in the GeoBattery, and how is the heat transported through the GeoBattery. Key outputs will be how much heat is present, where the heat is, and how much can be extracted through multi-source uses balanced against how much can be recharged from multi-point sources. This WP will create a hydrogeology and heat transport numerical model of current and potential subsurface heat use throughout the GeoBattery, and form the basis for understanding the transport of heat through the GeoBattery by conduction and through mine water advection and movement. The location and amount of heat available will be used to assess the long term thermal budget of the multi-user operation of the GeoBattery to ensure sustainability.
Task 4.1 Conceptual Models
Task 4.2 Construction of 3D Geometry
Task 4.3 Heat Source (Storage and Use) Characterisation
Task 4.4 Modelling Techniques for Multilevel Mine with Fluid Flow & Heat Transport
Task 4.5 Fluid Flow Model
Task 4.6 Heat Transport Model
Task 4.7 Generic Multi Source User Simulations
Task 4.8 Heat Model Dynamic Calibration

WP5 New Technologies for Dynamic Monitoring (Lead Dr. S.Gilfillan)
New emerging novel and smart monitoring technologies will be applied to provide spatially distributed real time data for the calibration of the numerical model developed in WP3 and providing early warning of possible environmental and operational risks. Beyond research into which technologies are best applied where, a further key question will be the provision of smart real time monitoring data which can facilitate community participation.
Task 5.1 Air Born Methane // CO_2 monitoring
Task 5.2 Noble Gas Interpretation
Task 5.3 Borehole Temperature and Salinity
Task 5.4 Thermal and Flow Rate Monitoring of Springs
Task 5.5 Participatory Monitoring of GW Quality
Task 5.6 Nano and DNA Tracer Technology
Task 5.7 SMART Community Monitoring Network

WP6 Social and Economic Legacy and Future Sustainability (Lead Dr. D. Van der Horst)
This WP will provide the social and economic framework necessary in order to ensure that the local and effected communities accept the change which will be necessary to implement the emerging technologies at the focus of this proposal. Understanding the socio-economic identity and industrial legacy of projects designed to impact multiple areas of society in urban environments is necessary to ensure wide spread acceptance and uptake. Community co-ownership of projects leading to social license to operate is essential to ensure that the project successfully engages all the key local actors and that there are relevant economic and health benefits.
Task 6.1 Mineworking Legacy, Type, Location & Structure
Task 6.2 Current Major Society Drivers, Energy Poverty and Health
Task 6.3 Community Involvement and Co-ownership
Task 6.4 Society and Licence to Operate
Task 6.5 Surface Heat Usage Mapping
Task 6.6 Local Business Regeneration

WP7 Economic and Business Models for Long term Success (Lead Prof. J.Gluyas, UoD)

This workpackage will provide insight into the types of the businesses and supply structure which can be developed based on the heating and cooling possibilities. We note that 1MW related to a space heating gross value of approximately £0.4M. We will demonstrate that businesses can work by accompanying the development of them in parallel with the expansion of the heat battery concept and construction of the demonstrator project, and construct investor ready business plans for the uptake of the technology from a local through district to regional scale.
Task 7.1 Heat Ownership Models
Task 7.2 Infrastructure and Network Provision
Task 7.3 Investor Ready Business Plans for Local and District Use
Task 7.4 Cost Benefit Analysis Social and Techno-Economic Aspects of Bush and Loanhead

WP8 Regulations, Planning & Permitting (Lead Dr C.I.McDermott)
The purpose of this workpackage is three fold. First to manage and document a pathway through all the necessary permitting, planning and regulatory requirements necessary for establishing an operational demonstration of the heat storage plant for the ACF into the legacy mineworkings. Secondly to compare and contrast the procedures under the UK devolved legislations and thereby develop recommendations for changes to legislation which could facilitate the uptake this technology. Thirdly, a key aspect of the diffusion of the technology will be a road map to developing district heating schemes incorporating heat storage and extraction technology at outline planning stages. The “road map” will be in the form of guideline documents to help others develop this type of scheme.
Task 8.1 SEPA Permitting
Task 8.2 Coal Authority Permitting
Task 8.3 Midlothian Council Planning
Task 8.4 GeoHeat Battery Current Status in Devolved UK Legislations
Task 8.5 Road Map Emplacing District Heat at Outline Planning Stage
Task 8.6 Policy and Legal Recommendations to Facilitate Similar Low Carbon Developments

WP9 Design and Build (Existing and Novel Technologies) (Lead A.Gunning RSK)
This workpackage maps existing technologies to the design requirements. Particular aspects of dealing with potentially chemical aggressive minewaters or iron oxide and goethite loaded mine waters which might lead to clogging are addressed. State of the art heat pump technologies for both domestic, commercial and community district heating, and heat storage are identified and matched to the project requirements. For existing housing and business facilities retrofit possibilities are investigated. For the creation of access to different levels of mine workings low impact drilling technologies are reviewed.
Task 9.1 Use of Existing Engineering Technology
Task 9.2 Heat Exchange Technologies in Ferruginous Waters
Task 9.3 Heat Pump Technologies for Community Heat Storage and Extraction
Task 9.4 Retrofit possibilities
Task 9.5 Novel Low Impact Drilling Technologies
Task 9.6 SMART Innovation for Controlling Heat Demand Storage and Use

WP10 Heat Storage Facility and Field Demonstrator Site (Lead Dr. C.I.McDermott)
This workpackage will deliver the management and scientific coordination of a fully working demonstrator plant of heat storage in legacy mines. This is coupled with the installation of monitoring of the operation of the facility and the transport of heat in the subsurface, providing a field site for teaching at multiple levels, for research and for dissemination. As the project progresses so the scale of operation increases. This proposal does not include costs for the design and construction of the Heat Storage Plant, but does cover all the geotechnical aspects and wider field monitoring.
Task 10.1 Engineered Design and Construction of Heat Storage Plant 2MW (Phase 1)
Task 10.2 Installation of Deep Level Monitoring Equipment
Task 10.3 Domestic Scale Demonstrator
Task 10.4 District ACF Demonstrator 10MW (Phase 2)

Task 10.5 Regional ACF based Demonstrator (Phase 3)
Task 10.6 Monitoring of the GeoBattery During Operation
Task 10.7 Performance Assessment

WP11 GeoBattery Integrated Dynamic Management Software Technology, GIST, (Lead Dr. C.I.McDermott)
A key project deliverable provided by this workpackage will be transferable software and knowhow of how to manage the heat within the GeoBattery during operation, GIST, GeoBattery Integrated Dynamic Management Software Technology. This will integrate
1) the balancing of multi user heat storage and heat extraction at multiple sites
2) real time monitoring to assess ongoing performance and calibrate the heat model
3) risk assessment based on hydrogeological understanding and potential environmental impacts
Task 11.1 Concept Mapping
Task 11.2 Data Formatting and Domain Data Description
Task 11.3 Integration of Regional TH Model
Task 11.4 Integration of Monitoring Data
Task 11.5 Heat Management
Task 11.6 Risk Assessment Integration
Task 11.7 GIST Release & support

WP12 Dissemination and Pathway to Impact (Lead Dr. K.Edlmann)
This workpackage will coordinate all dissemination activities and interface with all major stakeholders. Dissemination and engagement expertise and experience will be contributed by the Edinburgh Centre for Carbon Innovation, Scottish Carbon Capture Storage, the Durham Energy Institute and the BritGeothermal Research Partnership. Knowledge exchange and dissemination of research outputs at every stage will be undertaken. Early public engagement will be a priority. Communicating with primary and secondary industries that will be involved in the establishment, permitting and insurance aspects of the GeoBattery project and developing pathways to deployment will be undertaken. Strong links will be developed with local industry to explore business opportunities, define market viability of proposed innovation and establish commercial relationships. Ed-GeoBattery's policy recommendations will be promoted through engagement with government bodies. Specialist dissemination events and public engagement will be held to increase awareness amongst all stakeholders and to develop a societal licence to operate.
This will be delivered by the GeoBattery team of leading scientists and key industrial players at the forefront of the prospective geothermal sector in the UK.
Task 12.1 Science Industry Regulatory Advisory Board Engagement
Task 12.2 Conferences
Task 12.3 Publications
Task 12.4 Website
Task 12.5 Community Engagement
Task 12.6 GeoEnergy and Hydrogeology MSc. Projects & Knowledge Dissemination
Task 12.7 Technical Skills Training
Task 12.8 Field Site Accessibility

Funding Statement
Ed-GeoBattery funds all the aspects of the development of the heat battery approach apart from the costs of the physical plant necessary for the demonstrator project and its expansion from 2MW to 10MW and then to 20MW cooling. £2.015 M of matched funding (72%) has been committed with the University/School of Geosciences & Edinburgh Parallel Computing Centre providing £1.705M and six other organisations (4 private companies, University of Durham & the Coal Authority) providing the rest.

Ed-GeoBattery forms the scientific, social, regulatory and business support for the further application for funding for the hardware necessary to construct the demonstrator and beyond cooling plant. Within the current UK-EXASCALE computation bid (submitted) £3M is reserved for the construction of the

demonstrator plant. Additionally Ed-GeoBattery could form one of the three demonstrator projects within the HotScot strength in places funding bid. Given the strategic importance of the overall concept, and the potential long term commercial viability, we do not envisage insurmountable problems in obtaining the necessary funding for a demonstrator plant.

Images and pictures (optional)
Use this section to upload any pictures related to your project, as a single PDF document with the images in the order you would like them viewed and reference them in your response to the methodology questions.

- Case for support figures
- 10/02/2020
- 16:54:31
- pdf 1.88 MB

Gantt Chart
Use this section to upload a PDF Gantt Chart detailing the plan and timeline for the project over the 10 years of award.

- Ed GeoBattery Gantt Chart
- 10/02/2020
- 16:55:07
- pdf 159.68 KB

Risk management
Identify and assess any risks that may jeopardise the success of the project. Outline any contingency plans designed to mitigate these risks.

Risk 1. Construction of the demonstrator plant for the strategic storage of heat in the subsurface is delayed due to funding issues.
Multiple funding routes for the demonstrator plant are under investigation for this strategically important project. Within the current UK-EXASCALE computation bid £3M is reserved for the construction of the demonstrator plant. Ed-GeoBattery could form one of the three demonstrator projects within the HotScot strength in places funding bid. RAoE funding for the project plus the >50% matched funding will make the project extremely attractive for further investor funding. Large cooperate investment firms have already expressed concrete interest in the project. This has not been pursued, as it requires more complex business negotiations, and to some degree ownership of the project is transferred.

Risk 2. Planning // Regulatory problems
The Scottish government, Scottish Enterprise, Midlothian Council, the Coal Authority and the Scottish Environmental Protection Agency have all expressed their broad support for the project.

Risk 3.
Key personnel unable to complete the project over the period of 10 years
At the project lead level, the management can be shared by the project co-leaders, both extremely capable and qualified members of staff. Additionally the project is supported by a project manager, and the School of Geoscience and EPCC are unswervingly dedicated to the completion of the project. At a workpackage lead level there is ample inhouse expertise in Hydrogeology and computational modelling at a PhD and PDRA level so that cover is assured.

Risk 4.

Operation of the Ed-GeoBattery leads to unexpected environmental impacts
The Coal Authority, and the Scottish Environmental Protection Agency (SEPA) are project partners, and so rapid response to any possible environmental issues can be dealt with rapidly and with appropriate expertise. In the worst case operations can be stopped, and new protocols developed.

Choice of host organisation
Provide justification for the choice of your host UK university (and if applicable, partner institution).

The University of Edinburgh has a world class leading research reputation. The location of the Advanced Computer Facility (ACF) as a heat source is ideal, situated upstream of extensive legacy coalmine workings extending under Edinburgh. The University owns a substantial amount of land under which mines are present, and has excellent relationships with local authorities facilitating the development of monitoring sites and drilling. The natural groundwater flow through the mines will distribute the heat to communities where there is already planning permission for, or interest in, the development of several thousands of new homes and industry. The mining system links into new heat minewater heat extraction projects. The School of Geosciences with the Edinburgh Parallel Computing Centre (EPCC) who run the ACF are committed to 60% matchfund the project. Furthermore EPCC have submitted a bid for a UK-EXASCALE computational facility, which includes £3M funding for the demonstrator cooling plant.

Section 4 - Intended impact

Plans for outreach/public engagement
Describe plans for public engagement and outreach to increase impact of your research project over the ten-years of the award.

Public engagement and outreach is a core theme of Ed-GeoBattery's WP12, "Dissemination and Pathway to Impact" focusing on continual interaction with societal opinions. The WP provides a platform for multi-actor stakeholder engagement and formative feedback, thereby enabling the project to respond to important issues and concerns, and to ensure that the technological development within the project is feasible, relevant and maintains a societal licence to operate. Regular direct contact with industry partners, advisors and regulators is guaranteed through 6 monthly project meetings with the Science, Industry and Regulatory Advisory Board, SIRAB (WP1, governance). This ensures two way knowledge exchange.

For local and regional capacity building we will develop simplified briefings and guidance for schools, communities and policy makers on the geobattery and how to benefit from it. Local community engagement will be ensured through specialist dissemination events, strong links will be developed with local industry to explore business opportunities. We will supply information for parliamentary POST notes (Parliamentary Office for Science and Technology briefing notes) and offer presentations to PRESAG (All-Party Parliamentary Group for Renewable and Sustainability Energy) and PGES (All-Party Parliamentary Group for Energy Studies) providing policy makers with concise information about the opportunities presented by the geobattery approach.

Every WP within Ed-GeoBattery will contribute to both national and international conferences, and each WP will produce at least one peer reviewed publication. Consequently Ed-Geobattery will be represented at least twice a year at national and international conference level, and at least once a year at a peer reviewed publication level.

In-house Masters programs (MSc. GeoEnergy and MSc. Applied Hydrogeology) will include Ed-GeoBattery in their teaching and dissertation programs. The development of the field site will lead to easy community engagement events, wider research collaboration and also provide a platform for technical skills training in low enthalpy source heating engineering.

Beneficiaries and impact

What are the benefits of this research? Quantify the extent of the benefits and identify potential beneficiaries.

GeoBattery technology could constitute a timely and enormous benefit for society in general, provide a significant step forwards in terms of low carbon initiatives, and provide energy security from local low cost sources thereby addressing energy and heat poverty issues.

The unique aspect about the GeoBattery approach is the clear balancing of heat storage with heat use in the subsurface, and using legacy structures and intelligent management of the system to strategically recharge the available geothermally heat.

If business as usual continues through a wild west style exploitation of the subsurface heat, the whole theme of using low enthalpy geothermal heat pumps for low carbon heating will fall into disrepute. Already there are reports of ice being found in heat pumps. If managed properly the GeoBattery technology should make a massive sustainable impact on the carbon budget and availability of heat for society.

Where low enthalpy geothermal schemes have been developed world wide, there is a clear influx of business through low grade heat use, for instance horticulture, food preparation and drying. Demonstrable business models including heat supply will lead to a derisking of the industry and wider acceptance and uptake. Cheaper secure heating will lead to attractive housing and an influx to the local community.

Future generations of engineers and geoscientists will benefit from a unique field site with open access to data, including monitoring technology. The site and the monitoring of heat distribution will form world class facilities for the next generation looking at multiple aspects of hydrogeology, groundwater management, resource competition and engineering.

Planning, regulatory and local authorities will benefit from the provision of a clear road map of how such projects can be acceptably realised.

Exploitation

How will the results be exploited? In the previous question, you explained what the benefits of the research are. Here you should explain how the benefits and impacts mentioned above will be achieved.

The main exploitation of the Ed-Geobattery results will be the consequences of being able to demonstrate to multiple levels of stakeholders (local, regulatory, commercial, national, international) that the technology is viable, sustainable and commercially attractive.

Should the Ed-Geobattery be successful, it would establish the UK as an international leading nation for the provision of the technology and knowhow in the drive towards a zero carbon future, in addressing energy poverty through the provision of low cost widely available space heating and be a game changer for the international effort to reduce the impacts of Climate Change.

The principal problem to the acceptance of the geobattery technology and barrier to the described impact and benefits rests on the fact that the longer term impact of only extracting heat from an area using existing technology has not yet been widely understood. So far there was enough heat energy stored in the subsurface to allow the groundsource heat pump technology to function unsustainably without the impact of ground cooling being felt either at the surface or reflected in a longer term drop in the efficiency of the installed systems. However, as the drive towards zero carbon speeds up, this will change, and groundsource heat pumps coupled with mine water heat use will become a standard high demand technology for heat provision in new housing and commercial developments. As such this project is ahead of the curve in addressing a foreseeable problem, but one that has not yet manifested significantly.

Against this back drop the project will demonstrate that
1. there is a significant problem and heat extraction needs to be balanced against heat recharge to ensure sustainability.
2. there is a solution which involves the implementation of existing technology coupled with state of the art numerical models and smart monitoring systems advocated in Ed-GeoBattery.
4. the solution includes the intelligent use of legacy mine workings, the strategic storage of heat and the provision of a reward system for domestic and commercial users to store heat in, as well as extract heat from, the subsurface.
5. the solution can lead to commercially viable low to zero carbon sustainable heat and viable distribution systems.
6. the solution can tackle energy poverty in legacy industrial areas.
7. the solution leads to a significant reduction in community carbon footprints.
8. the solution is not just limited to industrial areas, a rural or domestic heat battery approach can be applied to ensure long term sustainability.

Ed-GeoBattery will achieve this by demonstrating a working commercially viable heat battery approach at a local and district scale. As the project moves from Phase 1 to Phase 2 to Phase 3 (see earlier descriptions of the phases) so all the aspects necessary for the implementation of the technology are developed and put too the test in a real life demonstration within the UK. As the project progresses through the phases solutions to all the perceived barriers will be illustrated.

At the community level the project will host a number of community information meetings, and engage with local authorities and key local community issues.

At a planning level the project will provide clear guidance documents and local community workshops and work closely with the local planning authority responsible for the area, Mid Lothian Council.

At a regulatory level the project will work closely with both SEPA, the Coal Authority, and other similar organisations.

At a governmental level the project will provide policy recommendations based on a legal review of all regulatory aspects. We will supply information for parliamentary POST notes (Parliamentary Office for Science and Technology briefing notes) and offer presentations to PRESAG (All-Party Parliamentary Group for Renewable and Sustainability Energy) and PGES (All-Party Parliamentary Group for Energy Studies) providing policy makers with concise information about the opportunities presented by the geobattery approach.

At a national level the Ed-GeoBattery will be promoted at various conferences and working groups, and the longer term benefits and commercial success will facilitate widespread diffusion of the technology.

The academic impact of our work and data will be realised by publishing results promptly in high-impact open access scientific journals and presenting regularly at international scientific conferences.

At a heat supply level the project includes partnership with Vattenfall, an energy giant in renewable sources and clearly committed to developing a heat market in this area. Additionally there are multiple contacts through the Coal authority to similar operators UK wide to disseminate the technology. Their combined assistance will open doors to international acceptance of the technology.

Furthermore the BritGeothermal network, (http://www.britgeothermal.org/), will be used to facilitate knowledge sharing amongst national and international academic geothermal stakeholders; including industry and regulatory bodies.

Section 5 - Funding requested

Table: Financial expenditure summary

The total value of each award must total to a sum of £2,780,000 for the full ten years of award. A start-up amount of £207,000 from the total value of the award must be dedicated to the start-up costs of the project in the first two years. The remainder of the award, allocated as £257,300 for each year of the award, can be utilised towards some, or all, of the categories listed as follows:

- Direct employment costs of award holder (80% fEC)
- Associated indirect and estate costs of award holder (80% fEC)
- Direct employment costs of research/ technical/ support staff (80% fEC)
- Associated indirect and estate costs of research/ technical/ support staff (80% fEC)
- Costs for research students (stipend and the UK student fee)
- Other, training or similar costs (100% fEC)
- Research expenses (100% direct cost)

Please note that the Academy will pay PhD studentships stipend and UK student fee. This value should be included in the 'Employment costs other' column.

Year 1 total costs can be a maximum of £362,300 (£105,000 Start-up + £257,300), year 2 costs can be a maximum of £359,300 (£102,000 Start-up + 257,300) and the total maximum of £257,300 for each of the remaining years for all/any of the listed categories. This will result in the total value of the award as £2,780,000 over the ten-year period.

Please refer to the guidance notes for further clarification and guidelines on 'eligible costs' within the mentioned categories.

A summary of costings can be provided in the application form: direct costs at 80%, indirect costs at 80%, and research and other costs at 100%.

Please note: the costing rules have changed slightly since the previous call to allow greater flexibility.

	Start-up costs	Direct costs 80%	Indirect costs 80%	Research costs 100%	Year total
Year 1	£105,000.00	£76,320.27	£69,243.12	£15,172.52	265,736
Year 2	£102,000.00	£94,782.17	£76,338.56	£185,232.46	458,353
Year 3	£0.00	£111,170.08	£88,563.12	£182,232.46	381,966
Year 4	£0.00	£136,680.24	£114,721.63	£127,138.12	378,540
Year 5	£0.00	£149,280.81	£119,850.75	£39,546.95	308,679
Year 6	£0.00	£147,474.32	£114,208.72	£21,918.77	283,602

Year 7	£0.00	£110,943.01	£78,390.21	£11,918.77	201,252
Year 8	£0.00	£101,891.06	£65,567.41	£11,951.42	179,410
Year 9	£0.00	£104,936.81	£65,567.41	£11,918.77	182,423
Year 10	£0.00	£82,386.02	£42,486.37	£11,918.77	136,791
Column total	207,000	1,115,865	834,937	618,949	2,776,751

Finance expenditure detail

Please use the template **to provide a detailed breakdown of expenditure for the award. Please upload this document as a PDF.**

- Matched Funding 10.02.20
- 10/02/2020
- 16:50:44
- pdf 464.23 KB

- Budget Plan Chris McDermott
- 04/02/2020
- 15:16:36
- pdf 30.63 KB

Grant value

Please state the total award value being sought

£2,776,751.00

Section 7 - Letters of support and declarations

Letter of support from the university
A Pro Vice-Chancellor, Dean or equivalent at the host university should provided this letter of support. It should be on a headed paper, signed by the author and uploaded by the applicant as a PDF.

The letter should address the points given below:

1. **The institutional commitment to supporting the emerging technology field and the candidate as a global leader of the field. The strategic alignment with university strategy and research priorities including details of previous and planned investment and support to facilitate the development of this research group over the ten years of award.**
2. **A clear commitment to free the candidate from administrative and teaching that do not promote the emerging technology**
3. **Details of how the university intends to reinvest any other funding for the employment costs recovered from the award to appropriate develop the institutions capability in the field.**
4. **Qualities and capabilities of the university department hosting the applicant and how this activity relates to the research strategy of the department/school.**
5. **Outline of the capabilities and achievements of the applicant, and why they have the qualities appropriate for global leadership in this field.**
6. **The institutions approach to commercialisation and intellectual property in regards to the emerging technology field.**

Letter of Support - McDermott - Royal Academy of Engineering - February 6 2020 V2

10/02/2020

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Letter of appointment from the university
A letter of appointment from the university, which may be conditional on receipt of the award, if the candidate is based outside the UK university system. This should be left blank if the candidate is currently working at the university where the award is intended to be carried out.

No Response

CV'S AND COMPANY PROFILES OF CONTRIBUTORS TO THE ED-GEOBATTERY PROPOSAL

The following CV appendix presents first the applicants CV, then the CV's of all those contributing to the project with their individual roles described, and then a brief description of the companies involved.

PRINCIPAL INVESTIGATOR

EXTENDED CV DR. RER. NAT, HABIL. CHRISTOPHER IAN MCDERMOTT, MSC., DEC 2019

Current Position: Reader in Hydrogeology and Coupled Process Modelling, University of Edinburgh.

1. NAME.
Christopher Ian McDermott

2. SCHOOL.
School of Geoscience

3. COLLEGE.
College of Science and Engineering

4. DATE OF FIRST APPOINTMENT AT THE UNIVERSITY OF EDINBURGH.
1st August 2007

5. DATE OF PROMOTIONS
Promoted to Reader 1 August 2016.

6. CAREER SINCE GRADUATION

- August 2016 to Current: Reader, University of Edinburgh, School of Geosciences.
- August 2007 –March 2016: Senior Lecturer, University of Edinburgh, School of Geosciences.
- October 2002 – July 2007: Senior Scientist & Work Group Leader: Hydro-geomechanics, Informatics, Heat Transport, Geothermal Energy, Reactive Transport, Finite Element Modelling. Chair of GeoSystems Research, Centre for Applied Geoscience, Eberhard Karls Universität, Germany.
- October 2000 – October 2002: Manager of the International Masters Courses Applied Environmental Geoscience and the International Masters Course Tropical Hydrogeology, Eberhard Karls Universität, Germany.
- October 1998 – October 2000: Manager and developer of the International Masters Course Applied Environmental Geoscience, Eberhard Karls Universität, Germany.
- March 1996 – July 1999: PhD student working on the research project "DFG-Verbundvorhaben Festgesteins-Aquiferanalog: Experimente und Modellierung". Translation "Hardrock aquifer analogue: experiments and modelling."
- October 1995 – February 1996: Assisted in research project for development of an aquifer analogue model based on architectural elements, Eberhard Karls Universität, Germany.
- October 1989 – January 1994: Consultant Engineering Geologist, Private Company Rendel Geotechnics, Birmingham, England.

7. UNIVERSITY EDUCATION.

DEGREES AWARDED

- 2010 Postgraduate Certificate in University Lecturing, University of Edinburgh.
- 2006 Habilitation[1], Areas of competence: Applied Geoscience and Hydro-informatics. Title: Reservoir Engineering and System Analysis: Hydraulic, Thermal and Geomechanical Coupled

[1] Habilitation is the highest academic qualification a scholar can achieve in many countries in Europe, Central Asia, and the Caucasus. Earned after obtaining a research doctorate, such as a PhD, habilitation requires that the candidate write a professorial thesis (or habilitation thesis) based on independent scholarship, reviewed by and defended before an academic committee in a process similar to that of the doctoral dissertation. The level of scholarship has to be considerably higher than that required for a research doctoral (PhD) thesis in terms of quality and quantity, and must be accomplished independently.

Processes in Geosystems. Presentation (held in German): "CO_2 Speicherung im Untergrund." (Subsurface storage of CO_2). Faculty for Geoscience, Eberhard Karls Universität Tübingen, Germany.

- 1999 Doktor der Naturwissenschaften (Dr. rer. nat.) (3.1996-7.1999). (Mark 1.0 = Grade A), Subject "New Experimental and Modelling Techniques to Investigate the Fractured Porous System", Faculty for Geoscience, Eberhard Karls Universität Tübingen, Germany.
- 1995 Advanced Studies Course Hydrogeology and Engineering Geology of Tropical and Subtropical Regions, (9.1994-9.1995), Eberhard Karls Universität Tübingen, Germany.
- 1989 Masters of Science in Engineering Geology (9.1988-9.1989), (Average Mark 69%), Thesis: "The Permeability and Structural Responses of Common Clay Minerals to Phosphate and Nitrate Anionic Exchange", University of Durham, England.
- 1988 Bachelor with Honours (9.1985-7.1989) 2:1, Geology with major subsidiary in Chemistry and minor subsidiary Surveying, University of Durham, England.

Other: Fluent in German, 4 A levels, 8 O levels

TEACHING

IMPORTANCE

My teaching focuses on training students in hydrogeology and the ability to understand and model physical processes in the subsurface relating to fluid flow. These are crucial skills necessary for the sustainable exploitation and engineering of earth resources which is of relevance world wide. These have a direct application to areas such as geothermal energy, water resources management, hazardous waste management, climate change impact, renewable energy exploitation, ground engineering and current themes such as fracking and CO_2 sequestration. I focus on developing the skill sets in students to facilitate the students in managing and solving applied real world problems. Applied engineering consultancies and regulatory bodies employ graduates with these skill sets. It is a great pleasure for me to know of a number of students who have taken my courses and are now working in Hydrogeology related areas across several continents due to my teaching efforts.

8. TEACHING EXPERIENCE

Led, developed, implemented and contribute specialist teaching in hydrogeology at UoE since 2008, core to Environmental Geoscience and Geology programmes, optional to multiple other programs within School of Geoscience and School of Engineering. Currently >90 students / year taking Hydrogeology courses

COURSES I AM CURRENTLY TEACHING

- CO for EASC10082 Hydrogeology 1: Applied Hydrogeology, Applied Hydrogeology, 10 Credits;
- CO for EASC10077 Hydrogeology 2: Simulation of Groundwater Flow and Transport, 10 Credits
- CO for EASC 10101. Applied Hydrogeology and Near Surface Geophysics, 20 Credits

In each case I was ~100% responsible for teaching, delivery and assessment of the Hydrogeology component up until 2018/19. As of current year am starting to share the load with a recently employed Chancellors fellow and a new Lecturer in Hydrogeology.

- contribute to EASC 10009 Environmental geoscience dissertations, PGGE11225 Future Geoenergy Resources->Geothermal energy lectures and tutorial, EASC 10011 Geology dissertation as assigned.

COURSES I HAVE TAUGHT PREVIOUSLY

- CO for EASC10078; Hydrogeology 3: Field and Modelling Project; 100% (2009 to 2013)

Participated in

- EASC10059; Environmental Geoscience Fieldwork and Synoptic Practical Examination; 11%
- EASC09032; Field Skills for Earth Surface Scientists; 20%
- Earth Surface Processes, UoE, 20 Credits, 100%, was 4th year (2008 & 2009)

At the University of Tuebingen (2005-2007) I was course organiser, examiner and lecturer for

- Mathematical Methods for Geoscience students. (equivalent 20 UoE credits) (contribution 50%)
- Engineering Geology. (equivalent 10 UoE credits) (100%)
- Environmental and Geotechnical Impact of Groundwater Abstraction. (Equivalent 10 UoE credits) (100%)
- Hydrochemical Modelling. (Equivalent 10 UoE credits) (100%)
- Yearly excursion to Mont Terri and Grimsel Field Underground Rock Laboratories (2 days).

EVIDENCE OF TEACHING EXCELLENCE

- Since 2010 I have been a Fellow of the Higher Education Academy
- PT/DoS (student tutor) since 2007 for ~ 140 students in total so far.
- Excellence in student support and favourable student feedback within the school and college.
- Cross school teaching : Hydrogeology courses established as core course within Environmental Geoscience, and recommended options in several other geoscience courses and several courses within the School of Engineering.

9. SUPERVISION OF TAUGHT POSTGRADUATE STUDENTS

Total : 15 MSc. level.

Kitty Nolan (2019) A Combined Experimental Investigation and Numerical Simulation of Stress-Dependant Fracture Permeability under True-Triaxial Stress Conditions, UoE (2nd supervisor)

Andrew Fraser Harris (2011-2012) Investigating the coupled Thermo-Hydro-Chemical effects on groundwater flow caused by disposal of High Level Radioactive Waste using Sellafield, UK, as a case study, UoE.

Edd Dodmann (2009 – 2010) Numerical investigation of saltwater intrusion in arid coastal aquifers, UoE.

Aisling Layden (2009) Groundwater geochemical reactive transport investigation of contaminant plumes from West Lothian Oil Shale Spoil heaps, UoE.

Lenar Sultanov (2006) Modelling supercritical CO2 in geothermal reservoir applications, Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I. McDermott M.Sc., Prof. Dr. O. Kolditz.

Maria Herold (2005) GeoSys as a tool for Groundwater Management and Contamination Risk Assessment Modelling: Application for Nagold Stadtwerk, Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.McDermott M.Sc., Peter Dengler (Wasser Meister, Nagold Stadtwerk), Prof. Dr. O. Kolditz

Eric Appiah Agypong (2005) Integrated groundwater management: Application of source functions to model basin water resources using the finite element approach, Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc., Prof. Dr. O. Kolditz.

Jóse Guillermo De Aguinaga R.E. (2005) Generation of 2D fractal fracture zones for application in finite element models, Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc., Prof. Dr. O. Kolditz.

Aziz Shaikh (2003): Modelling of Nitrate Concentration in the Aquifer Beneath the City of Larkana, Pakistan: Groundware Quality Assessment and Development of Hazard Management Plan, Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc., PD. Dr. R. Liedl

Sherif Shahatto (2003): Environmental Impact Of Development in Coastal Areas: Desalinisation, Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc., Prof. Dr. O. Kolditz, Prof. Dr. G. Teutsch

Tito Abele Taban Jongu (2003) Catchment Management in South Sudan: Water, Hydrology & Hydrogeology, Hazards, Demand and Planning Recommendations. Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc, Prof. Dr. O. Kolditz.

Michael Yemane (2003): Three Dimensional Groundwater Flow Modelling in the West Bank Region of the Jordan Valley (Upper Aquifer), Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc, Prof. Dr. O. Kolditz

Egle Grinkevicuite (2003): Directional and pressure dependent permeability: Effect of effective stress and poroelastic deformation on heat transfer in a geothermal reservoir, application to German Deep Continental Drilling Project (KTB), Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc, Prof. Dr. O. Kolditz

Andry Lazamanana Randriamanjatosoa (2003): Dependencies of heat transfer on fluid properties along a fracture in geothermal reservoir modelling, application to the German Continental Deep Drilling Program (KTB), Masters Thesis at the Geoscience Faculty of the Eberhard-Karls-University, Tübingen. Supervisors Dr. C.I.M^{c}Dermott M.Sc, Prof. Dr. O. Kolditz.

Hagemann B. (2001): Untersuchung und Modellierung von Wasserdurchlässigkeit und Transporteigenschaften in geklüftetem Gestein, Diplomarbeit, Lehrstuhl für Angewandte Geologie, Universität Tübingen, Supervisors Dr. C.I.M^{c}Dermott M.Sc, Prof. Dr. M. Sauter.

RESEARCH

10. MAJOR RESEARCH INTERESTS

Statement of research aims: My research aim is to advance the understanding, mathematical modelling and experimental investigation of coupled thermo-hydro-mechanical and chemical (THMC) processes particularly related to fluid flow in geological systems and building on this to develop new numerical tools for application to subsurface geo-engineering//geo-energy challenges.

Interdisciplinary research area, Geosciences & Engineering
PLEASE Note http://www.docs.csg.ed.ac.uk/HumanResources/Interdisciplinary_Jul15.pdf

SIGNIFICANCE//IMPORTANCE

Understanding subsurface coupled processes related to fluid flow is necessary to aid in the sustainable management of geo-resources, addressing issues of energy security, (conventional and unconventional resources, energy storage, geothermal energy, radioactive waste storage), water

resources, resource competition and climate change (CO_2 sequestration). These are major international themes affecting all aspects of society. Examples of the areas of recent or ongoing projects I am involved in include

- Geothermal Energy (shallow to intermediate aquifer systems geothermal reservoirs, and using legacy mine workings as "heat batteries")
- Fracking (Risk assessment, reduction of environmental impact, development on new lower impact fracking technology through freezing or controlled pressure wave superposition)
- Radioactive Waste Disposal in Geological Repositories (particularly (i) simulation of clay swelling in engineered barriers, (ii) investigation of fracture fluid flow under THMC conditions and (iii) changes to regional hydrogeological systems due to the thermal effects of waste disposal)
- CO2 Sequestration // Hydrogen storage (Geomechanics of injection and long term storage behaviour)
- Chemical dissolution and development of preferential flow paths in carbonate rocks, controls on karst formation.
- Provenance of mine water contamination in the Almond Catchment, West Lothian
- New hybrid analytical modelling techniques for multiphase flow

MY DISTINCTIVE CORE RESEARCH CAPACITY CONTRIBUTION TO UOE

1. Applied Geosciences Laboratory built and supported through EU and industry grants: Since 2007 I have led and managed a new core scale (~38 mm diameter) lab for investigating the coupled processes behaviour of rock under reservoir conditions of fluid pressure, reservoir temperature, reservoir stress and aggressive geo-chemical conditions. Employed a PDRA since 2009, a technician since 2014 and established ~ £1.3 M equipment, through several PhD projects, MSc. Projects and BSc. projects. Since 2018 this facility is managed by Katriona Edlmann.
https://www.ed.ac.uk/geosciences/facilities/applied-geosciences-laboratory

2. Unique GREAT cell PI on the international GREAT (Geo-Reservoir Experimental Analogue Technology) whereby large fractured samples (20 cm diameter) can be placed under true tri-axial stress conditions representative of typical reservoir conditions at 3-4 km depth. Installed at the UEDIN, with a value of ~£2M, this facility already contributed to grants worth £9.2M, providing a step change in experimental capability world wide.
https://www.ed.ac.uk/geosciences/facilities/great-cell-laboratory

3. OpenGeoSys Finite Element Simulator with Software Architecture to Facilitate Coupled Process Numerical Modelling: Extremely flexible numerical simulator in C++, as co-architect/co-developer of the code I support multiple users in adding extra plug ins to fit their specific research needs, and am training a PDRA to provide similar support. Used in house by ~20 MSc and final year honours students, 3 PhD students, a PDRA and myself to simulate regional groundwater management, saline intrusion, multiphase flow, mechanical deformation, heat transport and fluid flow, mechanical deformation of mine workings, geothermal energy extraction, impact of radioactive waste disposal on hydrogeology and fluid flow, reactive transport in carbonate systems and noble gas isotope transport.
https://www.opengeosys.org/

MY CURRENT RESEARCH FOCUS

The sustainable management of geothermal energy and the development of low environmental impact near well stimulation technology is the current focus of my research. I divided it into two areas below with a focus on A. Experimental Investigation of Fluid Flow and Coupled Processes and B. Modelling Development

A). EXPERIMENTAL INVESTIGATION OF FLUID FLOW AND COUPLED PROCESSES

Actual ongoing work in this area includes

- the investigation fracture flow under different stress conditions within naturally fluid flow sealing rocks (caprocks) such as the Opalinus clay, (of interest for Nuclear Waste Geological repositories) and through Granitic crystalline rocks (of interest for Geothermal applications).
- testing and developing new technologies to reduce the environmental foot print and increase the efficiency of hydraulic stimulation techniques, including pulse pumping and wave superposition. Currently acoustic emissions sensing technology is being integrated into the unconfined rig and pulse pump technology is being developed. The idea is to dynamically record the development of fracture growth, under "smart" stimulation conditions, and then repeat under true triaxial conditions.

Recent Evidence of output of research and impact regarding in this area

Publications PhD//BSc student underlined in italics

C. I. McDermott, A. Fraser-Harris, M. Sauter, G. Couples, K. Edlmann, O. Kolditz, A. Lightbody, J. Somerville, W. Wang, (2018) "New Experimental Equipment Recreating Geo-Reservoir Conditions in Large, Fractured, Porous Samples to Investigate Coupled Thermal, Hydraulic and Polyaxial Stress Processes." Scientific Reports 8(1): 14549.

O'Donnell, M., S. Gilfillan, K. Edlmann and C. McDermott (2018). "Wastewater from hydraulic fracturing in the UK: assessing the viability and cost of management." Environmental Science: Water Research & Technology 4(2): 325-335.

Edlmann, K., Haszeldine, S. and McDermott, C.(PI), 2013. Experimental investigation into the sealing capability of naturally fractured shale caprocks to supercritical carbon dioxide flow. Environmental earth sciences, 70(7): 3393-3409.-17.

Impact and importance of these publications

McDermott et al. 2018 demonstrated for the first time a global step change in the capability to investigate fluid flow in fractured porous reservoirs under in situ conditions of polyaxial stress and fluid pressure. A second device is now under construction in Germany, and there has been significant commercial interest expressed in the device. It is expected that this paper will be a 4* paper. O'Donnell et al. 2018 has been nominated one of the best 27 best papers of 2018 in the journal that it was published in Environmental Science: Water Research & Technology, and has been evaluated as a 4* paper. Edlmann et al. 2013 is a widely cited experimentally driven paper demonstrating for the first time unusual characteristics of the flow of supercritical CO2 through fractures in caprocks, later correlating to the assessment of security of storage and safety of CO2 storage locations and analogue sites.

B). NUMERICAL SIMULATION OF COUPLED PROCESSES: OpenGeoSys (http://www.opengeosys.org/)

As part of the development team of OpenGeoSys [OGS], (a free, multi-platform scientific modeling package that enables numerical simulations of individual or coupled thermo-hydro-mechanical (THMC) processes in porous and fractured media.) I have developed several new techniques for

addressing coupled process modeling problems. My next project regarding the use of OGS is to introduce hybrid analytical solutions and numerical solutions to facilitate the large scale simulation of heat storage and extraction from near surface mine workings. I am also supervising a project with the BGS, EQUIP4RISK, and am WP lead for the modelling development and devising new risk assessment methodologies for groundwater contaminant transport in heterogeneous geological environments.

Recent Evidence of output in numerical simulation of coupled processes

Publications, PhD//BSc student underlined in italics

Todd, F., McDermott, C., Harris, A. F., Bond, A., & Gilfillan, S. (2019). Coupled hydraulic and mechanical model of surface uplift due to mine water rebound: implications for mine water heating and cooling schemes. Scottish Journal of Geology, sjg2018-2028. doi:10.1144/sjg2018-028

Comerford, A., A. Fraser-Harris, G. Johnson and C. McDermott (2018). "Controls on geothermal heat recovery from a hot sedimentary aquifer in Guardbridge, Scotland: Field measurements, modelling and long term sustainability." Geothermics 76: 125-140.

Mouli-Castillo, Julien, Mark Wilkinson, Dimitri Mignard, Christopher McDermott, R. Stuart Haszeldine, and Zoe K. Shipton. 2019. 'Inter-seasonal compressed-air energy storage using saline aquifers', Nature Energy, 4: 131-39.

McDermott, C.I., Williams, J., Tucker, O., Jin, M., Mackay, E., Edlmann K., Haszeldine, R.S., Wang, W. Kolditz, O., Akhurst, M., (2016), Screening the Geomechanical Stability (Thermal & Mechanical) of Shared Multi-user CO2 Storage Assets, a Simple Effective Tool Applied to the Captain Sandstone Aquifer, International Journal of Greenhouse Gas Control 45, 43–61

Impact and importance of these publications

All these papers are of significance to the ongoing discussion surrounding the reduction of the carbon footprint of societies energy use. Todd et al. is already widely quoted at town hall // conference level discussions for demonstrating that legacy mineworkings can not provide more than ~ 7% sustainable heat energy for society unless the system includes heating storage (example evaluated for Scotland). This was at odds with previous calculations where values of the order of 30%+ were quoted, and will be an important driver in the development of sustainable low carbon energy investment, technology and policy. Likewise Comerford et al. 2018 demonstrated the long term realistic amount of heat energy which can be extracted from low to mid enthalpy, high permeability heat resources in Scottish aquifers. Mouli-Castillo et al. showed the realistic geological constraints of seasonal compressed air storage in saline aquifers, and provided a regional assessment of this storage potential for the United Kingdom, equivalent to approximately 160% of electricity consumption peak winter demand. McDermott et al. 2016 introduces a new surrogate modelling approach to capture complex geomechanical simulations and make the results accessible to standard industry software applications. The paper develops the methodology and demonstrates its use. The work led to a presentation at the house of Lords as part of the CO2Multistore project. A similar methodology has been taken up within the H2020 project FracRisk in the development and conditioning of surrogate models to express complex risk assessment information (see paper No. 47). OGS is used world wide, and the paper No. 27 in my publication list where I am a co-author, (Kolditz et al. 2013) has over 350 citations indicating the world wide impact of the OGS code, which includes modules written by myself.

OTHER EVIDENCE OF IMPACT//ACHIEVEMENTS

I was asked to be UoE/School of Geosciences representative for visit of President, Vice President and Director of the State Parliament of Lower Saxony. This was based on an evaluation by the University, that found that UoE staff co-authored 6,858 peer-reviewed papers with collaborators in Germany in the last 10 years. The biggest SciVal hits are: Michael Sullivan (Clinical Sciences) and Christopher McDermott (Geoscience)

11. Research Grants

Summary of Grants

Total (in career) number of grants:27
Total value of funding I have contributed to: £25.25 M
Total value to UoE: £6.78 M
Other indirect funding as a direct result of my work (see below): €2.3M Euro

Income since last promotion

UoE PI Number:5 Total £5.33M (Value to UoE £1.34M)
Co-I Number:2 Total £2.98M (Value to UoE £1.41M)

FEC Grant Chargeable Time Recovered in Last 5 years

My average staff time covered over the last five academic years by research grants,
(not including multiple other staff included on cooperative grants led by me)
2018/19..- 38%, 2017/18 - 46% , 2016/17 - 46%, 2015/16 - 46%, 2014/15 - 33%

Overview of grant income, to best of my knowledge

							SOURCE					
Ref No (CV)	Date	Name//Type	Funder	My Role	Value to UoE	Total Grant Income	Industry	EU	Third party	NERC, EPSRC, DFG	Teaching	Other
27	2019	CASE PhD	DTP & CA	PI	£5,000	£5,000	£5,000					
26	2019	HyStorPor	EPSRC	Co-I	£1,386,749	£1,386,749				£1,386,749		
25	2018	Smart Pumps	EPSRC	UoE PI	£986,772	£4,976,888	£2,488,444			£2,488,444		
24	2018	IPP	CPG	Co-I	£1,596,668	£1,596,668						
23	2018	EQUIP4RISK	NERC	UoE PI	£339,070	£339,070				£339,070		
22	2017	CASE PhD	DTP & Qu	PI	£5,000	£5,000	£5,000					
21	2017		OGIC	PI	£5,000	£5,000	£5,000					
20	2016		OGIC	PI	£10,000	£10,000	£10,000					
19	2015	New-ICCARE	TOTAL	Co-I	£197,600	£197,600	£197,600					
18	2015	FrackRisk	EU H2020	PI & Coord.	£527,015	£2,200,000		£2,200,000				
17	2015	GeoMeChem	PETROBRAS	PI	£433,000	£433,000	£433,000					
16	2014	CASE PhD	Industry	Co-I	£3,000	£3,000	£3,000					
15	2013	CO2Multistore	Industry	PI	£30,000	£30,000	£30,000					
14	2012	DECOVALEX	Quintessa	PI	£126,188	£126,188	£126,188					
13	2012	PANACEA	EU FP7	PI	£350,699	£4,000,000		£4,000,000				
12	2011	GREAT	Investment*	PI	£300,000	£880,000			£300,000			£580000*
11	2009	MUSTANG	EU FP7	PI	£392,448	£8,500,000		£8,500,000				
10	2008	DECOVALEX	Quintessa	PI	£82,000	£82,000	£82,000					
9	2006		DFG	PI	Pre Edinburgh	£66,957				£66,957		
8	2005		DFG	Co-I	Pre Edinburgh	£66,957				£66,957		
7	2004		DFG	Co-I	Pre Edinburgh	£66,957				£66,957		
6	2003		DFG	Co-I	Pre Edinburgh	£65,217				£65,217		
5	2001		SWN	PI	Pre Edinburgh	£2,609					£2,609	
4	2001		BMBF	PI	Pre Edinburgh	£50,000					£50,000	
3	2000		BMBF	PI	Pre Edinburgh	£50,000					£50,000	
2	1999		DAAD	PI	Pre Edinburgh	£110,000					£110,000	
1	1998		DFG	Co-I								
Total					£6,776,209	£25,254,859	£3,385,232	£14,700,000	£300,000	£4,480,350	£212,609	£580,000
			* £180,000 in kind from Heriot Watt University									
			* £400,000 sustainability pot UEDIN									

Grant Title//Descriptions

(linked to ref. No. in table above)

27) September 2019-August 2023, CASE partner award, £5000, with the Coal Authority, for NERC DTP Sponsored student Mylene Receveur, PI
26) September 2019-August 2022, EPSRC Grant EP/S027815/1 HyStorPor - Hydrogen Storage in Porous Media, Value to UoE £1.38M, Co-I.
25) October 2018 – September 2023, EPSRC Grant: EP/S005560/1, Prosperity Partnership Bid, Smart Pumping for Subsurface Engineering, Overall lead Prof. Shipton, Strathclyde University, Overall value £4.98 M Value to UoE £986,772. Design and implementation of experimental program to test and develop functionality of smart pumping technology, exploiting the superposition of controlled pressure pulses to enable pinpoint accuracy of hydraulic stimulation (fracking) in boreholes. UoE PI
24) March 2018-February 2021, CPG 17 1024: International Partnership Program, Advanced Hybrid Method for Pore-Scale Simulation of Shale Gas Flows, total value £1,596,668, Jason Reese, Matthew Borg, Timm Krüger, Chris McDermott Sponsors College of Petroleum Engineering & Geosciences (KFUPM), Saudi Arabia. Co-I.
23) June 2018-May 2022, NE/R018049X/1: Evaluation, Quantification and Identification of Pathways and Targets for the assessment of Shale Gas RISK (EQUIPT4RISK), Edinburgh PI, total UOE value £339,070, part of BGS consortium, responsible for risk assessment methodology combining air, water and solid earth source pathway receptor (SPR) reduced order models, UoE PI.
22) September 2017-August 2021, CASE partner award, £5000, with Quintessa ltd, for NERC DTP Sponsored student Fiona Todd, PI
21) 2017, Scoping Numerical Investigation of Freeze Thaw Technology for Heavy Oil Field, OGIC, ~£5k, UoE PI.
20) 2017, Phase Zero Polar Well Stimulations Ltd Study, Numerical Investigation of Freeze Thaw Technology for Near Well Stimulation, OGIC, ~£10k, UoE PI.
19) June 2015 – May 2019, New-ICCARE: New-Isotope Coupling & Classical tools: Applications to Reservoir and Exploration issues, funding from TOTAL. (Co-I)
18) June 2015 – April 2019, European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No. 636811 FracRisk: Lead and coordinate one of the four flag ship EU collaborative Horizon 2020 projects on Fracking. The project comprises 14 partners from 7 EU countries, +USA & Israel, additionally 5 international companies as advisors. Total value, 3M Euro, Value to Edinburgh 0.68M Euro. (Coordinator and overall PI)
17) April 2015 – January 2021, GeoMeChem (Geomechanical and chemical investigation of hydrocarbon production in carbonates) 2015, Includes multi-scale experimental research and numerical modelling of the flow and coupled process behaviour of carbonate rocks on highly sensitive commercial data/samples. Industry sponsorship from Petrobras, Value to Edinburgh ~£430k over March 2015 ~ September 2018. Supported Edlmann (PDRA), & further PDRA position, 1 x PhD position, technical staff and McDermott., (PI)
16) September 2014, CASE, Radioactive waste disposal in the UK - exploring for deep storage sites using geology, hydrogeology and coupled process modelling, Co-I
15) 2013-2015, CO2MULTISTORE, Geomechanical simulation of the impact of multiple storage sites on the geomechanical stability of a large scale aquifer in the North Sea. Part of a consortium, Edinburgh Income, ~£30k (Edinburgh PI for Geomechanical Modelling, collaboration with industry)
14). 2012 – 2015, NDA // Quintessa DECOVALEX DEvelopment of COupled models and their VALidation against EXperiments. Coupled process modelling of radioactive waste disposal issues in argillacious deposits. Edinburgh Income £126,188 (PI, collaboration with Industry)

13). January 2012 – December 2014, PANACEA, Predicting and monitoring the long-term behaviour of CO2 injected in deep geological formations THEME [ENERGY.2011.5.2-1 ENERGY.2011.5.2-1 ENERGY], FP7 Project number 282900. Total value ~£4M, Edinburgh Income £301,285 (UoE PI)
12). June 2012 – May 2020, GREAT GeoReservoir Experimental Analogue Technology (2012-2014) Total project value £880,000, funding through sustainability pot (£400k), value to Edinburgh from Heriot Watt University and Universitaet of Goettingen £480,000 (Over all PI)
11). June 2009 – May 2014, MUSTANG, A MUltiple Space and Time scale Approach for the quaNtification of deep saline formations for CO2 storaGe, ENERGY.2007.5.2.1, FP7 Project number 227286. Total value ~£8.5M, Edinburgh Income £392,448 (UoE PI)
10). 2008 – 2010, DECOVALEX DEvelopment of COupled models and their VALidation against EXperiments. Coupled process modelling of radioactive waste disposal issues in argillacious deposits. Value to Edinburgh £82,000 (PI, collaboration with industry)
9).2006, Christopher McDermott / Olaf Kolditz / Martin Sauter (2006): Investigation of thermo-hydro-mechanical processes in deep crystalline rock, Experiments and numerical modelling, Phase 5, DFG Schwerpunktprogramm "Internationales Kontinentales Bohrprogramm"ICDP, value circa 77000 Euro. MC 113/1-5 (PI)
8). 2005, Olaf Kolditz / Martin Sauter / Helmut Tenzer / Martin Herfort:** Investigation of thermo-hydro-mechanical processes in deep crystalline rock, Experiments and numerical modelling, Phase 4, DFG Schwerpunktprogramm "Internationales Kontinentales Bohrprogramm"ICDP, value circa 77000 Euro. KO 1591/2-4 (Co-I)
7). 2004, Olaf Kolditz / Martin Sauter / Helmut Tenzer /Martin Herfort:** Investigation of thermo-hydro-mechanical processes in deep crystalline rock, Experiments and numerical modelling, Phase 3, DFG Schwerpunktprogramm "Internationales Kontinentales Bohrprogramm"ICDP, value circa 77000 Euro. KO 1591/2-3 (Co-I)
6). 2003, Olaf Kolditz / Martin Sauter / Helmut Tenzer / Martin Herfort:** Investigation of thermo-hydro-mechanical processes in deep crystalline rock, Experiments and numerical modelling, Phase 2, DFG Schwerpunktprogramm "Internationales Kontinentales Bohrprogramm"ICDP, value circa 75000 Euro.KO 1591/2-2 (Co-I)
5). 2001, M^{c}Dermott C.I.: Groundwater Management and Risk Assessment, Stadtwerk Nagold. 3000 Euro (PI)
4). 2001, M^{c}Dermott C.I.: Proposal to BMBF for scholarships for ten students to take the International Masters Course, 3 students accepted, value circa 150,000 DM over two years.BMBF IPS 02/004 (PI)
3). 2000, M^{c}Dermott C.I.,: Proposal to BMBF for scholarships for ten students to take the International Masters Course, 3 students accepted, value circa 150,000 DM over two years. BMBF IPS 01/004 (PI)
2). 1999-2002, M^{c}Dermott C.I., & Teutsch G.: “Applied Environmental Geoscience, Proposal for Financial Aid of a M.Sc. Course, University of Tübingen, Faculty of Geoscience”, Four years of start up funding for an international Masters Course, value circa 420,000 DM over four years. DAAD D/99/16250 (PI)
1).1998, McDermott als Projektbearbeiter: “DFG-Verbundvorhaben Festgesteins-Aquiferanalog: Experimente und Modellierung, Forschungsberichte für die 2. Projektphase.”, Teilprojekt 2:

** As my own position was funded from these proposals at that time my name was not allowed to appear as proposal author, even though I was responsible for the majority of the work

Laborexperimente und Entwicklung neuer Untersuchungsmethoden. (Contribution in terms of concept, preparation and presentation) (Co-I)

Other indirect funding, €2.3M Euro (2017 & 2018)

Applied Geoscience, Universität Göttingen, declares that the following funding has been acquired as a result of the GREAT cell collaboration and my work

1.) Scientist: Modeler in Hydrogeomechanics (2 years) 150000 EUROs
2.) Scientist: Experimenter in Geomechanics (5 years) 375000 EUROs
3.) GREAT II - Experimental laboratory 1.8 Mio EUROs

Deutsche Forschungsgemeinschaft, DFG, grant: INST 186/1197 - 1 FUGG), and the German Lower Saxony Ministry of Science and Culture (Niedersächsisches Ministerium für Wissenschaft und Kultur, MWK, grant 11 – 76251-10-5/15 (ZN3271)

Other Proposals Currently in Preparation

• Lead on E-GEOBATTERY, Exploiting legacy mines to create a GEOthermal heat BATTERY, Possible impact: save UoE millions of pounds in the longer term electricity costs for the Advanced Computer Facility cooling, reduce UoE's Carbon footprint and create a geothermal heat storage battery with potential viable local commercial exploitation.

• Co-lead on international DECOVALEX 2023, Crystalline task proposal "SAFENET" Safety Assessment of Fluid Flow, Shear, Thermal and Reaction Processes within Crystalline Rock Fracture NETworks, UFZ, Leipzig, Germany, University of Edinburgh, Scotland, DynaFrax/KICT Korea Institute of Civil Engineering and Building Technology.

12. Research Supervision Experience

Of the six post docs I have supervised so far, three have gone on to academic positions (Edlmann, Kalbacher, Mettier), one is still employed as a post doc (Fraser-Harris).

Postdoc supervision

So far (6), as of March 2020 (7).

- Dr Jackie Kendrick (from March 2020 –February 2022) Novel near well stimulation technology.
- Dr Andrew Fraser-Harris (2016 – current) Experimental and numerical investigation of coupled processes
- Dr. Katriona Edlmann (2009 – 2019) Experimental investigation of the impact of supercritical CO2 on caprock integrity, Now chancellors fellow.
- Dr. Mike Edwards (2010 - 2011) Investigation of Caprock analogues for CO2 storage.
- Dr. Thomas Kalbacher (2006) Development of geometrical modelling software tools.
- Dr. Ralph Mettier (2006) Geostatistic analysis of flow and transport in a fractured shear zones (Grimsel Laboratory)
- Dr. Helmut Tenzer (2006 – 2007), Risk assessment of HDR/HWR geothermal applications.

PHD DISSERTATION SUPERVISION (18+2 CURRENTLY ADVERTISED OPEN POSITIONS)

*indicates 1st supervisor role

18.* Mylène Receveur (2019) Temperature controls of legacy coal mines and geothermal heat storage, (CASE & NERC)

17. Rebecca Chambers, (Oct 2018 – current), modelling and fingerprinting ground gas contamination in groundwaters. (CASE & NERC, overall UoE PI)

16. *Fiona Todd (2017-current), Modelling Geothermal Heat Extraction from Abandoned Mine Workings and Associated Ground Stability Issues (CASE&NERC)

15. Masoud Ghaderi, Modelling Multi-phase Reactive Flow in the Subsurface, ETP PhD, Heriot Watt student.

14. *Florent Brondolo (2015 - 2019) Experimental Investigation of Coupled Carbonate Rock Physics and Geochemistry.(Industry, PI)

13. Megan O Donnel (2015 - current) Managing produced water from European unconventional gas production.(EU, overall PI)

12. James Scott (2015 - current) Nobel gas transport in the subsurface (Industry, Co-I)

11. Julian Mouli Castillo (2014 – 2018) Assessing the potential for compressed air energy storage using the offshore UK saline aquifer resource.

10. Emma Hipkins (2014 – 2019) Thermal and hydraulic modelling of potential nuclear waste disposal sites in the UK (CASE, Co-I)

9. *Andrew Fraser-Harris (2012 – 2016) Development of a new non-linear elastic hydro-mechanical model for the simulation of compacted MX-80 bentonite: application to laboratory and in situ sealing experiments for geo-repository engineered barriers. (Industry, UoE PI)

8. *Johannes Miocic (2012 – 2016) A study of natural CO2 reservoirs - mechanisms and pathways for leakage and implications for geologically stored CO2. Contribution to EU project PANACEA. (EU, UoE PI)

7. *Claire McCraw (2012 – 2016) Supercritical CO2 flow through fractured low permeability geological media: experimental investigation under varying mechanical and thermal conditions. Contribution to EU project PANACEA. (EU, UoE PI)

6. Racheal Kilgallon (2010 – 2016) Investigating the role of chemical and geochemical tracers for CO2 transport and storage.(EU, UoE PI)

5. *Myles English (2008 – 2013) Coupled process modelling with applications to radionuclide storage and disposal.(Industry)

4. *Simon Haunch (2009 – 2013) The legacy of historic mining and water quality in a heavily mined Scottish river catchment. (ECOSSE)

3. *Robert Walsh,. 2007 (University of Tübingen): Application of a Geomechanical Facies model for upscaling of the flow and heat transport characteristics in fractured geothermal reservoir rock.

2. Dipl. Ing. Guido Blöcher 2008 (GFZ Potsdam & University of Tübingen): Micro network and pore space characteristics, flow and heat transport under deformation. Experimental and numerical investigation.

1. *Helmut Tenzer, Dipl. Geol. (University of Tübingen) 2006: The comparison of the hydro-geomechanical facies dominating the fluid flow and heat transport characteristics in Bad Urach and Soultz Geothermal investigation.

TECHNICAL STAFF EMPLOYED

Mr Alexander Lightbody (2016 – 2023+) Technician for GREAT cell development & Smart Pumps
Mr Grant Nichols (2013 – 2014) Technician for GREAT cell development.

KNOWLEDGE EXCHANGE AND IMPACT

13 CONTRIBUTION TO KNOWLEDGE EXCHANGE AND IMPACT

Since 2008, I have successfully established and maintained knowledge exchange relationship and industry collaboration to facilitate fundamental science with various parties from industry, to the benefit both of the students participating and to the companies and regulators involved. This has led to external funding for KE activity and Provision of consultancy for external organisations through ERI through a number of contracts, total value ~£3.38M with a value to Edinburgh of £1.88M. Below I list 9 key projects // areas, and describe in more detail the aims, my contribution and the impact.

1. DECOVALEX (www.DECOVALEX.org)

Within the DECOVALEX project (DEvelopment of COupled models and their VALidation against EXperiments) I have been working closely with Quintessa Limited since 2009, - Mathematical and Scientific Consultancy in Geo-modelling of Engineered Geo-reservoir Storage, application to radionuclide storage. This has resulted in multiple contracts and 2 x PhD students (DECOVALEX phase 5 and 6). Partners as part of these contracts have included AMEC, Radioactive Waste Management Directorate, previously Nuclear Decommissioning Agency. This collaboration and knowledge exchange has led to dissemination in 12 collaborative papers with various industry and regulatory partners. This is evidenced in my publication list, paper numbers 25,28, 30, 45,46,48,49,50,51,52,60 and four reports, numbers 4,6,10, 11.

Further impact is evidenced by the fact that I have been involved in multiple presentations to communicate research to a range of external organisations and audiences through DECOVALEX project meetings, included national radwaste organisations from throughout the world, for DECOVALEX 2012-2015 these audiences included.

- BGR: Federal Institute for Geosciences and Natural Resources, Germany
- CAS: Chinese Academy of Sciences
- DOE: Department of Energy, USA
- ENSI: Swiss Federal Nuclear Safety Inspectorate, Switzerland
- IRSN: Institut de Radioprotection et de Sûreté Nucléaire, France
- JAEA: Japan Atomic Energy Agency, Japan
- KAERI: Korean Atomic Energy Research Institute, Republic of Korea
- RWM: Radioactive Waste Management, UK
- NRC: Nuclear Regulatory Commission, USA
- SURAO: Radioactive Waste Repository Authority, Czech Republic
- UFZ: Helmholtz Centre for Environmental Research, Germany

Indication of ongoing impact

I have been selected by the extended DECOVALEX team to co-lead one of the next DECOVALEX tasks 2020 – 2023. This will include managing the modelling efforts and output of ten International modelling teams from nine countries including Canada, China, Czech Republic, Germany, Korea, Sweden, Thailand, the UK and the USA. Additionally the upcoming DECOVALEX project team will

include experimental results from the GREAT cell at UoE, described separately below. This represents world wide exposure of the experimental and modelling capabilities at the University of Edinburgh within both the Rad Waste Industry and the Rad Waste Regulatory authorities, and will include multiple international conference presentations. The UK Rad Waste regulatory authority has issued (November 2019) a call RWM242 for participation in DECOVALEX tasks, and includes the GREAT cell results in building modelling capability for coupled processes in crystalline rocks. This represents significant national and international acceptance and exposure.

Additionally the ongoing relationship with Quintessa has led to further knowledge exchange through Quintessa currently sponsoring a CASE PhD at UoE facilitating geothermal energy extraction and storage using legacy coal mine workings. Quintessa are also participating in the industry advisory board of the Hydrogen Storage project, and participated in the H2020 advisory board for FracRisk.

2. West Lothian Council and British Geological Survey

I2008 – 2012 I worked closely with BGS & West Lothian Council as first supervisor a PhD student on the Almondvale catchment, with the theme Sustainable Environmental Management of Groundwater Resources in Industrialised Areas". This led to a joint paper 32, and eventually to the student, Simon Haunch, being employed by SEPA. Simon is still employed at SEPA, and contributes to UoE teaching by presenting a lecture every year as part of the Hydrogeology course. In addition on going collaboration has led to SEPA being involved within the FracRisk project, and SEPA actively supporting ongoing geothermal projects (Edinburgh GeoBattery initiative).

3. CO2Multistore

https://www.sccs.org.uk/expertise/reports/co2multistore-joint-industry-project

The aim of this project was to facilitate the storage of CO2 in deep aquifers by multiple users. The project involved collaboration between British Geological Survey, an industrial partnership, regulatory bodies and academia for CO2 injection in multiple sites. Partners involved include (2012-2015)

- The Scottish Government
- The Crown Estate
- Shell UK
- Scottish Enterprise
- Vattenfall
- Scottish Carbon Capture and Storage.

The key knowledge exchange contributed to the project by myself was developing a new method of exporting geomechanical information and simulation results in the form of a surrogate model for the use of the industrial software package Eclipse. This was used by the consortium to ensure that the multiphase fluid flow simulations predicting the pressure distribution due to different CO2 injection scenarios did not cause geomechanical failure of the system.

The CO2MultiStore work had and continues to have a high impact for the planning for implementation of CCS in Scotland and the UK. The combination of geological modelling, CO2 injection simulation and geomechanical stability modelling increased confidence in the capacity of the Captain Sandstone, storing at more than one site in the 'fairway'. The results were used to inform selection of one of five sites selected for further investigation, by industry, in the ETI-funded Strategic

Storage Appraisal project. The findings from CO_2Multistore modelling are included in the appraisal of the Captain X site in the S-SAP project summary report. The work is discussed in detailed in the full Storage Development Plan for Captain X, with particular comparison to CO_2MultiStore in Appendix 11. The work in the Strategic Storage Appraisal Project became the underpinning work for the subsequent Acorn full-chain CCS project which now holds an EU permit for storage in the Captain Sandstone. CO2MultiStore project findings remain highly regarded and the findings referred to in discussions with industry.

Furthermore the project led to a well cited high quality paper (No. 41) describing the surrogate modelling approach where I am first author, and myself holding a presentation in the house of Lords, September 15th 2015.

4. International Collaborative Project GREAT cell, 2012-ongoing

The remit of the GREAT cell project was to design and build a working mark I version of this unique experimental kit in Scotland, and then "knowledge exchange" the construction and know how of how to build and operate the cell with the University of Goettingen. The project originated due to my long standing cooperation with Prof. Dr. M. Sauter from the University of Goettingen. I proposed the original idea in ~2000. At least three funding applications to different organisations failed from 2000 to 2008. However the University of Goettingen agreed to partially fund the project (£300k) with Heriot Watt University (£200k) and the University of Edinburgh (£400k) from ~2012.
Impact: The knowledge exchange to Goettingen has resulted in a further €2.3M being obtained by Goettingen to build the mark II version, currently under construction.

In terms of impact, the GREAT cell had contributed to ~£9.2M industry, EU and research council funding, of which £2.4M can be shown to be direct value to UoE. The project has received multiple international invitations to present, and published its first ~4* paper recently (No. 58) for REF2021 in Scientific Reports, a nature journal. A second paper is currently in submission. Additionally the GREAT cell is forming the basis for very significant wider international cooperation within the DECOVALEX 2023 project, with ten national radioactive waste regulators/science bodies confirming their participation in a task using experimental data from the GREAT cell. This includes Germany (BfE, BGR), Chinese Academy of Sciences (CAS), Canada (CNSC), USA (DOE), Korea (KAERI), UK (RWM), Czech Republic (SURAO), Sweden (SSM) and Thailand (Taipower). This will involve a number of international presentations over the next 4 years Finally, but also significantly the GREAT cell formed a decisive building block of the on going prosperity bid partnership with Strathclyde University and Weir Group PLC.

5. Geomechanical and chemical investigation of hydrocarbon production in carbonates, (2015-2019) Industry sponsorship from Petrobras, British Gas and Shell

As part of the wider ICCR2 project, this work included multi-scale experimental research and numerical modelling of the flow and coupled process behaviour of carbonate rocks on highly sensitive commercial data/samples. The work supported a PDRA, a PhD and technical staff. Multiple seminars were held with commercial partners participating. In terms of knowledge exchange I wrote a project specific industry training program for Petrobras, delivered 2016, pp150, by PDRA Andrew Fraser Harris, and not myself due to health reasons at the time.

6. NEW-ICCARE, SPONSORSHIP FROM TOTAL, NEW-ISOTOPE COUPLING & CLASSICAL TOOLS: APPLICATIONS TO RESERVOIR AND EXPLORATION ISSUES, 1 X PHD POSITION, KNOWLEDGE EXCHANGE OF MODELLING CAPABILITY. (2015 – 2019)

As part of this project, I developed a new modelling tool used by the PhD student on the project to investigate the diffusion profiles of noble gasses in the subsurface. The led to a new means to determine static reservoir connectivity using a combination of noble gas isotope coupling and reactive flow modelling from exploration wells. Both of these outcomes have provided new knowledge to assist Total in the responsible exploitation energy resources from both regions. The PhD student employed on this project, has gone on to be employed full time by Total.

7. UOE PI FOR EPSRC GRANT: EP/S005560/1, PROSPERITY PARTNERSHIP BID, SMART PUMPING FOR SUBSURFACE ENGINEERING, 1.10.2018, LED BY STRATHCLYDE UNIVERSITY, KNOWLEDGE EXCHANGE WITH WIER GROUP PLC (2018-2023)

Embedded PhD student.

My groups contribution in this project is to develop and exchange experimentally won knowledge on the hydraulic stimulation of rocks in the subsurface in order to reduce the environmental footprint of stimulation technology. Step by step we are implementing a new pumping methodology and investigating the rock failure response in combination with acoustic emissions technology in the Applied Geoscience Laboratory and within the GREAT cell. Monthly project meetings including industrial partners take place ensuring good knowledge exchange. The first knowledge exchange workshop with multiple partners regarding this project occurred on the 29th October 2019 in the Grant Institute, UoE.

8. FRACRISK

The aim of FracRisk, a multi-partner international H2020 project which I led, (www.fracrisk.eu) was to develop a knowledge base for understanding, preventing and mitigating the potential impact of the exploration and exploitation through hydraulic fracturing (fracking) of significant shale gas reserves found throughout Europe, and to develop a decision support tool for risk quantification of the environmental impacts of the technology. The focus was using a new surrogate modelling approach to provide key scientific-based practical recommendations aimed at minimising the environmental footprint of shale gas extraction through effective planning and regulation, and also to address public concerns.

Impact: The output of the project so far has been >32 peer reviewed papers, >44 conference presentations, multiple public and outreach activities including an e-forum, a widely disseminated project promotion brochure and a 20 minute u-tube documentary. In addition based on this project I was the organiser of the EU H2020 Dissemination Workshop for all H2020 Fracking Related Research Projects, FracRisk, SHEER, SXT and M4SHALEGAS, Brussels, May 16th 2018.

Research at UoE in this project has resulted in the 4* publication (54) to be submitted to REF2021. Involvement in this project led to my groups ongoing involvement in the EQUIP4RISK project led by the BGS. Additionally a number of key aspects of FracRisk included reviews of legislation in multiple EU countries which were presented to key authorities within Brussels.

9. COLLABORATIVE STUDENTSHIPS

I have involved external organisations in knowledge exchange through collaborative studentships, demonstrated through the fact that I have been/am supervisor for five fully funded industry PhDs and six CASE PhDs

Academic Leadership, Management and Citizenship

14 Academic Leadership and Management experience

Academic Teaching Management

Current Teaching Management

Currently applied for role as Board of Examiners Chair, 2020 ff.
Currently CO for 3 courses, see Teaching
Currently managing the development and application process for a new MSc. in Applied Environmental Hydrogeology at UoE

Previous Teaching Management & Leadership

Exam Regulations Officer (2014 – 2017)
Erasmus Coordinator for Earth Sciences (2008-2013).
Assessment officer Earth Sciences MSc. Cluster (Exam board member, 2009-2012)
1998 – 2002 Responsible for the development of Applied Environmental Geoscience (AEG) MSc. program, Eberhard Karls University Tuebingen and continuation of the MSc. In Tropical Hydrogeology (TropHy). The program I developed was one of the major forerunners of the extensive international Masters courses now offered in Germany and widely seen as such. AEG still exists at Tuebingen and TropHy has had a "re-birth" in Darmstadt. Management of the existing TropHy course and the development of the AEG course lead to me being responsible for

- 60 students from over 40 different countries
- some 500 applications per year and selection.
- 200 different lectures series, tutorials, excursions, block courses, language course lab etc.
- 50 different lecturers, 20 of which were external lecturers.
- Secretarial position, student help and the overall budget.

Academic Research Leadership

- Edinburgh PI for EPSRC Grant: EP/S005560/1, Prosperity Partnership Bid, Smart Pumping for Subsurface Engineering, 1.10.2018 -ongoing
- Edinburgh PI for NERC EQUIP4RISK grant NE/R01809X/1, £339k, 1.9.2018 - ongoing
- Coordinated European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No. 636811, one of the four flag ship EU collaborative Horizon 2020 projects on Fracking, FracRisk. The project comprises 14 partners from 7 EU countries, +USA & Israel, additionally 5 international companies as advisors. Total value, 3M Euro, Value to Edinburgh 0.68M Euro. (1.6.2015 – last admin stages as of 1.9.2018)
- PI for 19 grants listed before, 7 post docs, 18 PhD's and 14 MSc's.

Academic Research Management

Management of multiple UoE senior staff project inputs to EU FP7 grants and H2020 grant.
Management of 7 post docs, 18 PhD's.

Organisation of 7 x International Conferences, and 3 x Workshops

Mustang consortium meeting (~60 delegates), June 2011, Edinburgh
Mustang training workshop (~20 delegates), June 2011, Edinburgh
Panacea consortium meeting (~40 delegates), 2012, June 2012, Edinburgh
Fracrisk kick of meeting and workshop (~40 delegates), June 2015, Edinburgh
FracRisk FEP database workshop (~30 delegates), June 2015, Edinburgh.
Fracrisk consortium meeting. (~30 delegates), April 2016, PennState, USA
Fracrisk consortium meeting. (~30 delegates), September 2016, Milan, Italy
Fracrisk consortium meeting. (~30 delegates), May 2017, Vienna, Austria
Fracrisk consortium meeting. (~30 delegates), November 2017, Barcelona, Spain
Fracrisk consortium meeting. (~30 delegates), May 2018, Brussels, Belgium

Organisation of EU H2020 projects dissemination meeting on Shale Gas, May 2018, Brussels, Belgium

ACADEMIC CITIZENSHIP

Invited national and international proposal reviewer

NERC, Royal Society Open Science, NWO Netherlands, DFG Germany, BMBF Germany, Stanford, USA

Article peer reviewer for

Computers & Chemical Engineering, Chemical Engineering Communications, Environmental Earth Sciences, Geol Soc, Grundwasser, Geotechnique, Geothermics, Hydrogeology Journal, Hydrogeological Science Journal, International Journal of Computer Applications in Chemical Engineering, International Journal of Rock Mechanics and Mining Sciences. Journal of Hydrology, Marine and Petroleum Geology, Theoretical and Applied Fracture Mechanics, Tectonophysics, Transport in Porous Media, Journal of Volcanology Geothermal Research, Water Resources Research + multiple other journals.

15 MEMBERSHIP OF COMMITTEES

NA

16 APPOINTMENTS AS EXTERNAL EXAMINER FOR THE AWARD OF DOCTORAL DEGREES

- PhD examiner for the University of Birmingham, 2019, Modelling, characterisation and optimisation of deep geothermal energy in the Cheshire Basin
- PhD examiner for Durham University, 2019, Numerical simulation of ground surface subsidence due to coal-bed methane extraction.
- PhD examiner for Glasgow University, 2018, Deep geothermal potential in Indonesia, including high enthalpy and hot dry rock systems.
- PhD at Helmholtz Centre Geo Forschungs Zentrum Potsdam & University of Potsdam, Andreas Reinicke 2010. Mechanical and Hydraulic Aspects of Rock-Proppant Systems : Laboratory Experiments and Modelling Approaches., Deutsches GeoForschungsZentrum GFZ, 140.
- PhD at Helmholtz Centre Geo Forschungs Zentrum Potsdam & Technisches Universitaet Berlin, Guido Bloecher, G. 2008: Pore space reconstruction of porous media - Coupling of microstructure, rock mechanics and flow properties depending on effective pressure. Technische Universität, 95.

17 Editorships

- Editorial Board Member for Scientific Reports, a Nature Research journal since 2018.
- Associate Editor Hydrogeology Journal, one of the premier journals for hydrogeology world wide,, since February 2015
- Associate Editor Journal of Geothermal Energy, since ~2012
- Previous editorial member of Grundwasser, ~2009-2012

18 Consultancies

Provided consultancy support for

- The Scottish Government
- The Crown Estate
- Shell UK
- Scottish Enterprise
- Vattenfall
- British Geological Survey
- BGR: Federal Institute for Geosciences and Natural Resources, Germany
- Quintessa Ltd
- AECOM Ltd.
- RWM: Radioactive Waste Management, UK
- Oil and Gas Innovation Centre.

External Recognitions / Esteem

19 Memberships of societies where academic distinction is the criterion for membership

Member of the Open GeoSys steering committee, Helmholtz Centre for Environmental Research , Leipzig, olaf.kolditz@ufz.de

20 National and International Invitations

High Impact Policy Related Invitations

- UoE/School of Geosciences representative for visit of President, Vice President and Director of the State Parliament of Lower Saxony, January 2019.
- Invited speaker House of Lords, Secure containment of CO2 at two injection sites: Coupled flow and geomechanical analysis of CO2 injection, CO2MultiStore, 15th September 2015
- Invited speaker, Shale Gas in a Low Carbon Europe: the role of research, 23 February 2015, Brussels, hosted by the European Commission.
- Invited speaker, Technical Workshop organised by the International Energy Agency Gas & Oil Technologies Initiative, GOT in cooperation with the European Commission, Addressing Environmental Risks associated with Shale Gas and Oil through Worldwide R & D, Brussels, 27 & 28th October, 2015
- Invited speaker with Prime Minister of Lower Saxony, Launching Joint International Theme GeoReservoirs, 2012

EXTERNAL PROJECT REVIEWER INVITATIONS

- External project reviewer for the German research Foundation (DFG) “"Coupled thermo-hydro-mechanical-chemical (THMC) processes in swelling clay-sulfate rocks", August 2019.
- External project reviewer for the German Federal Ministry of Education and Research (BMBF). “Aus- und Wechselwirkungen von reaktiven mehrphasigen Transportprozessen auf Speicherkapazität, Injektivität und geomechanische Integrität – Prozessverständnis, Umweltauswirkungen und Monitoringansätze”, November 28-30th 2018, Berlin.
- External project reviewer NWO Domain Science, DeepNL, Netherlands, July 2018
- External project reviewer for the German Federal Ministry of Education and Research (BMBF). “Aus- und Wechselwirkungen von reaktiven mehrphasigen Transportprozessen auf Speicherkapazität, Injektivität und geomechanische Integrität – Prozessverständnis, Umweltauswirkungen und Monitoringansätze”, June 2016 3 days, November 2016 2 days.

INVITED TALKS//CONFERENCE PRESENTATIONS

- Invited Speaker, University of Nottingham, EU H2020 project SECURE, March 2019.
- Invited speaker, University of Tuebingen, Germany, August 2018
- Organiser of EU H2020 Dissemination Workshop for H2020 Fracking Related Research Projects, FracRisk, SHEER, SXT and M4SHALEGAS, Brussels, May 16th 2018
- Invited speaker, Shale World UK, ILEC Conference centre, London, May 2017
- Invitation Presentations for the Conference on TransAtlantic Knowledge Sharing on Unconventional Hydrocarbons: Resources, Risks, Impact and Research Needs, Netherlands, June 2017.
- Invited speaker, Shale World UK, ILEC Conference centre, London, May 2016
- Invited speaker, Shale World UK, ILEC Conference centre, London, May 2016
- Invited speaker to Unconventional Hydrocarbon Extraction, Meeting organized by the European Commission, Brussels February 23, 2016.
- Invited talk, “De-risking the use of Geo-reservoirs applying coupled modelling approaches. Examples from CO2 Sequestration, Fracking and Radwaste Storage Applications, ”Eberhard Karls University Tuebingen, 19.11.2015
- Invited speaker to Focused Topic Meeting SETAC (Soc. Envir. Chem. And Toxicology) North America: Environmental Quality Implications of Unconventional and Conventional Natural Gas Development, 17 to 19 March, 2016, in Texas, USA. Declined due to clash with planned EU project meeting.
- Invited speaker, Sino-German Geothermal Workshop, Sustainable Utilization of Geothermal Energy in China and Germany, 25-29.10.2015, Beijing. (Declined due to talk clash immediately below).
- Invited to represent School of Geoscience, UoE at Goettingen University, September 2015.
- Invited speaker, Paris, 2014 Brainstorming session, 5 FP7 EU Projects.
- Invited speaker, key note talk, EnvirVis, 2nd Workshop on Visualization in Environmental Sciences, Swansea 2014.
- Invited speaker, Trondheim 2013 Brainstorming session, 5 FP7 EU Projects.
- UFZ Leipzig, Germany, 19th June 2013, Hydro informatics group
- EU FP7 project PANACEA, Paris, September 2013, WP2 presentation and coordination.

- UFZ Leipzig, Germany, Presentation : GeoReservoir Experimental Analogue Technology, OGS developer community, October 2012
- Invited speaker UK SCCS networking conference, Leeds 2010.
- Invited speaker EGU 2009
- Invited speaker Central Scotland Regional Group Of The Geological Society 2009
- Invited speaker to Geo-processes proposal, Universitaet Tuebingen, 2008.
- Invited speaker to Groundwater commission, Germany, 2006.
- Invited speaker to Freiburg University, Geomechanical Facies, 2006.
- Invited speaker to GFZ Potsdam, Geothermal Department, 2005 & 2006.
- Invited member of the steering committee for the development group "OpenGeoSys" Umweltforshungszentrum Leipzig.

21 OTHER RELEVANT INFORMATION

Special circumstances to be taken into account: Interdisciplinary research area, Geosciences & Engineering
Note http://www.docs.csg.ed.ac.uk/HumanResources/Interdisciplinary_Jul15.pdf
A large proportion of my work is published in applied geoscience and engineering related literature where citation rates are lower than natural science journals. Additionally 9 years of my working life was in roles where there was no focus on academic publications (1989 – 1994 UK Industry, 1998 – 2002 international MSc. development and management).

B List of Publications

Peer Review Citations

Citations metrics as of November 2019, h index 15, ~1400 citations, google scholar.

Summary of publications

13 published book contributions.
60 Articles published in peer reviewed journals.
40+ Conference contributions
28 Public reports
15 Commercial in confidence reports.

1a. Books Published

NA

1b. Book sections

13. Gouze, P., K. Edlmann, C. I. McDermott and L. Luquot (2017). Laboratory Experiments. Geological Storage of CO2 in Deep Saline Formations, Springer: 249-307.
12. Niemi, A., Z. Yang, J. Carrera, H. Power, C. I. McDermott, D. Rebscher, J. L. Wolf, F. May, B. Figueiredo and V. Vilarrasa (2017). Mathematical Modeling: Approaches for Model Solution. Geological Storage of CO2 in Deep Saline Formations, Springer: 129-185.
11. McDermott, C. I., J. M. Miocic, K. Edlmann and S. M. Gilfillan (2017). Natural Analogue Studies. Geological Storage of CO2 in Deep Saline Formations, Springer: 473-520.
10. Le Guen, Y., S. Dias, O. Poupard, K. Edlmann and C. I. McDermott (2017). Risk Management for CO 2 Geological Storage Projects. Geological Storage of CO2 in Deep Saline Formations, Springer: 521-541.
9. Niemi, A., Edlmann, K., Carrera, J., Juhlin, C., Tatomir, A., Ghergut, I., Sauter, M., Bensabat, J., Fagerlund, F., Cornet, F., Vilarrasa, V. & McDermott, C. 2017 Geological Storage of CO2 in Deep Saline Formations. Springer Netherlands, p. 309-380, Site Characterization
8. McDermott C.I. 2012 in Kolditz, O. and Shao, H. eds. Contribution to OpenGeoSys Developer Benchmark Book, (~6 pages) UFZ Publisher, pp361.
7. O. Kolditz, M.G. Bloecher, C. Clauser, H.-J. Diersch, T. Kohl, M. Kuehn, C.I. McDermott, W. Wang, N. Watanabe, G. Zimmermann, (2010) Geothermal Reservoir Simulation, pp245 - 301, in Huenges. E. ed. Geothermal Energy Systems, pp463, ISBN 978-3-527-40831-3
6. Garitte, B., Gens, A., Liu, Q., Liu, X., Millard, A., Bond, A., McDermott, C., Fujita, T. & Nakama, S. 2010 Modelling benchmark of a laboratory drying test in Opalinus Clay, Rock Mechanics In Civil And Environmental Engineering. Zhao, J., Labiouse, V., Dudt, J. P. & Mathier, J. F. (eds.). Boca Raton: CRC Press-Taylor & Francis Group, p. 767-770 4 p.
5. McDermott, C. I., Leven, C., Sinclair, B., Sauter, M. and Dietrich, P. (2005) Preparation of fractured porous bench scale samples for conducting flow and transport experiments. In Eds: P. Dietrich, R. Helmig, M. Sauter, H. Hötzl, J. Köngeter and G. Teutsch. Flow and transport in fractured porous media. Springer: 103-126.
4. McDermott, C. I., Liedl, R., Sauter, M. and Teutsch, G. (2005) The multi-shell model - a conceptual model approach. In Eds: P. Dietrich, R. Helmig, M. Sauter, H. Hötzl, J. Köngeter and G. Teutsch. Flow and transport in fractured porous media. Springer: 306-321.

3. McDermott, C. I., Sauter, M., Liedl, R. and Teutsch, G. (2005) Flow and transport experiments conducted on laboratory cylinders. In Eds: P. Dietrich, R. Helmig, M. Sauter, H. Hötzl, J. Köngeter and G. Teutsch. Flow and transport in fractured porous media. Springer: 127-142.

2. Kolditz, O., Bauer, S., Beinhorn, M., de Jonge, J., Kalbacher, T., McDermott, C., Wang, W., Xie, M., Kaiser, R. and Kohlmeier, M., 2003. ROCKFLOW-Theory and Users Manual, Release 3.9, Groundwater Group. Center for Applied Geosciences, University of Tübingen, and Institute of Fluid Mechanics, University of Hannover.

1. Kolditz, O., de Jonge, J., Beinhorn, M., Xie, M., Kalbacher, T., Wang, W., Bauer, S., McDermott, C., Chen, C. and Beyer, C., 2003. GeoSys-Theory and users manual, release 3.9. 11. GeoHydrology/HydroInformatics. Center for Applied Geoscience, University of Tübingen: 1-67.

2. Books Edited

NA

3. Articles published as sole author

NA, my work is always in collaboration with someone

4a. Joint articles published

KEY

*most significant contributions to knowledge

[1] Name : First author, main contributor to paper, developed concept and IP of project

[2] Name :as above, but corresponding author, PhD student given first authorship. Without my technical and writing contribution work and IP publication would not have been possible.

[3] Name : A main technical contributor to paper.

[4] Name : Project PI, significant contribution to IP

Name : PhD student first author

Name : Contributor to paper

60. *Todd, F.*, McDermott, C., Harris, A. F., Bond, A., & Gilfillan, S. (2019). Coupled hydraulic and mechanical model of surface uplift due to mine water rebound: implications for mine water heating and cooling schemes. Scottish Journal of Geology, sjg2018-2028. doi:10.1144/sjg2018-028

59. *Mouli-Castillo, Julien,* Mark Wilkinson, Dimitri Mignard, Christopher McDermott, R. Stuart Haszeldine, and Zoe K. Shipton. (2019). 'Inter-seasonal compressed-air energy storage using saline aquifers', Nature Energy, 4: 131-39.

*58. C. I. McDermott[1], A. Fraser-Harris, M. Sauter, G. D. Couples, K. Edlmann, O. Kolditz, A. Lightbody, J. Somerville, W. Wang "New Experimental Equipment Recreating Geo-Reservoir Conditions in Large, Fractured, Porous Samples to Investigate Coupled Thermal, Hydraulic and Polyaxial Stress Processes." Scientific Reports 8(1): 14549.

57. Tatomir, A., C. McDermott[3], J. Bensabat, H. Class, K. Edlmann, R. Taherdangkoo and M. Sauter (2018). "Conceptual model development using a generic Features, Events, and Processes (FEP) database for assessing the potential impact of hydraulic fracturing on groundwater aquifers." Advances in Geosciences 45: 185-192.

56. Edlmann, K. Hinchliffe, S., N. Heinemann, G. Johnson, J. Ennis-King and C. McDermott[4] (2018). "Cyclic CO2–H2O injection and residual trapping: implications for CO2 injection efficiency and storage security."
55. *Comerford, A*., A. Fraser-Harris, G. Johnson and C. McDermott[4] (2018). "Controls on geothermal heat recovery from a hot sedimentary aquifer in Guardbridge, Scotland: Field measurements, modelling and long term sustainability." Geothermics 76: 125-140.
54. *O'Donnell, M*., S. Gilfillan, K. Edlmann and C. McDermott[4] (2018). "Wastewater from hydraulic fracturing in the UK: assessing the viability and cost of management." Environmental Science: Water Research & Technology 4(2): 325-335.
53. *Kilgallon, R.* S.M.V. Gilfillan, K. Edlmann, C.I. McDermott[4], M. Naylor, R.S. Haszeldine. 2017. Experimental determination of noble gases and SF6, as tracers of CO2 flow through porous sandstone. Chemical Geology. https://doi.org/10.1016/j.chemgeo.2017.09.022
52. Bond, A. E., Bruský, I., Cao, T., Chittenden, N., Fedors, R., Feng, X., Gwo, J., Kolditz, O., Lang, P., McDermott, C. [3], Neretnieks, I., Pan, P., Šembera, J., Shao, H., Watanabe, N., Yasuhara, H. & Zheng, H. 1 Jan 2017 A synthesis of approaches for modelling coupled thermal–hydraulic–mechanical–chemical processes in a single novaculite fracture experiment, Environmental Earth Sciences. 76, 1
51. Millard A., Mokni N., Barnichon J.D., Thatcher K.E., Bond A.E., Fraser Harris A.P., McDermott C.I., Blaheta R., Michalec Z., Hasal M., Nguyen S., Nasir O., Fedors R., Yi H., Kolditz O., 2016. Comparative modelling approaches of hydro-mechanical processes in sealing experiments at the Tournemire URL. Environmental Earth Sciences. 76(2)
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4B JOINT ARTICLES SELECTED CONFERENCES

42. Fraser Harris A.P., McDermott C.I., Couples G., Edlmann K., Lightbody A., Fazio M., Sauter M., 2019. Experimental Investigation of Hydraulic Fracturing and Stress Sensitivity of Fracture Permeability under Changing True-triaxial Conditions (poster) at EGU

41. *Miocic, J.*, S. Gilfillan, A. Schröder-Ritzau, N. Burnside, S. Haszeldine and C. McDermott (2018). Does CO2 leakage through faults make geological storage unviable?--Lessons from a natural analogue of a failed storage site. EGU General Assembly Conference Abstracts.

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31. Fraser Harris A.P., McDermott C.I., Brondolo F.. A novel methodology for the numerical modelling of extremely heterogeneous porous limestones. ICCR sponsors conference (2017)
30. Gary Couples, Chris McDermott, Darrell Kosakewich, Ian Phillips, Near-Well Fracturing Stimulations by Thermal Methods, Geothermal Cross Over Technology Workshop, Durham/ UK – April 25-26, 2017
29. *Mouli-Castillo J*., M. Wilkinson, C. McDermott, R.S. Haszeldine, Z. Shipton, D. Mignard. Unlocking Energy Storage with compressed air energy storage in porous rocks. ETP 5th Annual Conference. Thursday 3rd November 2016. King's College Conference Centre, University of Aberdeen.
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26. *Fraser Harris A.P.*, McDermott C.I., Bond A., Thatcher K., Norris S. 2015. A non-linear elastic approach to modelling the hydro-mechanical behaviour of bentonite (poster) at EUROCLAY 2015
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Environmental Simulation Benchmarking Workshop IV (SeS Bench IV) , Château de Cadarache, France

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10. Krug, S., Wang, W., McDermott, C.I., Shao, H., Kolditz, O., 2009, TIMODAZ conference 2009: impact of thermo-hydro-mechanical-chemical (THMC) processes on the safety of underground radioactive waste repositories, Validation of THM and THC simulation results for long-term predictions in a crystalline rock repository.
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7A. JOINT ARTICLES SUBMITTED UNDER CONSIDERATION

E. V. Hipkins, R. S. Haszeldine2, C. I. McDermott2, (submitted to Nature Energy) Comparing the hydrogeological prospectivity of deep radioactive waste disposal settings

A. P. Fraser-Harris, C. I. McDermott, G.D. Couples, K. Edlmann, A. Lightbody, M. Fazio, and M. Sauter (about to resubmit to Journal of Geophysical Research - Solid Earth) Experimental Investigation of Hydraulic Fracturing and Stress Sensitivity of Fracture Permeability under Changing True-triaxial Conditions

Scott, JA, Pujol, MHC, McDermott, C and Gilfillan, SMV, In review, 'Using noble gases to resolve the lateral connectivity of the Tormore field' Chemical Geology.

Florent Brondolo, Christopher Ian McDermott*, Andrew Fraser-Harris, Katriona Edlmann, Ian Butler, Gary Douglas Couples, (about to be submitted to Earth and Planetary Science Letters) Experimental investigation and modelling of coupled geomechanical- and chemical-driven dynamic permeability changes in carbonate rocks.

7B Book sections under consideration

NA

Peer reviewed journals articles in preparation

C.I.McDermott, K. Edlmann (In prep for Journal of Petroleum Engineering) A hybrid numerical analytical approach to hydro-fracturing applied to strata bound fracturing in sedimentary sequences

K. Edlmann, G, Couples and C. McDermott. (In prep for Environmental Earth Sciences) Assessing global shale gas potential and environmental impact using the geomechanical facies methodology – for Environmental Earth Sciences

Florent Brondolo, Christopher Ian McDermott*, Andrew Fraser-Harris, Katriona Edlmann, Ian Butler, Gary David Couples, Experimental investigation and modelling of geomechanical and chemical driven dynamic permeability changes in carbonate rocks. Preparation for Submission to Earth and Planetary Science Letters

8. Other Output Research reports

29. FILM https://www.youtube.com/watch?v=apq0MvV0P9Y&feature=youtu.be, Overall PI & Coordinator of project.
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19. Alexandru Tatomir, Martin Sauter, Mashia Foghi, Reza Taherdangkoo, Jacob Bensabat, Hagit Wiener, Christopher McDermott, Katriona Edlmann, Dennis Gläser, Holger Class, Rainer Helmig, Bruno Figueiredo, Maryeh Hedayati, Auli Niemi, Chin-Fu Tsang, Linda Luquot, Jesus Carrera, Ulrich Maier (2016) D3.2 Characterisation of key risk scenarios, https://www.fracrisk.eu/sites/default/files/FracRisk_deliverable_D32.pdf, pp97

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1993 M^{c}Dermott as author, Ratcliffe-On-Soar Power Station Gypsum Solution Cavities Site Investigation Report, Comercial Report for Powergen PLC., Report No. BJM/CS/B8AQ/052, Project Manager B.J. Messenger, prepared by Rendel Palmer and Tritton South West Civil and Structural Department. 55 pages.

1993 M^{c}Dermott as principal team member, The Occurrence and Significance of Erosion, Deposition and Flooding, Report on problems to land use and development, Report for the Department of the Environment, No. R/H848/1, by Rendel Geotechnics, 201 pages.

1993 M^{c}Dermott as author, Geotechnical Interpretive Report on Ground Investigation at Burniston Barracks Scarborough, North Yorkshire, Commercial Report A/S6AN by Rendel Geotechnics, 22 pages.

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1993 M^{c}Dermott as principal team member, Photo Geomorphological Survey, Scotland-Northern Ireland Pipeline Route, Twynholm to North Cairn & Island Magee, Commercial Report for British Gas No R/H867/1 by Rendel Geotechnics, 48 pages.

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1992 M^{c}Dermott as author, Fenton and Moor Street Foul and Storm Water Sewers, Ground Investigation, Commercial Report No. R/H844/01 for Dudley Metropolitan Borough Council, by Rendel Geotechnics. 144 pages.

1992 M^{c}Dermott as author, Isle of Wight Mineral Workings Data Bank, User Guide and Data Bank Lisiting, Comercial Report for the Planning Unit, Isle of Wight County Council, by Rendel Geotechnics. 74 pages.

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1992 M^{c}Dermott as contributory team member, Potters Lane Subsidiary Site, Ground Investigation, Commercial Report No. R/H843/01 for Black Country Development Corporation by Rendel Geotechnics. 108 pages.

1992 M^{c}Dermott as author, Ground Investigation "The Shire Business Park, Worcester Plot 16, Report prepared by Rendel Geotechnics for Rendel Palmer and Tritton, Report No. R/D/100/01, 54 pages.

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M^{c}Dermott, C.I., (1989): "The Permeability and structural Responses of Common Clay Minerals to Phosphate and Nitrate Anionic Exchange." Unpublished Dissertation of the University of Durham, England. Supervisor Prof. P. Attewell & Dr. A. Selby, 136 pages. (M.Sc.)

M^{c}Dermott, C.I., (1988): "The Geology of the Langdales, Northwest England", Unpublished Dissertation of the University of Durham, England. (B.Sc. Hons)

RESEARCH STAFF CONTRIBUTING TO ED-GEOBATTERY

JOANNA BERRY (JB), UNIVERSITY OF DURHAM

Roles:
Key contribution to WP6 Social and Economic Legacy and Future Sustainability, overseeing Tasks 6.5: Surface heat usage mapping and 6.6: local business regeneration.
Key contribution to WP7 Economic and Business Models for Long Term Success.
PhD supervision

Joanna Berry's professional experience runs from her Oxford University law degree in 1985. Her professional and academic interests are underpinned by significant and long-term exposure to new developments in online media and digital technologies, leaving her fascinated by the interfaces between business, science/creativity and technology. Her MBA focussed on broadband distribution and her PhD analysed the music industry's increasingly technologically-mediated business models and value chains.

Joanna's experience is underpinned by a deep and broad range of regional, national and international corporate and public sector contacts, which she builds into her day to day activities in HE and external relations. Pedagogical writing is informed by her practice in flipped classrooms, blended and online learning and Problem Based Learning. Teaching includes traditional classroom-based, as well as online masters and MBA modules, interdisciplinary Summer Schools, and international executive education, largely focussing on MBA and MSc students and first year undergraduate mixed cohorts. She covers a wide variety of innovation, entrepreneurship and digital subjects, encompassing leadership, strategy and SME agendas. She places a particular emphasis on supporting women in business, and the 'women in STEM' agenda, in a variety of practical ways including mentoring, and relevant event hosting, both within and outside the University. In June 2019 she won the Award for Enhanced Learning and Teaching (Digital and Online Learning) from the Durham Centre for Academic Development. She also won the Forward Ladies 2019 Regional Awards for Scotland, Yorkshire and the Northeast in November 2019, in the Academia/Public Sector Leader category and is nominated for membership of the Northern Power Women 'Power List 2020'.

She has undertaken a wide variety of public and media activities, on behalf of the School, and through her roles as Regional Chair for the Chartered Institute of Marketing and Regional Chair for the IoD. She is a regular commentator on TV, radio and in press, and is a Director of Acumen Community Buildings (focussing on community businesses and social enterprises). Joanna is also an Advisory Board member for the NorthEast LEP "ScaleUp NorthEast" programme (where she advises companies across the NorthEast LEP geography and in most industrial sectors, to help them scale and succeed).

Born and brought up in Hartlepool, Joanna is delighted to be a co-Director for the DEI and hopes to contribute her energy, enthusiasm and ability to connect across boundaries to Durham's important, timely, world-class interdisciplinary Energy Institute.

DR. KATRIONA EDLMANN (KE), THE UNIVERSITY OF EDINBURGH

Roles:

Co-lead of project with 5% time per year for 10 years

Key contribution to WP2 Environmental and Geoscience Site Characterisation, overseeing Task 2.2: Geomechanical facies description.

Lead of WP3 The Dynamic System

Key contribution to WP10 heat Storage Facility and Field Demonstrator Site, overseeing Task 10.6: Monitoring of the GeoBattery during operation.

Lead of WP12 Dissemination

Assist PhD & PDRA supervision

Co-I Dr Katriona Edlmann is The Chancellor's Fellow in Energy at the UoE, with a background in reservoir geology and fluid flow. She has co-established the Applied Geoscience Laboratory at the UoE, a state of the art multiphase and reactive transport coupled process flow laboratory, which will host a significant share of the research proposed. The laboratory produces internationally leading research into multiphysics and multiscale fluid flow where experimental results are integrated with field data and benchmark numerical modelling to help to meet the world's energy and environmental challenges. Recent PhD students are working on water quality associated with hydraulic fracturing, coupled rock physics and geochemistry in carbonates, CO_2 / caprock interactions and noble gasses as tracers. Of particular relevance to this proposal is the recent development of unique reactive experiments to determine the composition of produced water quality associated with hydraulic fracturing to investigate how the inherent properties of shales and formation fluids influence the anions, cations, metals, NORMS, CO_2, H_2S and hydrocarbon within the well clean-up, fracturing, flowback and production fluids generated during fracturing operations. This research informs the UK produced water wastewater management strategy, has led to a 4* peer reviewed paper and direct links with Cuadrilla, Scottish Water and the Environmental Agency. Also relevant is her unique multi-scale experimental and numerical investigations combined with machine learning to determine the key chemical and stress driven controls on dissolution and precipitation in carbonate rocks during brine flow.

Total grant income directly associated with her research and experimental capability is valued at over £3.8M to the UoE. She has an h-index of 10 (09.01.2020; google scholar) from +40 published works. Three recently co-authored papers have had a significant media impact. "Assessing the Viability and Costs of Managing Wastewater from Hydraulic Fracturing" was picked up by 78 news outlets, "Estimating geological CO2 storage security to deliver on climate mitigation" was picked up by 12 news outlets and "Controls on CO2 storage security in natural reservoirs and implications for CO2 storage site selection" was picked up by 7 news outlets. Socioeconomic impact and knowledge exchange is vital to the work undertaken by Dr Edlmann. She recently co-organised with Chris McDermott a meeting at Scotland House, Brussels to promulgate the FracRisk project findings and best practise guidelines to a number of members the EU commission including those from the DG of research, energy and environment. Her recent Alcalde et al. CO2 security paper was used as background material / cited in the JP Morgan Asset Management energy paper on energy and climate 2019. https://www.jpmorgan.com/directdoc/MountainsAndMolehills.pdf and her O'Donnell et al. wastewater paper cited by UK Parliament Briefing notes Future of the UK oil and gas industry on 05 Oct 2018.

DR. ANDREW FRASER-HARRIS (AFH), THE UNIVERSITY OF EDINBURGH

Roles:
Key contribution to WP4 Thermal Resource Assessment and Sustainable Management
Key contribution to WP11 GIST GeoBattery Evolving Complex Software Development
Assist PhD & PDRA supervision

Researcher-I Dr. Andrew Fraser-Harris is an early career researcher at the University of Edinburgh using experimental and numerical modelling techniques to investigate geoenergy applications. He has a background in geology with a particular interest in trying to understand the coupled processes that occur in the subsurface during the transport of fluid and heat. Andrew's research has included numerical modelling of geothermal systems such as Enhanced Geothermal Systems, hot sedimentary aquifers, and minewater geothermal, as well as the coupled processes associated with radioactive waste storage, both on the regional and near-field scales. He is currently involved in Equipt4Risk, a NERC funded project to develop integrated risk assessments for shale gas development in the UK, and his main role is the software development that will enable the integration of multiple modelling outputs from each work package to calculate a spatial and temporal evolution of risk. This is to ensure effective management of a potential resource as it evolves through each stage of design and implementation.

Andrew is currently co-supervisor for two PhD students developing models for minewater geothermal resource estimation and geomechanical stability of pillar-and-stall mine workings. He has directly contributed to successful funding applications totalling approximately £1M and has been involved in international consortia collaborations within EU Horizon2020, DECOVALEX, and the International Centre for Carbonate Research (ICCR) projects, fostering multiple links within industry.

DR. STUART GILFILLAN (SG), THE UNIVERSITY OF EDINBURGH

Roles:

Key contribution to WP2 Environmental and Geoscience Site Characterisation, overseeing Task 2.4 baseline ground gas characterisation.

Lead of WP5 New Technologies for Integrated Monitoring

Key contribution to WP10 heat Storage Facility and Field Demonstrator Site, overseeing Task 10.6: Monitoring of the GeoBattery during operation.

Key contribution to WP11 GIST GeoBattery Evolving Complex Software Development, overseeing Task 11.4: Integration of monitoring data.

Assist PhD & PDRA supervision

Co-I Dr. Stuart Gilfillan is a Senior Lecturer in Geochemistry in the School of GeoSciences at the University of Edinburgh. Educated in Earth Science at the University of Glasgow (BSc) and Geology at the University of Manchester (PhD) his early research focused on understanding how carbon dioxide has been naturally stored in the subsurface. Following his PhD he moved to Edinburgh in 2006, where he has developed means of fingerprinting carbon dioxide in order to track its movement and means of storage in subsurface reservoirs, as part of efforts to develop carbon capture and storage technologies. More recently, he has been applying this knowledge to the environmental monitoring of unconventional gas extraction, geothermal energy production and understanding the connectivity of hydrocarbon reservoirs. He has a keen interest in all areas of utilising the subsurface for energy production or storage and is the Deputy Programme Director for the GeoEnergy MSc course at The University of Edinburgh.

The total grant income directly associated with his research is valued at over £3.45M with £2.30M to Edinburgh. He has authored or co-authored 41 published works, which have received 1263 citations, resulting in a h-index of 17, and i10-index of 21 according Google Scholar (December 2019). He had his work reported extensively reported in both national (including The Independent, The Daily Telegraph, BBC News) and international media (including Nature news, New Scientist and Science Magazine). He has also acted as an expert reviewer for proposals submitted to the Leverhulme Trust and the American Chemical Society along with scientific journals including Chemical Geology, G-cubed, Journal of Quaternary Science, Geology, International Journal of Greenhouse Gas Control and Geochimica et Cosmochimica Acta. He has been involved with the supervision of 16 PhD students to date, including 7 which were CASE supported and one solely industry funded. He has acted as an external examiner to both PhD and MRes students at Durham University.

PROF. JOHN GLUYAS (JG), UNIVERSITY OF DURHAM

Roles:

Key contribution to WP6 Social and Economic Legacy and Future Sustainability, overseeing Tasks 6.5: Surface heat usage mapping and 6.6: local business regeneration.

Lead WP7 Economic and Business Models for Long Term Success

PhD supervision

Co-I Jon Gluyas is a geoscientist with 28 years' experience in industry and 10 years' experience in academia. He is currently the Director of Durham Energy Institute at Durham University. His main research interests are in geothermal energy, helium exploration, human induced earthquakes and CCS. Jon founded BritGeothermal, a nationwide research collective with the aim of developing widespread geothermal energy for heat in the UK so improving UK energy security and reducing greenhouse gas emissions by displacing fossil fuels. Jon also led the research that delivered the first new helium province in a century and the only one found while looking for helium rather than hydrocarbon gases. Once developed the Tanzanian discovery will help alleviate the current global helium shortage. He has served as chairman of the UK CCS Research Centre development board, as Chairman of the British Geological Survey and President of both the Earth Science Teachers Association and the Petroleum Exploration Society of Great Britain.

Jon launched his first company Acorn Oil and Gas in 2001 and a second Fairfield Energy in 2005. The latter was launched with £300 million of equity and £1.2 billion of debt funding. More recently in 2010 Jon founded university spin-out GeoEnergy Durham and several other university spin-outs including in 2019 Geoptic, a company based upon technology he helped develop for monitoring CO2 in the subsurface and which has found application in ensuring the UK's Victorian railway infrastructure remains safe. Jon has published widely including Petroleum geoscience a best-selling textbook as well as having had papers published in Nature, Geochimica et Cosmochimica and a wealth of other high-ranking journals. He is frequently invited to give keynote addresses on his research and has addressed UK parliament as well as political party conferences on low-carbon sustainable energy provision for the UK.

PROF. STUART HASZELDINE (SH), THE UNIVERSITY OF EDINBURGH

Roles:

Co-lead project, 2% time per year for 10 years

Co-I Stuart Haszeldine has worked on coal, oil and gas deposits, with a wide interest in fossil fuels, radioactive waste disposal and environmental impact. He is Professor of Carbon Capture and Storage at the University of Edinburgh, and his current research examines geological storage of CO2, in the context of climate change and changing energy use. This has rapidly developed as a topic of great scientific and political impact. He was first leader for Carbon Management in the UK Energy Research Centre www.ukerc.ac.uk . He currently leads the UK's largest university research group for CO2 storage and capture (at Edinburgh, five Scottish Universities and British Geological Survey at Edinburgh) www.geos.ed.ac.uk/sccs/ and is co-leader of the academic UK Carbon Capture and Storage Research Centre https://ukccsrc.ac.uk. In 1999 he was awarded the Saltire Society and Royal Society of Edinburgh Science Prize for his work on radioactive waste disposal and hydrocarbon geology. In 2003 he was elected Fellow of the Royal Society of Edinburgh. In 2011 he was awarded the global William Smith Medal of the Geological Society for global excellence in Applied Geology. In 2012 he was appointed OBE for services to climate change technologies. In 2015 he was the only academic writing the influential Oxburgh report on CCS, which led to the CCS Cost Reduction Task Force from BEIS, evolving into the 50-strong industry "CAG - CCS Advisory Group) which is creating three waves of ISCF funding, totalling over £700M of Government funding. In 2016 he was invited to the EPSRC Science Advisory Committee. In 2018 he was appointed UK Government Advisory Council on CCS, reporting to the Energy Minister. Recent research includes analysis of geological factors controlling natural containment or leakage of CO2; the first systemic global analysis of CO2 storage security, and pre-commercial appraisal of candidate CO2 storage sites for Acorn project to service decarbonisation of the UK's first industrial cluster

Research grant funding since 2016 - approximately £2.9M to UoE, from £15M. Lifetime funding to UoE about £20M and he has 214 peer reviewed academic publications, plus presentations and briefing reports, with an H index of 44 and i10 of 127. Since 2015 Haszeldine has expanded the subsurface research remit to investigate diverse types of CO2 storage to enable Net Zero emissions by 2050. He has also investigated CO2 storage in geothermal systems mineralising basalt on Iceland (CarbFix). He has investigated inter-seasonal energy storage - innovated and directed high-level appraisal of CAES compressed air storage, and Hydrogen storage in depleted gas reservoirs and saline formations onshore and offshore the UK. Hydrogen work has created industry interest - leading to the first Academic Alliance with Scottish Gas Networks (SGN), evaluating regulation, safety and networks. Interseasonal storage of H2 is being investigated for the first time by EPSRC HySTorPor project. This will support the world's first deployment of 100% hydrogen to domestic customers around 2021 and the first injection of hydrogen to the UK national gas grid around 2024. That is planned to link with Acorn CCS to remove carbon from methane, and send to offshore storage

Impact is systematically communicated to publics, policy advisers, industry end users by policy working papers, academic publications and augmented by regular media engagement on UK radio, TV, broadsheet news, global science, media and professional associations websites.

DR. IAN MOLNAR (IM), THE UNIVERSITY OF EDINBURGH

Roles:
Lead WP2 Environmental and Geoscience Site Characterisation
Key contribution to WP4 Thermal Resource Assessment and Suitable Management, overseeing Task 4.6: Heat transport model.
Key contribution to WP5 New Technologies for Integrated Monitoring, overseeing Task 5.6: Tracer technology
Key contribution to WP10 heat Storage Facility and Field Demonstrator Site, overseeing Task 10.6: Monitoring of the GeoBattery during operation.
Key contribution to WP11 GIST GeoBattery Evolving Complex Software Development, overseeing Task 11.4: Integration of monitoring data.
Assist PhD & PDRA supervision

Co-I Dr. Ian L. Molnar is an early career researcher (4 years post-PhD), a lecturer in hydrogeology at the University of Edinburgh (UoE), and an adjunct assistant professor at York University in Canada. Ian is highly qualified to lead WP2 and be a key contributor to WP5 and WP10 as he has significant expertise utilizing numerical and experimental techniques to characterise subsurface/groundwater processes with a specialty in coupled heat and mass (both aqueous species and multiphase) transport processes. Specific projects have included multiphase flow at contaminated brownfield sites, fate and transport of nanotechnology in groundwater, thermal remediation of contaminated brownfield sites, and transport of corrosive chemicals at deep geologic repositories for nuclear waste storage. These qualifications are demonstrated by publication track record; in the last 8 years he has published 8 first-author peer reviewed publications directly related to groundwater heat and mass transport with a total of 180 citations (as per Google Scholar). He also has qualifications in Civil and Environmental Engineering (BESc, MESc, PhD, NSERC PDF) and has lectured on topics such as Applied Hydrogeology, Environmental Design for Waste Disposal, and Numerical Modelling of Environmental Processes in both Canada and UK.

Ian has a track record of developing and applying innovative experimental techniques to characterise groundwater transport processes (e.g., Molnar et al. 2014), and developing numerical models to explore coupled heat and mass transport in multiphase groundwater systems (Molnar et al 2019). He has demonstrated international leadership on these topics as well by developing and leading international collaborations on multiple projects (Molnar et al. 2014, 2015a, 2015b, 2016, 2019). In addition, he is currently serving on the American Geophysical Union's (AGU) Vadose Zone technical committee, has co-chaired the 14th International Environmental Specialty Conference at the 2016 Canadian Society for Civil Engineering Annual Conference, as well as convened a session at the 2016 AGU Fall Meeting on "Microorganisms, Colloids, Engineered Nanoparticles, and Emerging Contaminants in the Environment". Ian is currently co-supervising 1 PhD student on modelling coupled heat-mass-groundwater transport behaviour at deep geologic repositories, and has supervised 3 undergraduate summer students on similar topics.

PROF. JOHN MONCRIEFF (JM), THE UNIVERSITY OF EDINBURGH

Roles:

Key contribution to WP5 New Technologies for Integrated Monitoring, overseeing Task 5.1: Air borne Methane / CO2 monitoring

Assist MSc supervision

Co-I John Moncrieff has been Professor in Micrometeorology in the School of GeoSciences since 2006. His research and teaching interests are in land-atmosphere interactions and in particular the exchange of radiatively-active trace gases between the land surface and the surface boundary layer. Since his initial appointment as lecturer in 1985 he has obtained 35 research grants to a value exceeding £5 million since then as PI. He has published over 90 papers in the fields of micrometeorology, environmental physics and modelling. In the context of this application, his interests are complementary given he is an expert in the high-quality measurement of various greenhouse gases in field experiments.

In 1996 he established our long-term (17+ years) study site on forest micrometeorology at Griffin Forest examining heat, mass and moisture exchange between the surface and atmosphere. In 2006 he also established the UK's first 'Tall Tower' near Dundee to observe various Greenhouse Gases (GHG) to very high levels of precision and accuracy and to relate their measured concentrations to sources/sinks in the landscape. In that same year he initiated our Airborne GeoSciences unit with the purchase and development of a small research aircraft. We are now a NERC Recognised Facility with the added capability of a fleet of unmanned aerial vehicles used for hyper- and multi-spectral imaging. His most recent activity (since 2012) has been developing our Differential Absorption LiDAR (DIAL) to give range-resolved concentrations of various GHGs (initially CO2 and CH4). This project aims to develop a field-portable LiDAR which could be used to observe fugitive emissions of GHGs from various sources such as landfill, permafrost and old mine workings.

PROF. BRYNE NGWENYA (BN), THE UNIVERSITY OF EDINBURGH

Roles:

Key contribution to WP3 The Dynamic System, overseeing Task 3.3: Biological Changes due to Temperature Alterations.

Professional career:	2018: Professor of Microbial Geochemistry, University of Edinburgh:
	2010: Reader in Microbial Geochemistry, University of Edinburgh.
	2006: Senior Lecturer, University of Edinburgh.
	1996: Lecturer in Aqueous Geochemistry, University of Edinburgh.
	1990: Post-Doctoral Research Associate, University of Edinburgh
Tertiary Education:	1987: BSc. (Hons.) Geochemistry, Reading University:
	1992: PhD in Geochemistry, Reading University (ORS Award)

Major Research Grants (2006-2019)

- 2018-2020 Community Based Aquaculture as a Catalyst for Locally Managed Marine Areas, Madagascar. €250,000, €50,000. With Meriwether Wilson (PI), Sandy Tudhope and Sebastian Hennige.
- 2013-2014 Understanding genesis of HREE deposits through eXperimental and spectroscopic methods coupled with atomistic Simulations. £95629, NERC SoS Minerals Program Catalyst grant, with Simon Harley, Linda Kirstein (Edinburgh), Ian Butler (Edinburgh), Geoffrey Bromiley (Edinburgh), Kate Saunders (Edinburgh), Rachel Walcott (Nat. Museums Scot.), Andrew Walker (Leeds) and J Frederick Mosselmans (Diamond Light Source)
- 2009-2012. Biobased geological CO2 Storage (CO2SOLSTOCK). EC FP7 Collaborative Project, with Ian Butler, Stephen Elphick, Rachel Wood and Stuart Haszeldine, Lead PI and Consortium Co-ordinator. €2.96 of which €853,000 to Edinburgh.
- 2008-2012. Towards improved groundwater vulnerability assessment (IMVUL). EU Marie Curie Initial Training Network, with Stephen Elphick and Ian Butler, €3.2M of which €405,000 to Edinburgh.
- 2006-2008. Macroscopic and molecular characterisation of lanthanide sorption to bacterial cells: A potential chemical biosignature. NERC Grant #NE/C519462/1, Lead PI, in collaboration with Prof. Fred Mosselmans, Diamond Ltd, R81522, £97,583. Associated with this project were 4 successful beamtime applications at Daresbury.

Relevant publications

1. Martin, D., Dodds, K., Butler, I.B., Ngwenya, B.T.(2013). Carbonate precipitation under pressure for bioengineering in the anaerobic subsurface via denitrification. Environ. Sci. Technol., 47, 8692–8699.
2. Kurlanda-Witek, H., Ngwenya, B.T., Butler, I.B.(2015). The influence of biofilms on the mobility of bare and capped zinc oxide nanoparticles in saturated sand and glass beads. J. Contam. Hydrol., 179, 160-170.
3. Yang, S., Ngwenya, B.T., Butler, I.B., Kurlanda, H. and Elphick, S.C. (2013). Coupled interactions between metals and bacterial biofilms in porous media: implications for biofilm stability, fluid flow and metal transport. Chem. Geol. 337-338, 20-29.

4. Joshi, N., Ngwenya, B.T. and French, C.E. (2012). Enhanced resistance to nanoparticle toxicity is conferred by overproduction of extracellular polymeric substances. J. Hazard. Mater., 241–242, 363-370.
5. Kurlanda-Witek, H., Ngwenya, B.T., Butler, I.B.(2014). Transport of bare and capped zinc oxide nanoparticles is dependent on porous media composition. J. Contam. Hydrol., 162-163, 17-26.
6. Ngwenya, B.T., Curry, P. and Kapetas, L. (2015). Transport and viability of Escherichia coli cells in clean and iron oxide coated sand following coating with silver nanoparticles. J. Contam. Hydrol., 179, 35-46.
7. Joshi, N., Ngwenya, B.T., Butler, I.B. and French, C.E. (2015). Use of bioreporters and deletion mutants reveals ionic silver and ROS to be equally important in silver nanotoxicity. J. Hazard. Mater., 287, 51-58.
8. Kapetas, L., Ngwenya, B.T., MacDonald, A.M. and Elphick, S.C. (2012). Thermodynamic and kinetic controls on co-transport of Pantoea agglomerans cells and Zn through clean and iron oxide coated sand columns. Environ. Sci. Technol. 46, 13193-13201.
9. Adele, N.C., Ngwenya, B.T., Heal, K.V., Mosselmans, J.F.W. (2018). Soil bacteria override speciation effects on zinc phytotoxicity in zinc-contaminated soils. Environ. Sci. & Technol., 52, 3412–3421.
10. Tourney, J. and Ngwenya, B.T. (2009). Bacterial exopolymeric substances (EPS) mediate CaCO3 morphology and polymorphism. Chem. Geol., 262(3-4), 138-146.

Other selected recent publications (2009-2019)
11. Liang, L., Ngwenya, B.T. (2018). Metal internalisation by bacterial cells depends on metal biotoxicity and metal to biomass ratio. Chemosphere,, 212, 585-593
12. Adediran, G.A., Ngwenya, B.T., Mosselmans, J.F.W., Heal, K.V. (2016). Bacteria-zinc co-localisation implicates enhanced synthesis of cysteine-rich peptides in zinc detoxification when Brassica juncea is inoculated with Rhizobium leguminosarum. New Phytologist., 209, 280-293.
13. Adediran, G.A., Ngwenya, B.T., Mosselmans, J.F.W., Heal, K.V., Harvie, B.A. (2015). Mechanisms behind bacteria induced plant growth promotion and Zn accumulation in Brassica juncea. J. Hazard. Mater. 283, 490-499.

Research staff supervision as PI (2006-2017)
- 2013-2014: Dr. Sami Mikhail (UK), Post-doctoral Research Associate, Critical Metals Catalyst grant.
- 2009-2012: Dr. Derek Martin (UK): Post-doctoral Research Associate, FP7 CO2SOLSTOCK Project.
- 2009-2011: Dr. Suyin Yang (China/Poland): Post-doctoral Research Associate, Marie Curie ITN IMVUL Project.
- 2009-2012: Dr. Hanna Kurlanda (Poland), Marie Curie ITN Early Stage Researcher (PhD).
- 2009-2012: Mr. Kevin Dodds (UK): Experimental Officer, FP7 CO2SOLSTOCK Project.
- 2009-2010: Dr. Muhua Feng (academic visitor), Associate Professor, Nanjing Institute of Geography & Limnology.
- 2006-2008: Dr. Marisa Magennis (UK), Research Associate, NERC Lanthanide Project.

Postgraduate students as Primary Supervisor (2006-2019, 4 current second supervisor)

- 2013-2016: Mr. Matthew Holloway (NERC): Models for hydrothermal REE mineralisation in carbonate-bearing systems.
- 2011-2014: Ms Adele Nyekachi (Nigerian Government). Role of metal speciation and plant growth-promoting bacteria in phytoremediation of zinc-contaminated soils.
- 2011-2014: Mr. Gbotemi Adediran (Principal's Scholarship): The role of plant growth promoting bacteria in metal sequestration from metal contaminated environments.
- 2009-2012: Dr. Hanna Kurlanda (Marie Curie ITN Early Stage Researcher): Microbial controls on fluid flow and contaminant speciation in dual porosity media.
- 2009-2012: Dr Nimisha Joshi (ORS/School studentship): Bactericidal mechanisms of nanoparticles and microbial defence strategies.
- 2006-2010: Dr. Leon Kapetas (Greek Scholarship Foundation): Microbial controls on contaminant metal transport in porous media.

External examiner of 9 PhD theses, including TU Delft and University of Toronto.

Professional duties
- 2018: present Council Trustee of the Geological Society of London
- 2017- present: Convenor, Environment Network, Geological Society of London.
- 2017- present: Member of peer-review panel, Diamond Light Source Ltd.
- 2009-present : Associate Editor, Applied Geochemistry
- 2008- present: Editorial Board, Chemical Geology

MS. MYLENE RECEVEUR (MR), THE UNIVERSITY OF EDINBURGH

Roles:

Key contribution to WP3 The Dynamic System, in particular Task 2.5 Initial Heat Distribution in the GeoBattery

Mylene Receveur is a first year PhD student at the University of Edinburgh (School of Geosciences), undertaking research studies within the Edinburgh Earth, Ecology and Environment Doctoral Training Partnership (E4 DTP). Her PhD project, aims to advance understanding of the temperature distribution and the geothermal potential of abandoned flooded coal mines in the UK, and is fully-funded by NERC and the Coal Authority as a CASE sponsor. She obtained a Master's degree in Geology specialized in petroleum geology in 2017. In 2018, completed a Research Master in Geothermal Sciences at the University of Iceland. Mylene's research assesed the sub-surface processes responsible for the ground subsidence observed at the Reykjanes high-temperature geothermal field, Iceland, using InSAR analysis of Sentinel-1 satellite images. The methods and results have been published in "Receveur, M., Sigmundsson, F., Drouin, V., Parks, M, 2019. Ground deformation due to steam cap processes at Reykjanes, SW-Iceland: Effects of geothermal exploitation inferred from interferometric analysis of Sentinel-1 images 2015-2017. In Geophys. J. Int , Vol 216 (3), 2183-2212". In addition to her academic studies, Mylene realised in 2015 a 4-month placement as a hydrogeologist in the Geothermal Department of the BRGM (French GeoSurvey). In 2019, Mylene obtained a 3-month position as a geothermal reservoir engineer, during which she had the opportunity to work on several projects related to the low-temperature geothermal resources in the Paris Basin, both looking at the scientific (i.e.thermo-hydrological numerical modelling of geothermal doublets) and technical aspects. Those included the study of the evolution of the share of geothermal in French district heat networks, and the assessment of the conversion potential of old oil and gas wells into geothermal wells.

Through these experiences, Mylene has developed a strong interest in using her scientific knowledge in geology, geophysics and hydrogeology to better understand geothermal resources and the sustainability of geothermal utilisation. Flooded coal mine workings represent enhanced permeability geothermal reservoirs able to provide access locally to a low-carbon energy source for domestic heating/cooling. It is however essential to better characterise this low-temperature resource to ensure sustainable heat production from minewater. Using numerical modelling, her PhD work will consist in assessing the nature and the extent of the heat available over the long-term in coal mine workings, and get improved knowledge of the rate and mechanisms of heat recharge around production/injection wells. Not only could mine workings be used as an energy source, but also as a storage system where diverse energy sources could contribute to its heat recharge to form a balanced heat system. The main objective is therefore to develop a conceptual or numerical tool allowing predicting the minewater temperature over the long-term, which would support the dimensioning of energy projects at a global scale.

MS. FIONA TODD (FT), THE UNIVERSITY OF EDINBURGH

Roles:

Key contribution to WP3 The Dynamic System, in particular Task 3.4 Rock Mechanical Stress Impacts of Cyclical Heat Storage: Rock Weakening.

Fiona Todd is a third year PhD student researching the geomechanical risks of mine water heat schemes. She is modelling the impacts of groundwater alterations and thermal stress on the geomechanical stability of shallow legacy mine workings. Initial findings from her research project have been published in a peer reviewed journal. Her PhD is funded through the E3 NERC DTP and via a CASE sponsorship. She has disseminated her research at several conferences to a variety of audiences and has recently been asked to present at an upcoming Mine Water Geothermal Energy Symposium being organised by the International Energy Agency. This symposium will cover current research and policy issues in mine water heating and cooling with speakers from throughout Europe. She was awarded the prize for best MSc dissertation for research into modelling sub-surface heat flow and presented this work at an international conference.

Prior to undertaking her PhD she worked as a hydrogeologist at several environmental consultancy firms and also at the Coal Authority. The Coal Authority are a non-departmental government body with the responsibility for legacy issues around abandoned coal and metal mines. Her experience and knowledge working in the industry will be invaluable to ensure the project considers the wide variety of factors and stakeholders necessary. Fiona gained chartered geologist (CGeol) status in 2015.

DR. DAN VAN DER HORST (DVDH), THE UNIVERSITY OF EDINBURGH

Roles:

Lead WP6 Social and Economic Legacy and Future Sustainability.

Key contribution to WP8 Regulations, Planning and Permitting, overseeing Task 8.4: GeoHeat Battery current status in devolved UK legislation, Task 8.5: Road map emplacing district heat at outline planning stage and Task 8.6: Policy and legal recommendations to facilitate similar low carbon developments.

PhD and PDRA supervision

Dan van der Horst is a Reader in Energy, Environment & Society. He has a background in environmental modeling, ecological economics and environmental social science. Dan's trans-disciplinary research is problem-oriented and user-facing, examining how natural science and data science may be adopted and translated into effective (local, national or international) policies, how it can improve environmental management, stimulate (clean) business innovation, address inequalities and help to co-produce wider societal benefits. Dan have co-authored >75 articles in peer reviewed journals and won 23 grants >£5k (£2.6M as PI). From 2013 till 2018 he led a national research & practitioners network on smart energy metering and indoor environmental sensors (see www.teddinet.org). He currently holds NERC, EPSRC and ESRC grants (as Edinburgh PI) on local climate governance, focused especially on exposure to urban air pollution and the need for new, affordable and low carbon housing developments.

His research concerns the dilemmas of managing multi-functional but scarce resources in crowded and contested spaces with technologies that (unfortunately) are never 100% fit for purpose. The environmental challenges facing the world in the 21st century require us to think outside and across disciplinary boxes, and think beyond the binary distinctions of humans and nature, technology and ecology. His work concerns both socio-ecological and socio-technical systems and is focused on understanding trade-offs and synergies – many of which are context specific. As an environmental social scientist, Dan seek's to find insights from combining different disciplinary perspectives and to translate 'actionable' knowledge between scientists, policy makers and civil society, examining how measures of technical feasibility and economic efficiency can be combined to deliver environmental (i.e. social) goods and services in a (more) fair and equitable manner.

In recent years Dan launched a novel and successful MSc programme ("Energy, Society & Sustainability") which trains students in the above issues, and developed a research portfolio (> £1.5m) on urban climate governance (Scotland, UK and China). Thematically, this includes 'smart' energy use, design of healthy & affordable low carbon homes and neighbourhoods and urban and regional air pollution management.

External Research Funding [only listing grants >£100k] (Co-I = co-investigator; PI = principal investigator)

2007-2009 Insights from pioneers in renewable energy (INSPIRE) PI (£200k, ESRC).

2010-2012 Seanergy 2020; best practice in marine spatial planning for renewables. Co-I (€350k, IEE).

2011-2013 Knowledge systems & pro-poor management of ecosystem services. Co-I (£250k, NERC).

2012-2017 Smarter Households PI (£250k, EPSRC).

2013-2017 Transforming Energy Demand in Buildings through Digital Innovation. PI (£700k, EPSRC)

2014-2018 Renewable energy and landscape quality ("RELY") UK & WP leader (€350k, EU COST).

2015-2017 ICF forest projects; developing a KPI on valuing ecosystem services PI (£100k, DFID).

2015-2018 Renewable energy & adaptive governance in rural policy" PI (£120k, Czech Council of Research).

2016-2017 Assessment of biomass energy technologies for development in Africa. Co-I (£200k, DFID)

2017-2020 Forest 2020; Political economy of forest monitoring & protection Co-I (£1m, UK Space Agency).

2018-2022 UK Centre for Research on Energy Demand (UKCREDS), Edinburgh PI (£370k, EPSRC)

2019-2022 People-centric air pollution modelling (APEX). Edinburgh PI (£140k, NERC)

2019-2021 Translational Services – models for climate & air pollution. Co-I (£400k, Met Office/BEIS)

2019-2024 Place-based Climate Action Networks (PCAN). Edinburgh PI (£500k, ESRC)

Example Publications (total publications=90; Scopus h-index=23; total Scopus citations=1800 [Nov. 2019])

Van Veelen B. and van der Horst D. (2018). What is Energy Democracy? Connecting social science energy research and political theory. Energy Research and Social Sciences 46, 19-28.

Van der Horst D. and Staddon S. (2018). Types of learning identified in reflective energy diaries of post-graduate students. Energy Efficiency 11, 1783-1995.

Frantal B., van der Horst D., et al. (2018). Spatial targeting, synergies and scale: Exploring the criteria of smart practices for siting renewable energy projects. Energy Policy 120, 85-93.

Van der Horst D. (2017). Energy landscapes of less than 2 degrees global warming. In: Calvert K. and Solomon B. (eds.) Handbook on the Geographies of Energy. Edward Elgar.

Van der Horst D., Harrison C., Staddon S. and Wood G. (2016). Improving Energy Literacy through Student-Led Fieldwork - at Home. Journal of Geography in Higher Education 40(1), 67-76.

Bowe C. and van der Horst D. (2015). Positive externalities, knowledge exchange and corporate farm extension services; creating shared value in a water scarce area. Ecosystem Services 15, 1-10.

Van der Horst D. (2014). Climate policy and the siting of renewable energy projects: towards common but differentiated responsibility at the community level. People, Place and Policy 8(3), 222-234.

Van der Horst D., Staddon S. and Webb J. (2014). Smart Energy, and Society? Technology Assessment and Strategic Management 26(10), 1111-1117.

DR. HARRY VAN DER WEIJDE (DVDW), THE UNIVERSITY OF EDINBURGH

Roles:

Key contribution to WP9 Economic and Business Models for Long Term Success, in particular co-supervision of PhD.

Co-I Harry van der Weijde is an interdisciplinary energy economist with over 10 years of experience working at the intersection between economics, operations research and engineering of energy systems. He holds an BA in Liberal Arts & Sciences from the University of Utrecht, an MSc in Economics from the University of Edinburgh and a PhD in Spatial Economics from the Vrije Universiteit Amsterdam and the Tinbergen Institute. He is currently Lecturer and Head of Management Teaching in the School of Engineering at the University of Edinburgh and Turing Fellow at the Alan Turing Institute for Data Science, having previously held positions at the University of Cambridge and the Vrije Universiteit Amsterdam.

Dr van der Weijde has published on the economics of energy systems, including storage, in a wide range of high-impact journals and is principal or co-investigator on more than £30M in research funding, including as co-investigator in the UK National Centre for Energy Systems Integration (EP/P001173/1), as work package leader in the EU-funded Energy Systems in Transition project (EU MSCA 765515) and as co-investigator in the recently completed Realising Energy Storage in Low-Carbon Energy Systems project (EP/N001893/1). He also completed a wide range of private and public sector consulting projects, including advising land owners, energy infrastructure providers and the Scottish Government on energy investments and market modelling. He is Member of the Energy Institute, Fellow of the Higher Education Academy, Associate Researcher of the Energy Policy Research Group at the University of Cambridge and EnCN Fellow at the Energie Campus Nürnberg. He has recently been awarded a Schöller Fellowship by the Theo and Friedl Schöller Foundation and a best paper award from the German Association for Energy Economics (GEE) for his work on energy market modelling.

INDUSTRY PARTNERS AND REGULATORY PARTNERS CONTRIBUTING TO ED-GEOBATTERY

QUINTESSA LTD, DR ALEX BOND

Roles

Ed-GeoBattery Science Industry Regulatory Advisory Board member

Key contribution to WP2 Environmental and Geoscience Site Characterisation, overseeing Task 2.6: Key Environmental Impact Assessment Vectors.

Key contribution to WP4 Thermal Resource Assessment and Sustainable Management, overseeing Task 4.2: Construction of 3D Geometry, Task 4.5: Fluid Flow Model and Task 4.6: Heat Transport Model

A company Virtual Contribution of £40,000

Quintessa Brief description

Quintessa Ltd, which was founded in 1999, has always focused on delivering the highest quality applied science and research, while ensuring that this research addresses the direct needs of the client. Quintessa operates at the interface between academia and industry, facilitating the application of leading-edge knowledge in a timely and cost-effective manner. This close engagement with academia is evidenced by Quintessa employees extensive publication record and continuing support in supervising PhD students.

Quintessa's services cover decision support, geosciences, materials modelling, mathematics, risk assessment and software development together with the provision of customised training in all these areas. Quintessa has particular expertise in addressing complex problems where uncertainty is large and so focuses on geological and sophisticated engineering systems. Quintessa have experts in statistical analysis, detailed coupled process modelling, hydrogeological modelling, high-level 'systems' analysis and decision support, as well as detailed domain knowledge in a wide range of applied sciences. This allows Quintessa employees to generate a holistic and integrated understanding of a given system, with a clear 'real-world' industrial focus.

This expertise has been applied extensively to the nuclear sector, in particular geological disposal of radioactive waste, site decommissioning and maintaining the continued safe operation of the UK AGR nuclear reactor fleet. Quintessa have also been very active in sub-surface CO2 storage, general sub-surface waste disposal, underground gas storage and are currently supporting University of Edinburgh in the HyStorPor project and considering mine workings for heat extraction and storage.

Quintessa's employee-owned structure enables a high degree of organisational permanence that is frequently not seen in other research and consultancy organisations. This organisational structure also supports the free thinking and low employee turn-over required to participate in projects with such long time-scales. Our commitment to training and increasing value to clients through maximising the potential of our employees is evident through Quintessa's Gold 'Investors in People' accreditation. Quintessa Ltd is also ISO9001:2015 (Quality), ISO27001:2013 (Information Security) and CyberEssentials Plus accredited. Associated certificates can be provided on request.

Funding Contribution

Quintessa will match the funding available through this proposal (£40,000, excluding VAT) by supplying the same value of consultant time (using the same day rates) and any travel and

subsistence as the ‘Virtual Contribution’. The same employees will be used for both the funded and ‘Virtual Contribution’. Hence Quintessa will perform a total of £80,000 (excluding VAT) of work under this contract.

CV Dr Alex Bond

Alex Bond is a Chartered Scientist and Geologist with nearly twenty years’ industrial experience of radioactive waste management. Alex trained in Earth Sciences and Hydrogeology (MA, MSc, PhD). Both through his academic training and recent experience, he has developed extensive experience of the characterisation, conceptualisation, numerical modelling and safety assessment of geological and hydrogeological systems.

Alex has a long-standing engagement in the UK radioactive waste management programme. Alex has had significant input to the R&D programme associated with the UK deep disposal programme; heavily involved with the UK’s cutting-edge international research collaboration in coupled thermal-hydraulic-mechanical-chemical analysis and also ‘bigger-picture’ questions such as assessing thermal and gas issues for the UK wastes in the context of the post-closure safety case. Alex has also gained a great deal of international experience, for example supporting the regulator in Sweden and Finland, and working for the potential disposer in Switzerland, France, Canada Japan and Romania. As evidence of Alex’s internationally recognised expertise in complex coupled systems, he is the technical coordinator for the well-respected and long-running DECOVALEX project (www.decovalex.org). Since 2002 until the present day, he has also had a key involvement in the understanding and management of the complex issues associated with the restoration of Sellafield site, including total systems analysis of waste and residual contamination. This expertise has been applied more broadly, not only within the UK but also internationally.

Alex has also been heavily involved in Quintessa's participation in various other complex sub-surface analysis including geological CO2 storage, hazardous waste disposal in salt caverns, underground gas storage and mine-heat storage/extraction. Alex is also a supervisor to a PhD student at University of Edinburgh examining issues around mine-heat storage and extraction.

RSK, ANDREW PICKEN

Roles

Ed-GeoBattery Science Industry Regulatory Advisory Board member

Key contribution to WP2 Environmental and Geoscience Site Characterisation, overseeing Task 2.6: Key Environmental Impact Assessment Vectors.

Key contribution to WP5 New Technologies for Integrated Monitoring, overseeing Task 5.6: Tracer Technology

Lead of WP9 Economic and Business Models for Long Term Success and overseeing Task 9.1: Use of Existing Engineering Technology, Task 9.2: Heat Exchange Technologies in Ferruginous Waters, Task 9.3: Heat Pump Technologies for Community Heat Storage and Extraction, Task 9.4: Retrofit possibilities and Task 9.5: Novel Low Impact Drilling Technologies

A company Virtual Contribution of £45,000

Involvement in SIRAB

RSK Brief Description

Since its establishment in 1989, RSK has grown into a leading integrated environmental, engineering and technical services business with 3,600 staff in UK, Europe, the Middle East and East Africa. We provide end-to-end services to help organisations achieve their aspirations in a sustainable and efficient manner.

RSK strives to be a company of which its staff members are proud to be part. Working across a wide array of sectors, we are committed to supplying high-quality services tailored to the needs of our clients, adhering consistently to our guiding principles and strict health and safety standards.

The services RSK provides include: environmental studies; buildings and structures; design and engineering; rural studies and agriculture; health, safety and risk; laboratory services and digital media and communications.

RSK has in-depth experience in groundwater studies, geotechnical investigation, drilling for ground source and geothermal application, water quality assessment and asset management in the water and waste water sectors. Regular services provided include risk management and mitigation, strategy development, innovation particularly in technology and research and development. RSK provides consultancy related to Groundwater. Services related to groundwater include: Hydrogeological risk management, mitigation and strategic advice related to aquifer protection, water quality and pollution; Hydrology fluvial geomorphology and flooding; Drilling and testing of boreholes for groundwater applications; Long-term monitoring of groundwater and surface water; Technology & innovation principally related principally to water monitoring techniques; Peatland mapping and stability analysis. Unconventional Oil and Gas (onshore): Support with meeting regulatory and planning requirements particularly related to the water environment; Risk management and strategy development particularly for stakeholders, such as water companies, in the exploration and production process.

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Telephone: +44 (0)1786 478 450
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Our Ref: RSK/apg/200210

Date 7th February 2020

Dr. Isabil. C. I. McDermott M.Sc.

Reader Hydrogeology and Coupled Process Modelling

Grant Institute.

The King's Buildings,

James Hutton Road,

Edinburgh

EH9 3FE

Letter of Support: Low Carbon Heat from Urban Multi-user Sustainable GEOthermal BATTERYs (Ed-GeoBattery)

Dear Dr McDermott,

As you know RSK provide management and technical consultancy solutions to the renewable energy, rail and industrial sectors. We believe it is essential to deliver our niche services using specialists with in-depth of experience and innovative skills. We assemble project teams to ensure we can fulfil that belief and provide robust, pioneering solutions that really make a difference. To maintain this market position it is import to RSK to be involved in research projects with leading Universities and research organisations such as University of Edinburgh.

RSK recognises that the UK has large untapped low carbon geothermal resources that could make a significant different to energy security within the UK. We would like to support the development of this industry and therefore support efforts such as the Low Carbon Heat from Urban Multi-user Sustainable GEOthermal BATTERYs (Ed-GeoBattery) for research as a potential major future energy resource.

RSK will participate in the project work-packages as follows:

2.6 Key Environmental Impact Assessment (EIA) Vectors (a contribution to identifying the processes and tasks that will be required and key timelines).

INVESTORS IN PEOPLE

RSK Group Ltd
Registered in England No. 4851246
www.rsk.co.uk

5.6 Tracer Technology (a contribute towards assessing how tracer technology and particularly novel tracer techniques based on DNA, will be able to assist with assessing coal mine connectivity and minewater flow)

Plus RSK will lead on WP9 which includes covering

9.1 Use of Existing Engineering Technology

9.2 Heat Exchange Technologies in Ferruginous Waters

9.3 Heat Pump Technologies for Community Heat Storage and Extraction

9.4 Retrofit possibilities

9.5 Novel Low Impact Drilling Technologies

(RSK has wide drilling experience and capability as well as experience with heat exchange technologies which will help in developing report and desk studies in relation to WP9).

We have agreed that UoP will ring fence a budget of £90k distributed as follows:

- 2021 £10k
- 2022 £30k
- 2023 £30k
- 2024 £20k

and that in return RSK will provide a financial contribution 'in kind' of a further £45k.

We trust that our proposal is acceptable and look forward to hearing from you in due course.

Yours sincerely,

Andrew Picken
Principal Hydrologist

SIMON PARRY, SANDOWN

Roles

Ed-GeoBattery Science Industry Regulatory Advisory Board member

Key contribution to WP8 Regulations, Planning and Permitting, overseeing Task 8.4: GeoHeat Battery current status in devolved UK legislation, Task 8.5: Road map emplacing district heat at outline planning stage and Task 8.6: Policy and legal recommendations to facilitate similar low carbon developments.

Email, 7/02/202

Sandown Limited is private limited company registered in the UK that was founded in June 2015 to provide consulting services in the fields of construction and environmental law, geotechnical engineering, hydrogeology and the geosciences. The staff member from Sandown Ltd working on this project has over twenty-five years of international consulting experience with major design consultancies. Staff scientific and engineering experience includes design, client advice and project management of UK and international projects involving soil and rock mechanics, tunnelling, groundwater modelling, and reservoir engineering, and includes the use of numerous proprietary finite element and finite difference modelling and design codes. Staff at Sandown Ltd also have legal risk management experience including legal interpretation of UK, EU and other jurisdictions legislation; the conducting of commercially sensitive contract analyses, negotiations and dispute resolutions; and legal drafting. Sandown Ltd's knowledge of both the science behind geomechanics as well as the law and its practical application in industry, significantly assists realistic assessment of any new measures that might be proposed for legislative reform as a result of the science findings of this project.

Funding Contribution

Sandown Limited, as a SME, will match 33% of the £30,000 EX VAT funding available through this proposal by supplying this value of consultant time (using the same day rates) and any travel and subsistence as a 'Virtual Contribution'. The same staff member will be used for both the funded and 'Virtual Contribution'. Hence Sandown Limited will perform a total of £40,000 (excluding VAT) of work under this contract.

CV Simon Parry

Simon Parry LLB BSc MSc CEng MICE FGS (male) is a UK Chartered Civil Engineer, who holds degrees in geology and English law as well as a masters in geotechnical engineering. He practices in the disciplines of engineering hazard management, legal risk management, geotechnical engineering and hydrogeology. Has worked as both engineering staff and project management (geotechnical / hydrogeological) within leading international consulting firms out of the UK as well as in Hong Kong and the USA; and in corporate roles within such organisations in the capacity of commercial / contract risk manager.

His academic training and experience have fostered an extensive understanding of the characterisation, conceptualisation, numerical modelling and safety assessment of geological and

hydrogeological systems and the legal implications of promoter/consultant delict/tort negligence and statutory non-compliance in undertaking operations in such systems.

His scientific and engineering experience includes soil and rock mechanics, tunnelling, groundwater modelling, and reservoir engineering, and includes the use of numerous proprietary finite element and finite difference modelling and design codes. His legal risk management experience includes legal interpretation of UK, EU and other jurisdictions legislation; the conducting of commercially sensitive contract analyses, negotiations and dispute resolutions; and legal drafting. His knowledge of both the science behind geomechanics as well as the law and its practical application in industry, significantly assists realistic assessment of any new measures that might be proposed for legislative reform as a result of the science findings of this project.

A GUNNING & ASSOCIATES

Andrew Gunning MSc BSc CGeol FGS CEng MCIWEM.

Andrew Gunning is a Partner in and co-founder of A Gunning & Associates. Andrew is an experienced Company Director and has skills in leadership and innovation alongside commercial and project management expertise which encompass experience with both new company start-ups and large multi-national corporations. He is educated to MSc level in engineering and hydrogeology (Newcastle University), has a Diploma in Company Direction (Institute of Directors) and is a Chartered Engineer and a Chartered Director.

He has broad experience in upstream oil and gas, mining and groundwater. He is actively involved in leading projects that utilize a portfolio of analysis and assessment techniques to deliver risk assessments and strategic reviews to enable organisations to better understanding the future business environment in which they will operate. Andrew's experience includes the design and implementation of geological exploration and groundwater appraisal programs. Project Director for various hydrogeological and geomorphological projects related to construction activities and flood protection involving field studies, long-term monitoring, hydrogeological modelling and risk assessment and mitigation.

Email 10-02-20

Our Ref: apg/Ed Geobattery
Date 10th February 202018
Dr. habil. C. I. McDermott M.Sc.
Reader Hydrogeology and Coupled Process Modelling
Geosciences
University of Edinburgh

Low Carbon Heat from Urban Multi-user Sustainable GEOthermal BATTERYs (Ed-GeoBattery)

Dear Dr McDermott,

A Gunning & Associates provides management and technical consultancy solutions to the energy sector including renewable energy plus the utilities and industrial sectors. We believe it is essential to deliver our niche services using specialists with in-depth of experience and innovative skills. We assemble project teams to ensure we can fulfil that belief and provide robust, pioneering solutions that really make a difference. To maintain this market position it is import that A Gunning & Associates for us to be involved in research projects with leading Universities and research organisations such as University of Edinburgh.

The UK has large geothermal resources that could make a contribution to energy security within the UK. We would like to support the development of this industry and therefore support efforts such as the Low Carbon Heat from Urban Multi-user Sustainable GEOthermal BATTERYs (Ed-GeoBattery) for research as a potential major future energy resource.

We will participate in the project work-packages as follows:

8.1 SEPA Permitting (help facilitate obtaining permits for subsurface testing)

8.2 Coal Authority Permitting (help facilitate relevant permits and data relating to coal workings)

8.3 East Lothian Council (help facilitate contact // planning meetings)

We have agreed that University of Edinburgh will provide a budget of £20k and that A Gunning & Associates will provide a financial contribution ‘in kind’ of a further £10k.
We look forward to hearing from you in due course
Yours sincerely
Andrew Gunning MSc BSc FGS CGeol

VATTENFALL HEAT UK, DR. EOGHAN MAGUIRE, DIRECTOR OF SCOTLAND, AND THE NORTH, HEAD OF BUSINESS DEVELOPMENT

Roles: Ed-GeoBattery Science Industry Regulatory Advisory Board member

Vattenfall is an integrated energy company with the customer at the core of our business. Investing in net zero for a fossil free future. We believe sustainable growth will guide us into the future.

Vattenfall business activities

Power production
Vattenfall produces electricity from many types of energy sources, including hydro, nuclear, coal, natural gas, wind, solar, biomass and waste. We are actively phasing out fossil-based production and investing in a greater share of renewable generation.

Electricity distribution
Being able to guarantee secure supply requires well-functioning distribution networks and development of smart network solutions. Vattenfall enables customers to feed self-generated electricity into the grid, thereby becoming so-called prosumers who both buy and sell electricity. Vattenfall conducts electricity grid operations in Sweden and Germany. Electricity distribution is a regulated monopoly business that is supervised by national grid authorities.

Sales of electricity, heat and gas
Vattenfall sells electricity, heat and gas to consumers and business customers. We focus on optimising the customer experience by offering various price and service models and by giving customers opportunities to reduce their environmental impact.

District heating
Vattenfall is one of Europe's largest producers and distributors of district heating, supplying households and industries in metropolitan areas. In partnership with cities and regions we are driving the transformation towards fossil-free heating solutions, such as by integrating surplus or waste heat from third parties in our district heating networks.

Energy services and decentralised generation
Vattenfall offers energy services, including battery storage, network services, charging solutions for electric vehicles, solar panels, heat pumps and smart meters. We also provide marketplaces and access to marketplaces where customers can buy and sell electricity, as well as solutions for customers to optimise their energy use, and access convenient and smart energy solutions.

THE COAL AUTHORITY, DR. J. CROOKS, DR I. WATSON

Roles: Ed-GeoBattery Science Industry Regulatory Advisory Board member, CASE PhD sponsor Mylene Receveur

Data contribution and BH planning contribution

The Coal Authority

Resolving the impacts of mining

200 Lichfield Lane
Mansfield
Nottinghamshire
NG18 4RG
T: 01623 637307
E: Jeremycrooks@coal.gov.uk
www.gov.uk/coalauthority

Dr. habil. C. I. McDermott
Reader in Hydrogeology and Coupled Process Modelling
Edinburgh University
School of Geosciences
The King's Buildings,
James Hutton Road,
Edinburgh EH9 3FE

7 February 2020

Dear Dr McDermott,

Re: Letter of Support – ED-GeoBattery Project

The Coal Authority manages the United Kingdom's mining legacy on behalf of UK Government. This includes the management of subsidence events; the prevention of pollution from mine water and the licensing of activities that affect the coal reserves, for example, boreholes to pump water for the extraction of heat.

Abandoned coal mines are no longer being viewed by BEIS as a £2.4 billion liability but as an asset of strategic importance to the UK. The vast labyrinth of flooded workings are considered as having significant resilience potential in being developed for water supply, geothermal energy, cooling, energy storage, food production, employment creation and building expertise to export.

We are pleased to offer support for the Ed-GeoBattery project as it has the potential to significantly increase the knowledge base in an area of great interest to the authority and to BEIS.

We will provide the following assistance:

- To be part of the project board attending regular meetings
- To provide technical information related to the associated mine workings
- To provide expert interpretation of the mine workings
- To assist in the location of sites for drilling abstraction, reinjection and monitoring boreholes
- To assist with the design of boreholes, procurement, drilling and pump tests
- To provide technical support in regards analysis of data

Yours faithfully,

Jeremy Crooks
Head of Innovation

5/02/2020
Chris,

Great to hear you are progressing this and we are keen to assist and be involved where we can.

The Coal Authority at the moment is not directly funded for mine energy so we have to secure funding from other pots other than our own, so we cannot contribute monetarily. We would be willing to match fund with our own time and attend meetings. As part of building our knowledge we would make data available at no charge, though we have to pay for this internally so would be a cost my team would absorb. We would be willing to attend meetings at our own cost. You could consider our match funding in time to be circa £40k.

A monitoring borehole suitable for sampling would be circa £250k plus or minus £100k. We have no need for such a borehole in this location so cannot provide funding however we would be willing to carry out target location work and procurement assistance at our own cost which would be circa £30k.

We would also be willing to provide a letter of support to the project and provide input to the text if that is of interest.

If you require more information or would like to discuss further please contact me.

Best regards,

Jez

The Coal Authority

Jeremy Crooks
Head of Innovation
T : 07879 692 066
E : jeremycrooks@coal.gov.uk

SEPA (SCOTTISH ENVIRONMENTAL PROTECTION AGENCY), DR. P. BUTLER

Roles: Ed-GeoBattery Science Industry Regulatory Advisory Board member

7/02/2020
Hello Chris,

I'm happy to confirm that SEPA would be pleased to be part of the Science, Industry, Regulatory Advisory Board (SIRAB) for the Ed-GeoBattery Project.

We can attend board meetings and provide additional advice as needed.

Many thanks

Paul

Paul Butler
Mining and Quarrying Sector Plan Development Lead
Principal Hydrogeologist | Water Resources Unit
Scottish Environment Protection Agency | Strathallan House | Castle Business Park | Stirling | FK9 4TZ
Tel: 01786 452610 or 07900 606645
Usual working days Monday to Thursday

MIDLOTHIAN COUNCIL PROJECT DIRECTOR, RESOURCES, GORDON POLLOCK

Roles

Ed-GeoBattery Science Industry Regulatory Advisory Board member

7/02/2020

Dear Dr McDermott

The Ed-GeoBattery proposal is a very interesting project which I personally believe has broad policy support. You may be aware that Midlothian Council has now declared a climate emergency. This fits well with some of our current interests which include taking heat from the energy from waste plant at Millerhill and providing low carbon heating to the Shawfair town. Additionally we have also been in discussions with the coal authority about the potential for linking in with the Monktonhall colliery and potential opportunities relating to Bilston Glen.

I am happy to provide support to this project in terms of participating in the Science, Industry, Regulatory Advisory Board, which I understand will meet twice a year in the Edinburgh region. I have to just caveat my enthusiasm for the project by confirming that I am not responding on behalf of the Council in its planning authority role.

Gordon Pollock

Gordon Pollock
Project Director
Resources
Midlothian Council
07836 785119

THE UNIVERSITY of EDINBURGH

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Bayes Centre
47 Potterrow
Edinburgh
EH8 9BT United Kingdom

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Fax +44 (0) 131 650 6555

www.epcc.ed.ac.uk

Dr. Christopher McDermott
The University of Edinburgh
School of Geosciences
The King's Buildings,
James Hutton Road,
Edinburgh EH9 3FE

Friday, 24 January 2020

Dear Chris,

Support for RAEng Chair in Emerging Technologies

I am writing to offer EPCC's full support to your proposal to apply to the Royal Academy of Engineering Chair in Emerging Technologies call.

EPCC has been committed to running the Advanced Computing Facility efficiently and minimising energy usage since refurbishing the site in 2004. Since then all National High Performance Computing services have been installed in rooms with cooling designed specifically for them. We have a strong focus on "free cooling" – using the cool climate for 70% of the year to remove heat from our hot water rather than chilling. We also minimise the use of Uninterruptable Power Supplies (saving around a 10% overhead each year).

The next generation of Exascale supercomputers will consume over 30MW of electricity. We are therefore developing novel approaches to cooling and heat reclamation. As a first step, you prepared a report for EPCC in early 2018 considering options for using nearby mine workings to cool our equipment and as a potential heat battery.

Following your report, we are currently funding a £25,000 study to develop a 3D model of the mine workings which we will of course contribute to you. We are also future proofing our Computer Room 4 design to allow access to our hot water for future projects such as you propose. We see the development of your Heat Battery concept as a collaboration between the research you will lead to develop and test the concept and our requirement to develop the infrastructure with Estates Department to cool our systems more efficiently.

In my role as Chair of the UK Government's Exascale Project Working Group, a budget of £3m has been included in the Outline Business Case as a contribution to the total infrastructure costs which would contribute to the experiments you propose in your application. Furthermore, EPCC will contribute £50,000 of access to HPC systems for simulation and modelling required by your project.

PTO

epcc

SUMMARY OF MATCHED FUNDING

University of Edinburgh (School of Geoscience & EPCC)	£1.705M
Quintessa Ltd (Bond)	£40k
RSK (Picken)	£45k
AG Associates (Gunning)	£10k
Sandown (Parry)	£10k
Coal Authority (Crooks)	£70k
University of Durham (Gluyas)	£135k
Total	**£2.015M**

SUMMARY OF START UP COSTS PREDICTED EXPENDITURE

WP2 Environmental Geoscience Characterisation - £20,000

2.2 Baseline aquatic geochemistry multiple sample collection and analysis, £5k

2.3 Diagnostic testing will be undertaken to establish the geochemical and isotopic character of groundwaters associated with the current mine-water collected via the main shaft and known mine-water flows from existing adits. This characterisation will include noble-gas dissolved concentrations and ratios (He, Ne, Ar, 3He/4He, 20Ne/22Ne, 40r/36Ar), 13CCH4 13CCO2 of any dissolved gases present along with 14C, δ13CDIC, δ2HH2O, δ18OH2O of any solutes present. These results will be used to establish potential pollutant characteristics of the mine-waters against local groundwater baselines, and to estimate recharge sources, timing and temperatures of the current mine-waters. Field visits & Sample Evaluation £15k (Includes WP5, 5.2)

WP3 The Dynamic System - £30,000

Experimental investigations make a significant contribution to the GeoBattery project, to understand the chemical and mechanical response of the subsurface to the dynamic thermal and hydrogeological GeoBattery system. UoE requests £30,000 for the geo-chemical and mechanical experiments. This includes £5,000 for 6x bespoke high-pressure batch reaction vessels plus pipework, fittings and valves, £6,500 for a HPLC pump and £6,000 for laboratory consumables. UoE also requests £5,000 for bespoke vessels and consumables to monitor the biological changes with temperature. WP3 experiments will be conducted on site-specific rocks so we request £1000 for sample collection and preparation. WP3 also requires significant analysis so the amount requested also includes £800 for 20 thin sections, £1000 for XRD analysis, £2,000 for X-Ray CT analysis, £1,700 for SEM analysis and £1,000 for ICP fluid analysis.

WP4 Thermal Resource Assessment and Sustainable Management £12,000

4 x high end lap top // work stations with TecPlot graphical presentation software and ArcGIS (2020 x 2, 2024 x 2) £12,000

WP5 New Technologies for Integrated Monitoring £30,000

5.3 Borehole Temperature and Salinity, Field costs, equipment purchase £5k

5.4 Thermal and Flow Rate Monitoring of Springs, Field costs, equipment purchase £5k

5.5 Participatory Monitoring of GW Quality, Equipment costs & thermal camera £5k

5.6 Tracer Technology (DNA tracers, Nanoparticle tracers) £5k

5.7 SMART Community Monitoring Network (Installation of thermal and EC remote sensors at monitoring points) £10k

WP6 Social and Economic Legacy and Future Sustainability £5000

Community outreach events specifically related to social and economic legacy work £5k

WP10 Heat Storage Facility and Field Demonstrator £70,000

Preparatory work for engineered design of heat storage plant £5k

Design and construction of heat pump and 2 x local monitoring boreholes to investigate at a field scale efficiency of subsurface heat recharge technology £25k.

Detailed design, costing and locating of monitoring boreholes, injection boreholes and extraction boreholes £40k

WP 12 Dissemination - £15,000

To ensure good quality engagement of the GeoBattery project with citizens and opinion-shapers we request a total of £15,000 for the social science and public elements of the GeoBattery project, requiring venue hire and catering for stakeholder and citizen events (£8,000) and £3000 for the copywriting, design and printing of promotional and dissemination material. Knowledge exchange and dissemination of research outputs are an essential component of the GeoBattery project and will be achieved through a range of events, resources and techniques. We therefore request £5000 for the GeoBattery project website design and hosting and £4000 for public outreach activities and resources.

Contingency £25,000

Overall total £207k

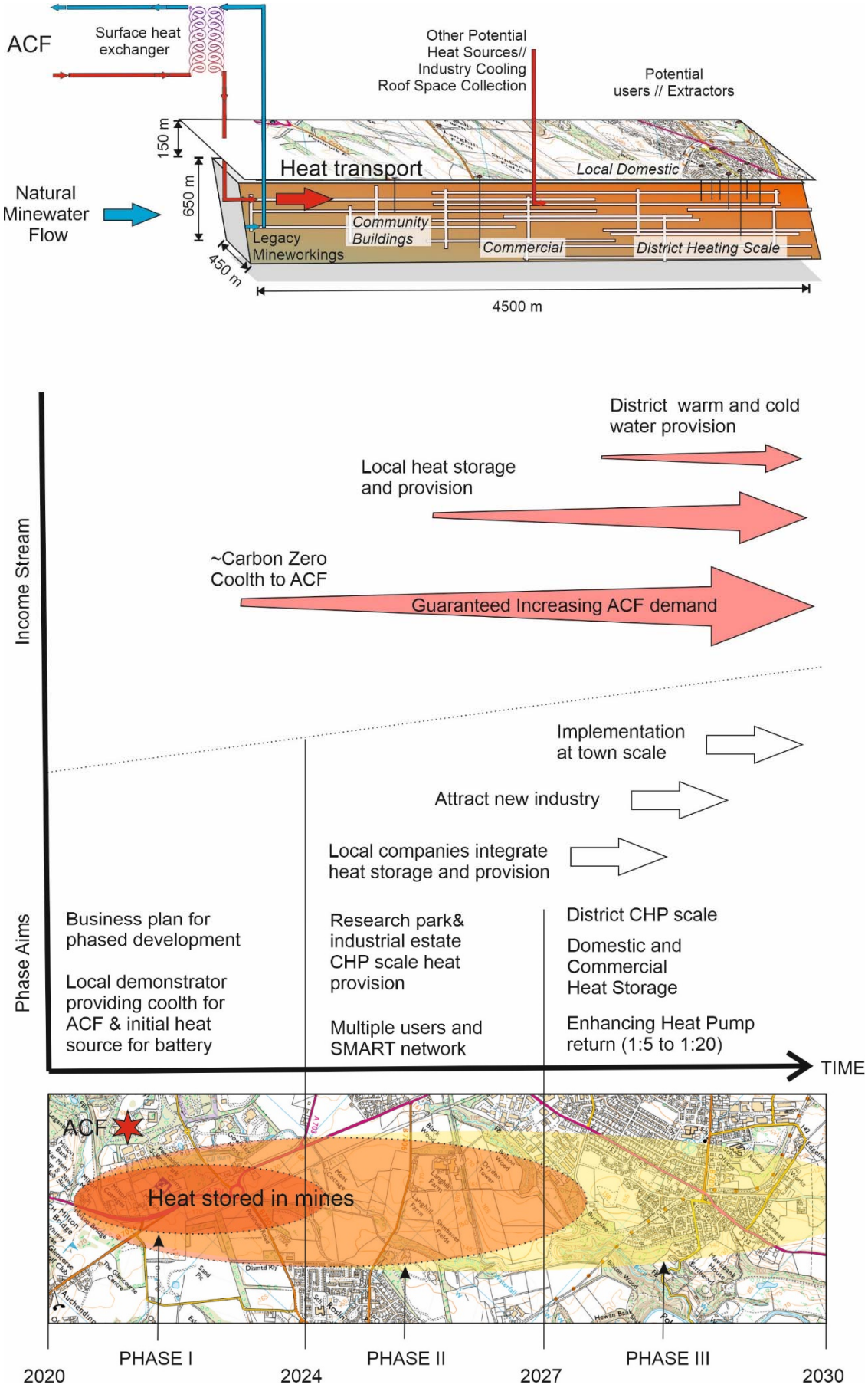


Figure 1 Concept and Phases

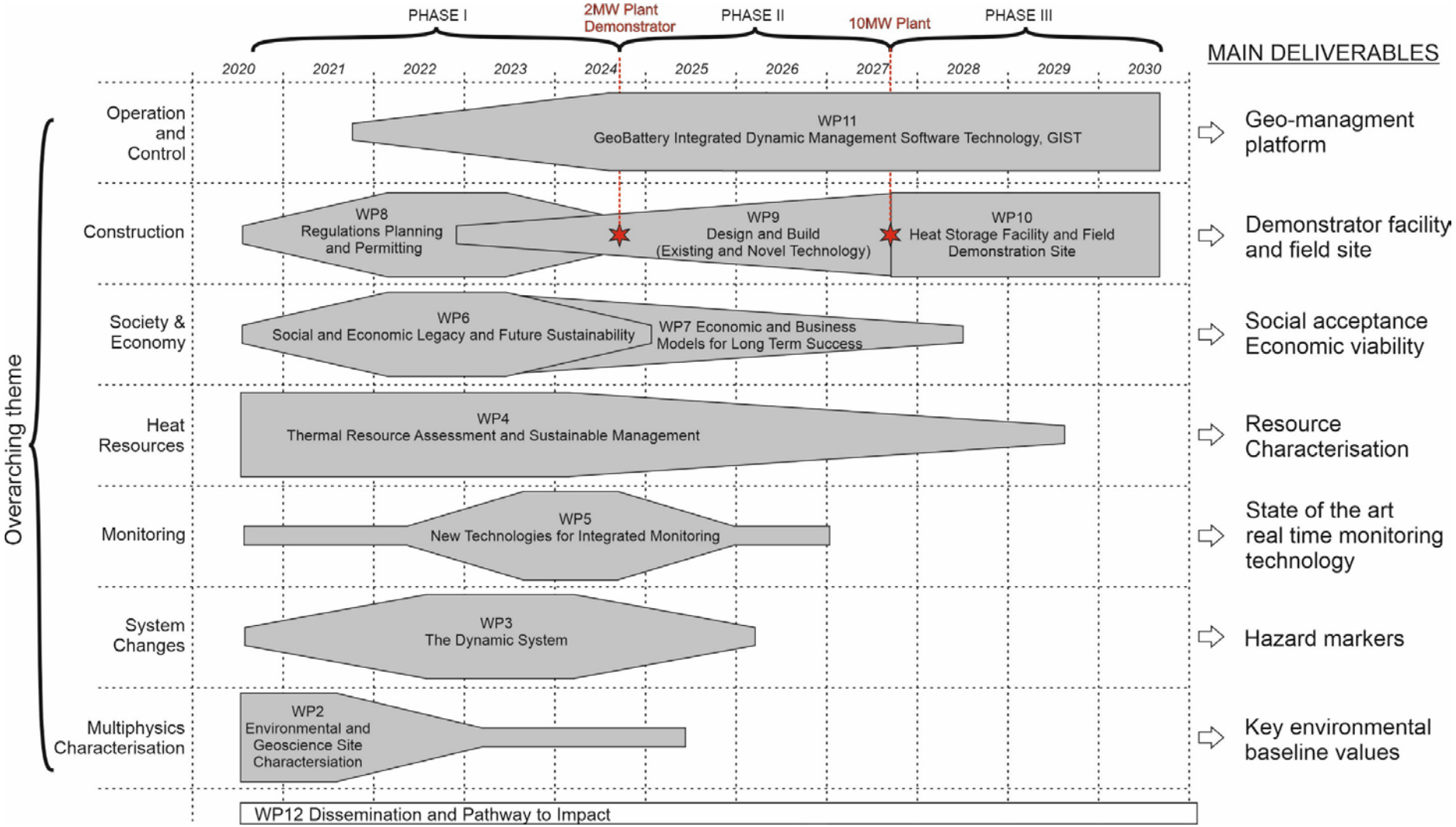


Figure 2 General Overview of Workpackages and Project Struture

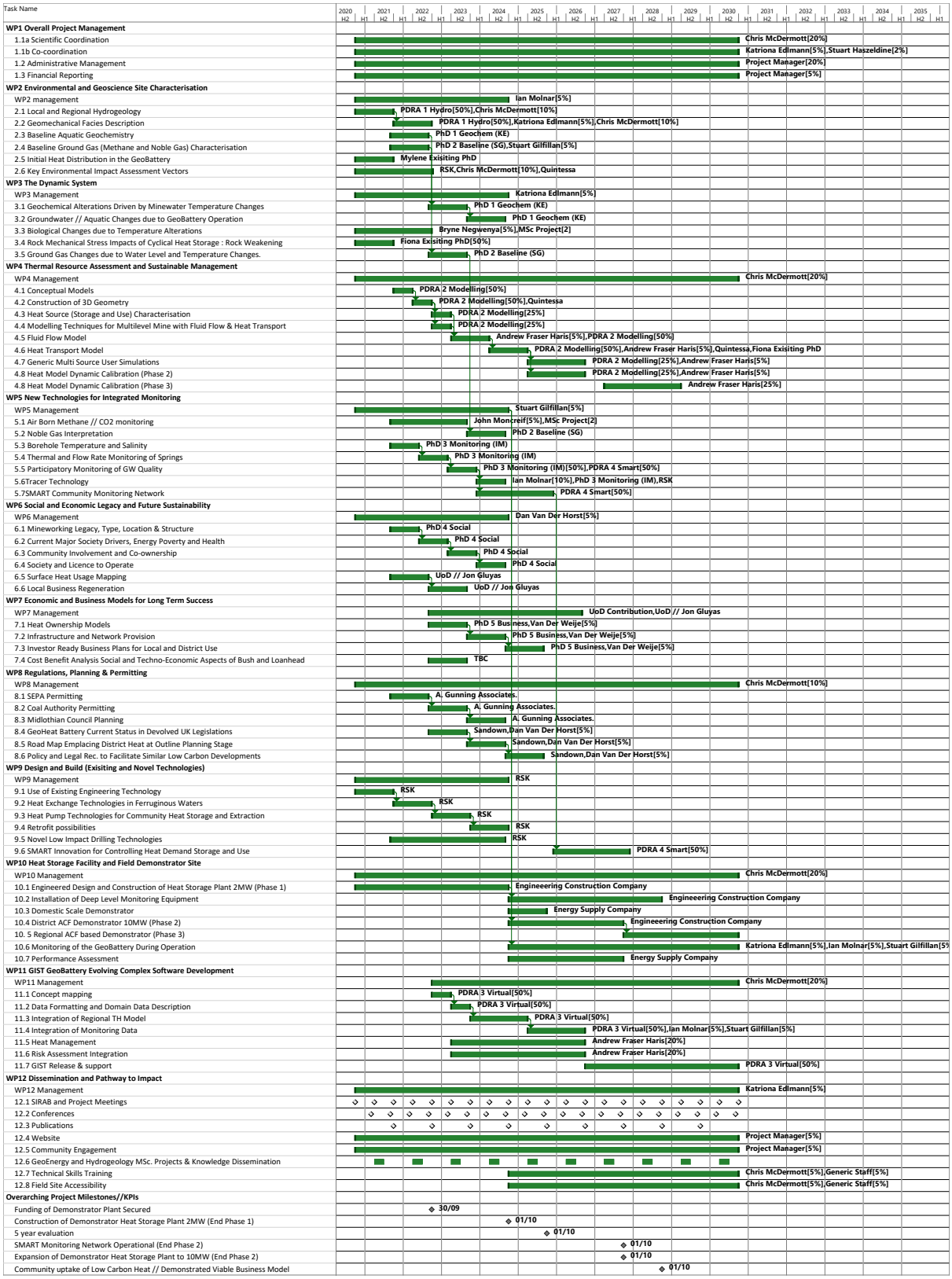
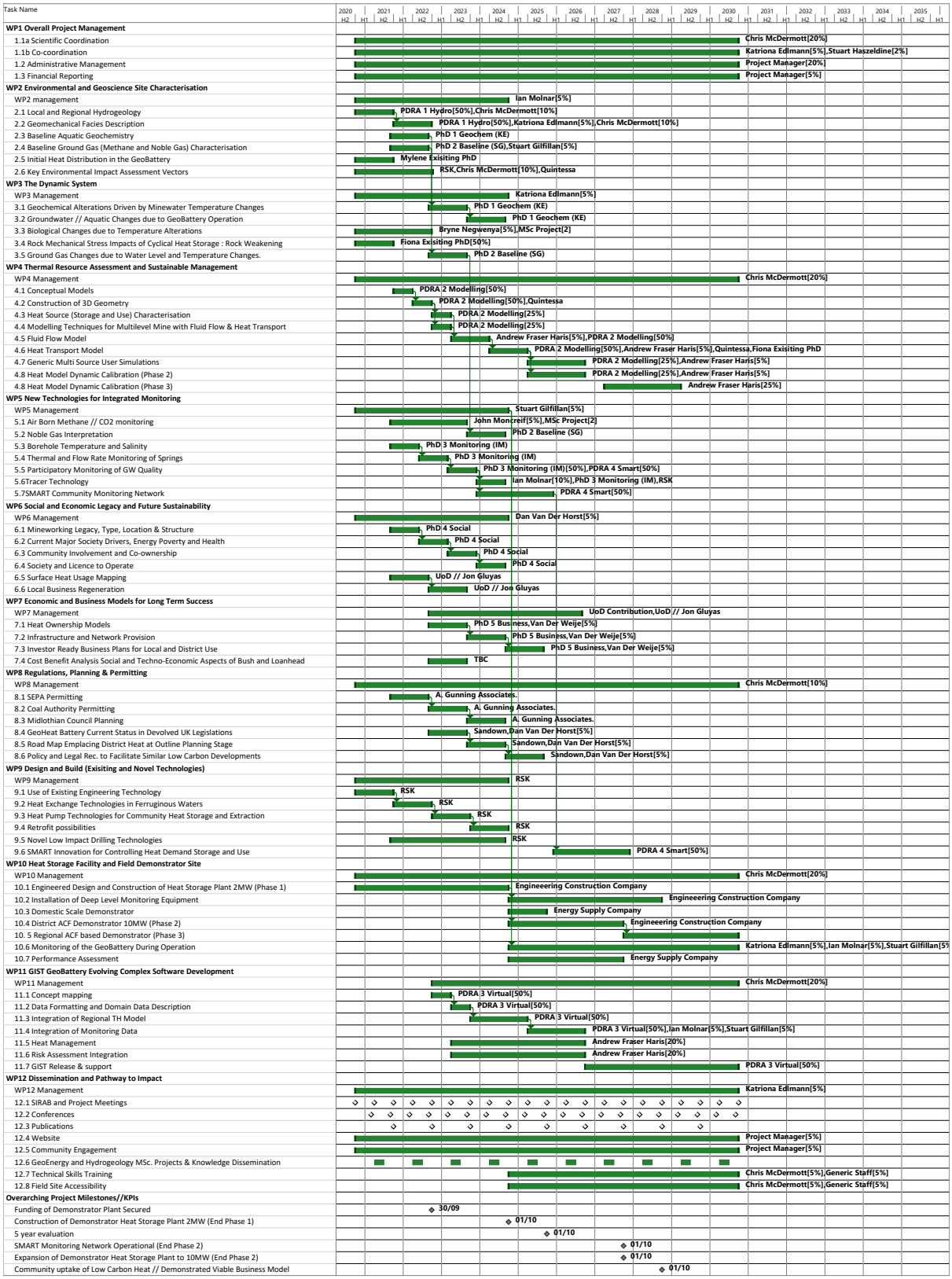


Figure 3 Ed-GeoBattery Gantt Chart

Ed-GeoBattery Gantt Chart



	Start-up cost	Direct employment costs of award holder (80% fEC)	Indirect employment costs of award holder (80% fEC)	Direct employment costs of research support staff (80% fEC)	Indirect employment costs of research and support staff (80% fEC)	Research student costs (100%)	Research expenses (100%)	Other, training or similar (100%)	Year Total
Year 1	£105,000			76,320.27	69,243.12		5,172.52	10,000.00	265,735.91
Year 2	£102,000			94,782.17	76,338.56	85,428.67	19,803.79	80,000.00	458,353.18
Year 3				111,170.08	88,563.12	98,378.33	18,854.12	65,000.00	381,965.66
Year 4				136,680.24	114,721.63	98,378.33	3,759.79	25,000.00	378,540.00
Year 5				149,280.81	119,850.75	19,675.67	4,871.28	15,000.00	308,678.51
Year 6				147,474.32	114,208.72		6,918.77	15,000.00	283,601.81
Year 7				110,943.01	78,390.21		11,918.77		201,251.99
Year 8				101,891.06	65,567.41		11,951.42		179,409.89
Year 9				104,936.81	65,567.41		11,918.77		182,422.99
Year 10				82,386.02	42,486.37		11,918.77		136,791.16
Column Total	£207,000	0	0	1,115,864.80	834,937.30	301,861.00	107,088.00	210,000.00	
									£2,776,751

Award Holder Costs of approximately £1.5 million fEC will be covered by the Host Instittuion

SCHOOL *of* GEOSCIENCES
The University of Edinburgh
Grant Institute
The King's Buildings
James Hutton Road
EH9 3FE
Telephone +44 (0)131 650 7737
http://www.ed.ac.uk/schools-departments/geosciences/

geos-hr@staffmail.ed.ac.uk

Dear RAE,

Please find below details of matched funding being provided as part of tthis bid split by the relevant institution and the financial value attached to the funding being provided.

University of Edinburgh (School of Geoscience & EPCC)	£1,705,000
Quintessa Ltd (Bond)	£40,000
RSK (Picken)	£45,000
AG Associates (Gunning)	£10,000
Sandown (Parry)	£10,000
Coal Authority (Crooks)	£70,000
University of Durham (Gluyas)	£135,000
Total Matched Funding	**£2,015,000**

The matched contribution from University of Edinburgh includes 10 years of Dr Chris McDermott's salary plus associated overheads.

If any clarifcation is required then please don't hesitate to contact me.

Kind Regards

Brendan Martin
Research Finance Manager
School of Geosciences
University of Edinburgh

THE UNIVERSITY *of* EDINBURGH

Professor Jonathan Seckl OBE
BSc MB BS PhD FRCPE FMedSci FRSE
Vice Principal Planning Resources & Research Policy
Moncrieff-Arnott Professor of Molecular Medicine
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Email: J.Seckl@ed.ac.uk
www.ed.ac.uk

5th February 2020

Royal Academy of Engineering
Prince Philip House
3 Carlton House Terrace
London
SW1Y 5DG

Dear Sir/Madam

RE: Chair in Emerging Technologies – Low Carbon Heat from Urban Multi-user Sustainable GEOthermal BATTERY (Ed-Geobattery)

The University of Edinburgh (UoE) is delighted to support Chris McDermott in his application for a **Chair in Emerging Technologies**.

Chris McDermott has led UoE's development of the interdisciplinary field of coupled processes in hydrogeology, at the interface between geosciences and engineering. Chris's research record demonstrates global leadership. He has developed and sustained a scientific research programme in geoenergy (securing substantial support from diverse sources in experimental and numerical coupled process modelling), with a particular focus on geothermal energy, and the development of education and training for a cohort of ~100 students per year in Hydrogeology.

Specifically, Chris has demonstrated global leadership in applied subsurface engineering applications, providing scientific insight, originality, leadership and drive. Evidence includes his publication "Simulation of heat extraction from crystalline rocks: The influence of coupled processes on differential reservoir cooling", one of the most cited works on fractured geothermal systems. He also invented and built at Edinburgh world-unique experimental equipment (the GREAT system and cell) for the investigation of geothermal reservoir rock behaviour at large scale under variable and true triaxial conditions of stress and temperature. This has stimulated significant industry interest and is now being reproduced at the University of Göttingen. First GREAT results have been published in highly-ranked journals and are now included in the DECOVALEX (for DEvelopment of COupled models and their VALidation against Experiments) 2023 programme phase, which starts this year and is one of the most important global benchmarking initiatives in geosciences. McDermott has shown European scientific leadership through the Horizon2020 project FracRisk, which involves 14 international partners across industry, engineering, computational simulation and geosciences. The aims are to develop numerical methods for the assessment of subsurface coupled processes related to fluid flow during hydraulic stimulation (fracking) of shales for long term extraction of methane gas,

to find ways of identifying the key risks and to provide evidence based decision making tools to assess and mitigate the environmental impact of these processes. This has been highly successful to date, with 32 peer reviewed papers, 44 conference presentations and multiple public engagement and outreach activities; for example he coordinated the dissemination workshop for all H2020 Fracking Related Research Projects, FracRisk, SHEER, SXT and M4SHALEGAS in Brussels in 2018.

UoE is fully committed to supporting this emerging technology field and Chris McDermott's Ed-GeoBattery Chair application. Of the nine core themes identified for CiET, three are addressed by the Ed-GeoBattery programme; clean energy and technologies; climate change; and digital transformation, and as a University our vision is to provide world leadership in science and engineering to address global challenges, including the local, UK and global transitions to a zero net emissions economy. UoE is consistently in the top 25 Universities world-wide and was ranked 4th in the UK for research power (quality and breadth) in REF2014. The School of GeoSciences was identified having the greatest concentration of 'world leading' and 'internationally excellent' researchers in the UK. Our School of Engineering (joint submission with Heriot-Watt) was 1st by research power in general engineering. As Ed-Geobattery will enhance our international standing, facilitate future wide reaching international collaborations and will have clear impact both locally and globally.

Building on our hosting of ARCHER and ARCHER 2, the university has already committed £25,000 for preliminary work on the project and has also committed £3M for similar works should a large bid to host UK Exascale HPC be successful. Chris's leadership and Ed-Geobattery project development is required to ensure this UK HPC infrastructure is a UK low carbon resource for many years into the future, and that we will then lead the world in such development. In parallel with demonstrating this global potential (Chris will look to exploit UoE and Geoscience's UK-leading success in attracting GCRF funding), the availability of this low carbon local energy for space heating will be developed through involvement of multiple levels of stakeholders and engagement of local communities. To ensure the success of Ed-GeoBattery and building upon Chris's visionary leadership, the programme therefore includes multidisciplinary input from a wide range of researchers across the University, including social scientists, engineers, geoscientists and computational "big data" specialists. The latter leverages a strategic direction of UoE with its ambition for Edinburgh to become the 'Data Capital of Europe', underpinned by £300m grant funding committed by UK and Scottish Governments in data-driven innovation that form the key elements of the £1.3bn Edinburgh City Region Deal. To ensure wider pathways to impact, Ed-Geobattery also includes input from key industry and regulatory stakeholders as well as partnership with the University of Durham.

In terms of host support, the University has already demonstrated its commitment to Chris through significant investment in this research area, particularly in the form of experimental equipment (partially funding the GREAT cell with a sustainability award of £400k) and in technical personnel (providing technical staff over five years, to a value of £200k, as part of a successful Prosperity Partnership programme). Chris is being supported by the School of Geosciences for promotion to chair this year, recognising his research, innovation and leadership qualities. For this RAEng Chair proposal:

- We will free Chris of all administrative duties and teaching that do not promote this emerging technology. (It is worth noting that there are a number of embedded PhD and MSc students within the project, so he will choose to retain limited relevant teaching in hydrogeology, and

he will continue PhD and MSc dissertation supervision in areas related to Ed-GeoBattery for research and technology development and capacity building).

- commit that all employment costs recovered from this award will be invested back into the overall Ed-GeoBattery project to support associated colleagues and the development of an associated MSc programme in Applied Hydrogeology for further capacity building.

The School of Geosciences is exceptionally well-equipped with relevant facilities for, and expertise in, the analysis of rocks, minerals and fluids, isotope analysis, measurement of the physical properties of rocks, scientific computing in geographic information systems, hydrogeology, subsurface fluid flow coupled processes modelling, meteorological models and geophysics. The University's technology transfer company Edinburgh Innovations (EI), fully endorses and will support the Ed-GeoBattery development and programme, including providing local support through its Business Development Executives. Although much of the research underpinning the Ed-GeoBattery concept is based on already published material and is already available in the public domain, we regard the proposal as likely to generate new innovation, arising from the knowhow embodied within the suite of experimental facilities established by the applicant and others within the University over the previous decade. For any new IP arising during the project, we propose that ownership remains with the contributing party or parties. EI is ready to provide the support necessary for usage and/or commercial development, to enter into suitable collaboration agreements and licensing when required, to meet the needs of the parties and ensure innovation development.

In summary, the University fully supports Chris McDermott's nomination for a Royal Academy of Engineering Chair in Emerging Technologies. His exciting and innovative proposal to lead the research and innovation programme required to develop the Ed-Geobattery will place Edinburgh and the UK at the global forefront of the emerging technologies of sustainable heat recovery and reuse, and be a key component of transition to low carbon energy and to meet the target of net-zero emissions in the UK by 2050 and in Edinburgh by 2030.

Yours sincerely

Professor Jonathan Seckl OBE FRSE, FRCPE, FMedSci
Vice-Principal Planning, Resources and Research Policy, University of Edinburgh