Coal Research Forum 23rd AGM and meeting of the combustion division

Drax power Ltd, Drax Power Station, Selby, North Yorkshire.
25th April 2012

An Overview of Oxyfuel Combustion Academic Programme for the UK (OxyCAP UK)

Ignatio Trabadela
and Jon Gibbins
jon.gibbins@ed.ac.uk

Research Councils UK

Carbon Capture and Storage in the Energy Programme

CCS has been identified as a priority area for the Energy Programme. We now support over £38M in current grants for 36 research and capacity building projects in CCS including:

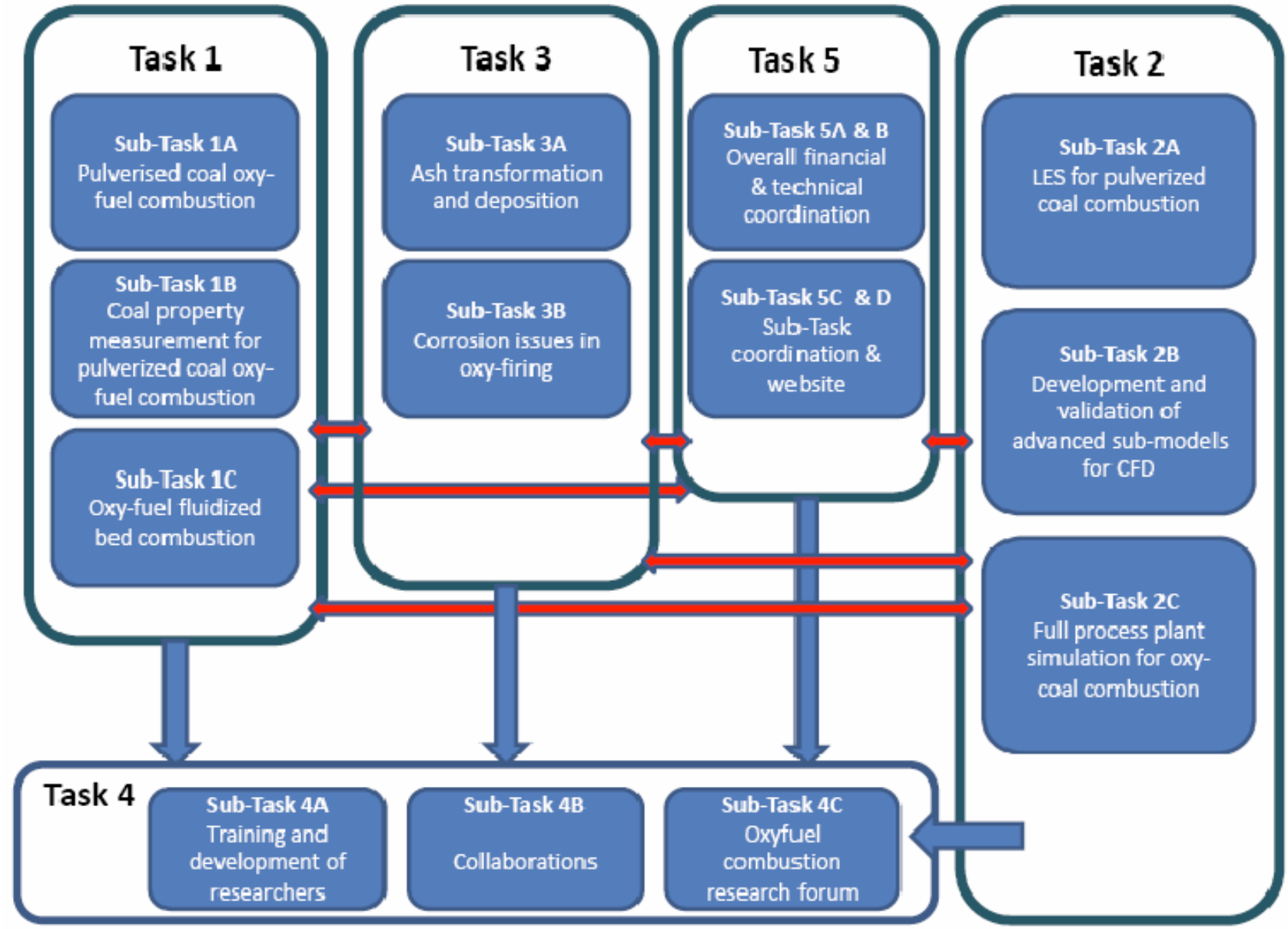
- 4 Consortia researching carbon capture and transport (3 jointly supported with E.ON). £6.5m investment.

EPSRC-E.ON Strategic Partnership, CCS: OxyCAP UK

Objective: "to develop academic research capability for oxy-fuel combustion in five key areas":

1) New experimental techniques for oxy-fuel combustion.
2) Advanced computer modelling techniques (LES, integrated CFD/system)
3) Experimental data on coal ash/boiler material behaviour under oxy-fuel conditions.
4) UK capacity in oxy-fuel fluidised bed combustion (FBC).
5) Training & development new researchers.

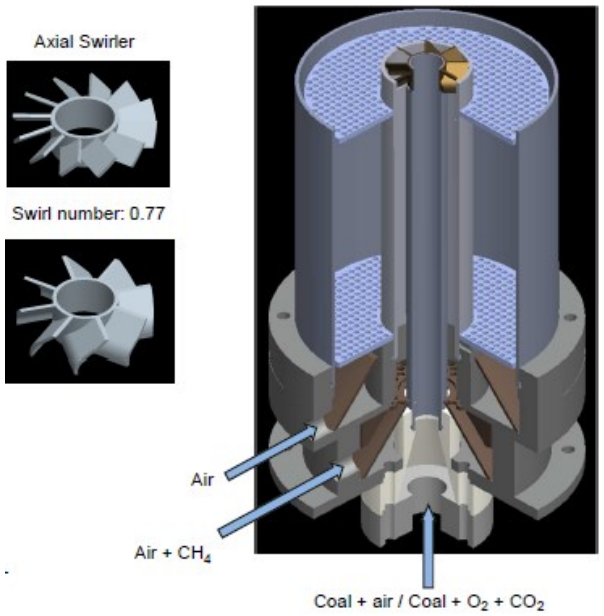
Link and information flow between tasks-OxyCAP UK Project

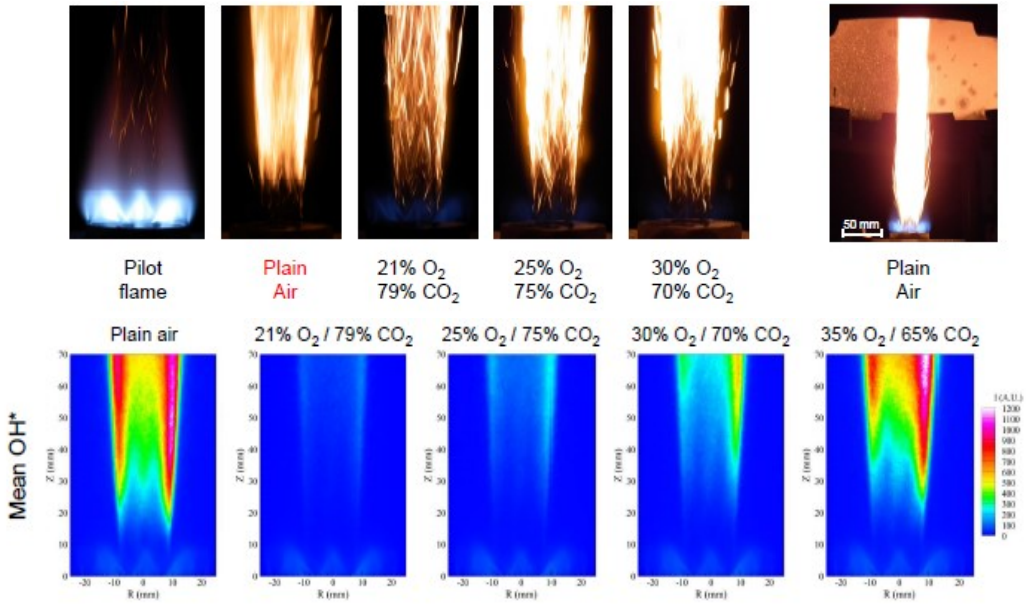


University of Cambridge

Task: ST1-A, application of optical diagnostic techniques to particle laden flows

Goals: a) Create a database of turbulent combustion experiments with coal particles
b) Analyze the difference between oxy-firing and air-firing and to
c) Identify the limitations of optical diagnostic techniques to the coal combustion.





Methodology: Laser Doppler Velocimetry (LDV), Particle Image Velocimetry (PIV) and chemiluminescence imaging techniques to generate flow and scalar field measurements.

Researchers: Saravanan Balusamy, Alexander Schmidt, Simone Hochgreb, Stuart Scott, John Dennis.

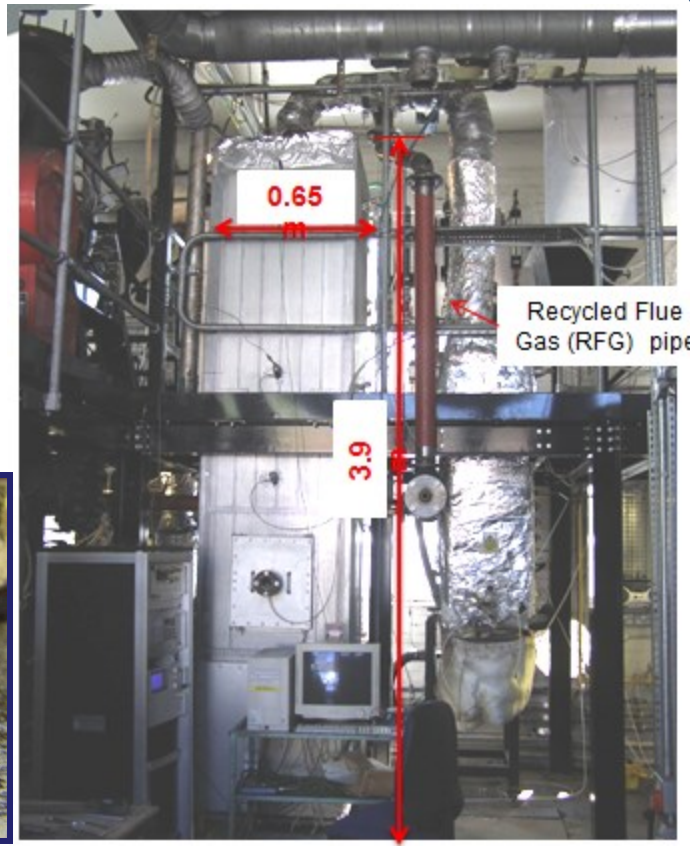
Images/content courtesy of University of Cambridge

Cranfield University

Task: ST1-A (P.F. exp. Oxycomb), STI3-A & ST3-B

Goals: a) Study oxyfuel combustion
b) Ash transformation.
c) Ash deposition and corrosion studies.

Ash Deposit Probe CCP 100%



Methodology: Experiments in 150 kWh oxyfuel combustion with RFG.
Analysis of morphology of the ash comparing different fuels.

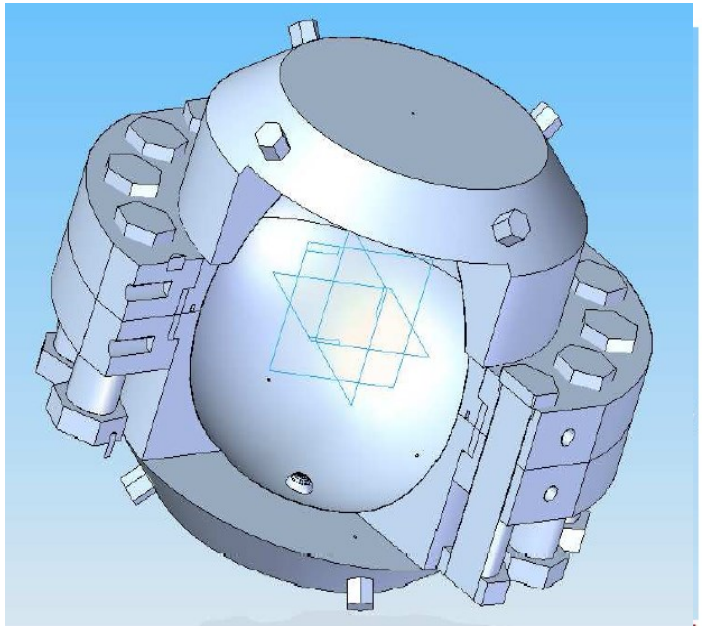
Researchers: Nelia Jurado, Hamid Darabkhani, John E Oakey.

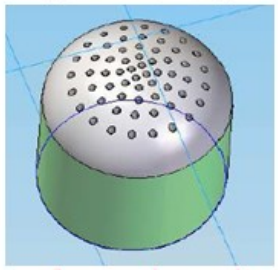
Images/content courtesy of Cranfield University

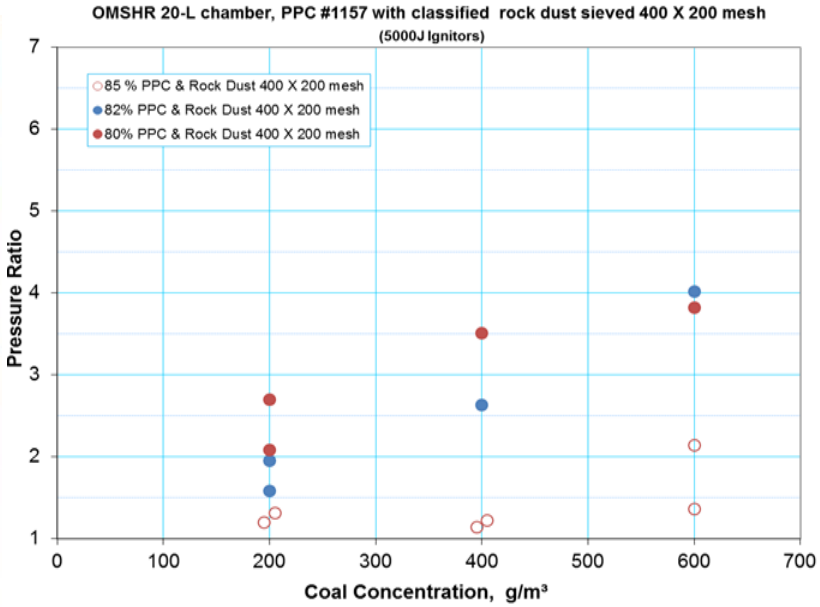
University of Edinburgh

Task: ST1-A (P.F. exp. Oxy-combustion), ST5-B (technical coordination).

Goals: a) Determine safe levels of O_2 in O_2/CO_2 in FGR.
b) Mill safety.
c) Ignition/combustion fundamentals under oxyfuel conditions.







Methodology: Coal dust ignition tests under oxy-fuel conditions in 20 L and 200L bombs. Peak pressure and dP/dt. Analysis of char from ignition with TGA.

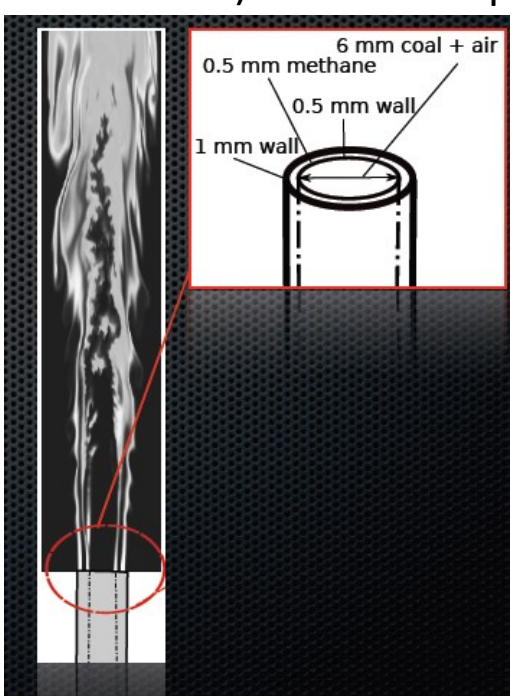
Researchers: Ignacio Trabadela, Hannah Chalmers, Jon Gibbins.

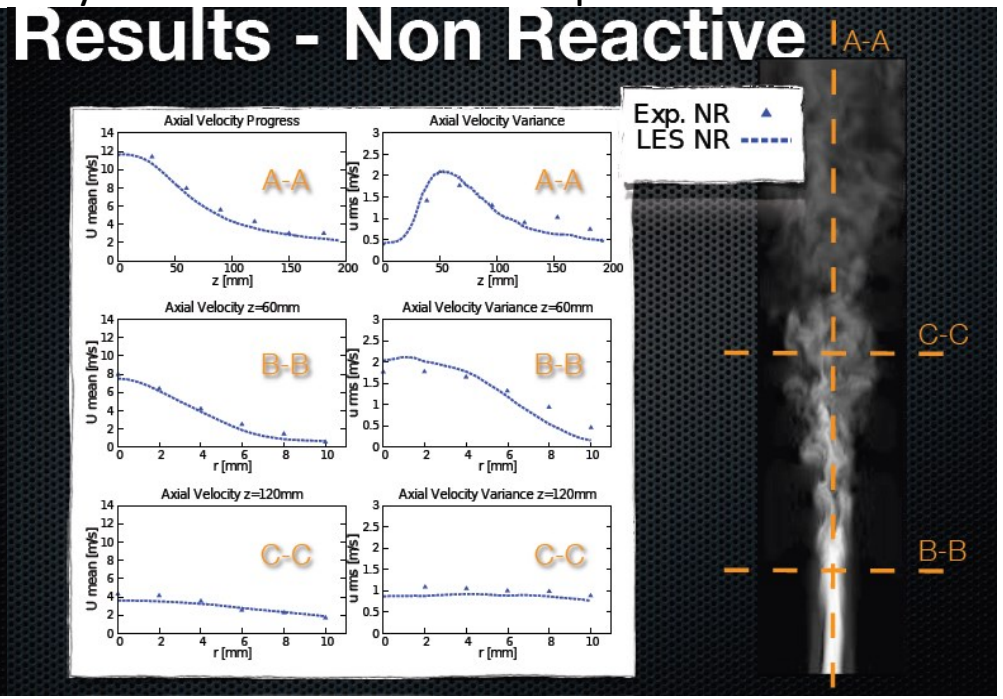
Images/content courtesy of University of Edinburgh

Imperial College

Task: ST2-A (LES for Oxy-combustion).

Goals: a) Improve understanding of oxy-combustion.
b) Model coal particles burning in oxy-combustion and other species.





Methodology: LES, development of code from Eulerian-Eulerian to Eulerian-Lagrangian
Use LES for air combustion before oxy-combustion simulation.

Researchers: Benjamin Franchetti, Fabrizio Cavallo Marincola, Andreas Kempf.

Images/content courtesy of Imperial College London

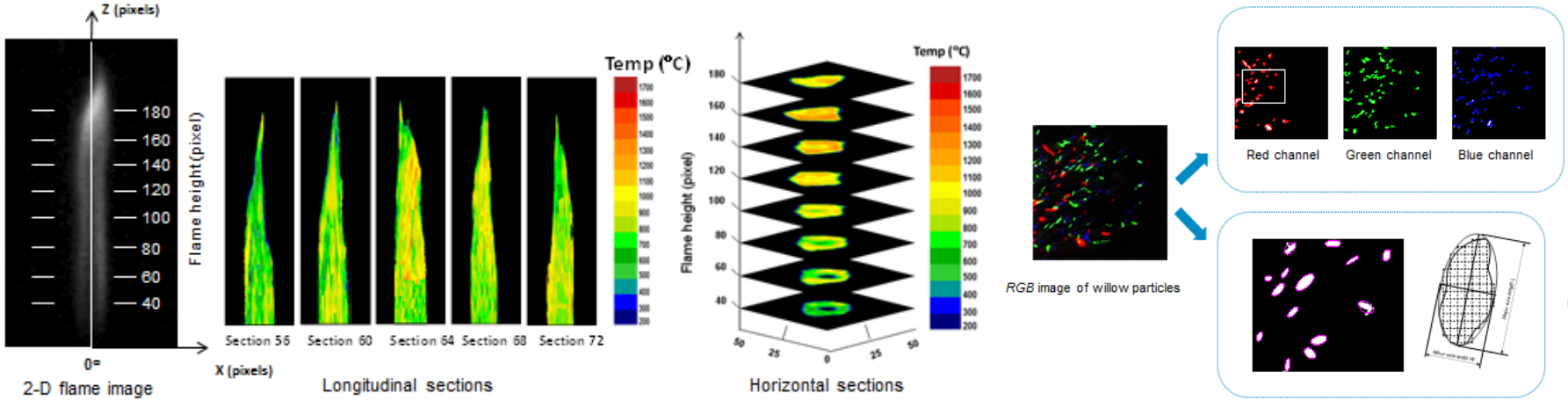
University of Kent

Task: ST1-A (P.Fexp. Oxycomb), STI4 & ST5 (web)

Goals: a) 3D Flame imaging.

b) Flow metering and on-line sizing of pulverised coal.

c) Particle image characterization.



Methodology: The 3-D temperature distribution of flame cross-and longitudinal sections can be measured based on two-colour method.

.

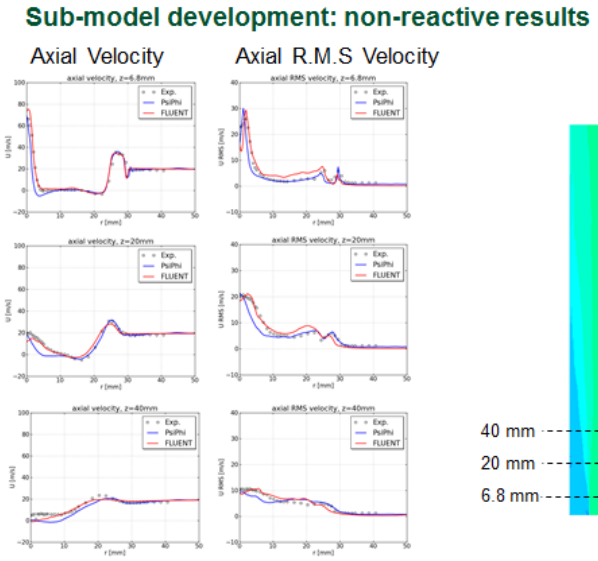
Researchers: Y. Yan, G. Lu, M. M. Hossain and L. Gao.

Images/content courtesy of University of Kent

University of Leeds

Task: ST1-A, ST2A, ST2B, ST2C & ST5AB (financial & technical coordination.)

Goals: a) PF Oxy-combustion fundamentals (and fuel characterisation).
b) LES, CFD and global plant simulation.



Figures: non-reactive mean axial and axial R.M.S velocities (LES: PsiPhi, LES: FLUENT)

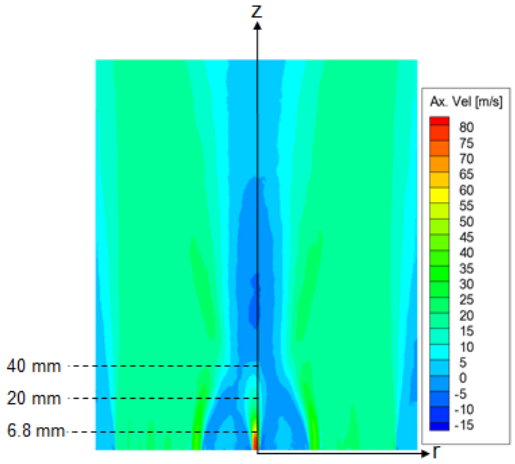


Figure: Mean axial velocity from PsiPhi

Methodology: Oxy/air solid fuels CTF 250 kW rig (PACT facilities).

Develop CFD sub-models and Large Eddy Simulation.

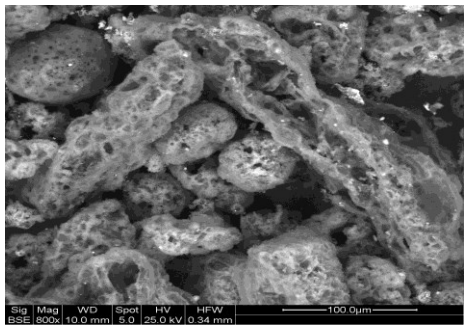
Researchers: János Szuhánszki, Sandy Black, Alessandro Pranzitelli, M. Pourkashanian, L. Ma, and B. Nimmo.

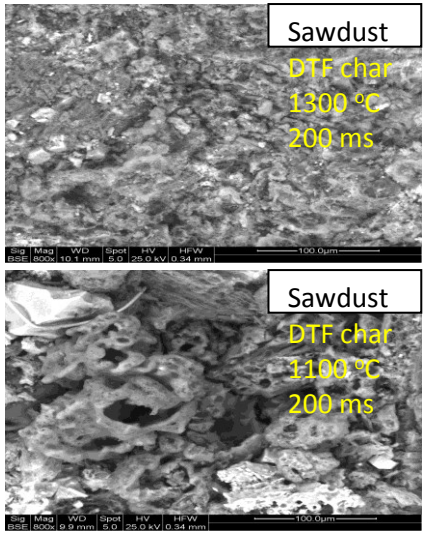
Images/content courtesy of University of Leeds

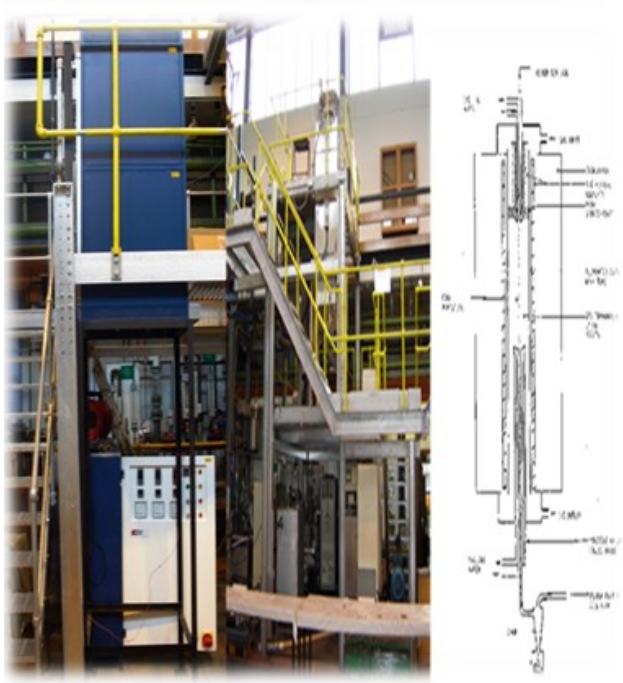
University of Nottingham

Task: ST1-A (P.F. Oxyfuel combustion)

Goals: a) Coal devolatilisation and subsequent char burnout characteristics
b) The effect of mineral matter and potential formation of carbonate species.
c) Coal/biomass oxy-cofiring + char analysis.
d) Water vapour content in FGR.







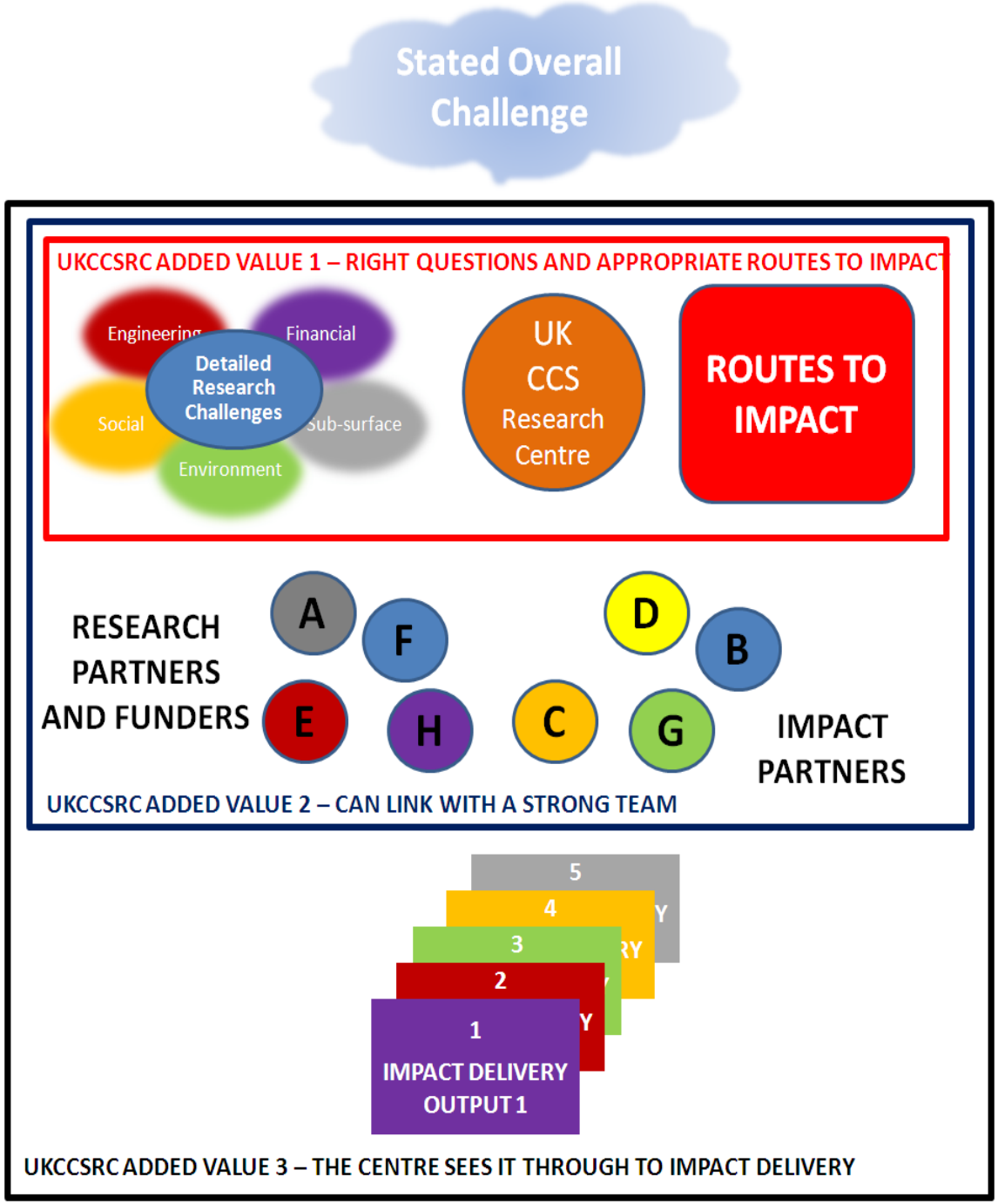
Methodology: Drop tube furnace (DTF) tests under conditions of different temperatures (up to 1500ºC), residences times (≥ 25 ms) and oxy-combustion atmospheres (+TGA)

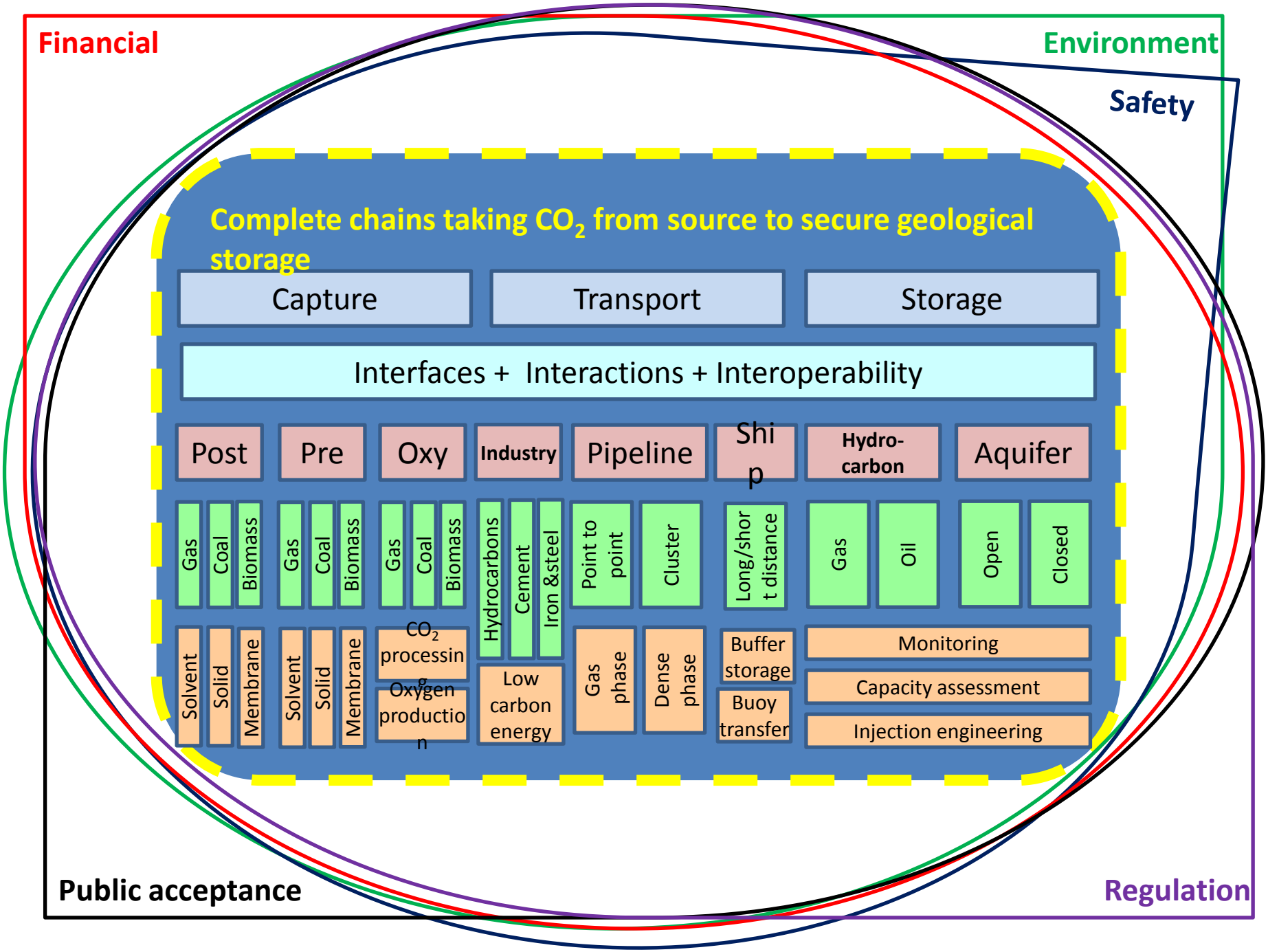
Researchers: Colin Snape, Chenggong Sun and Donglin Zhao.

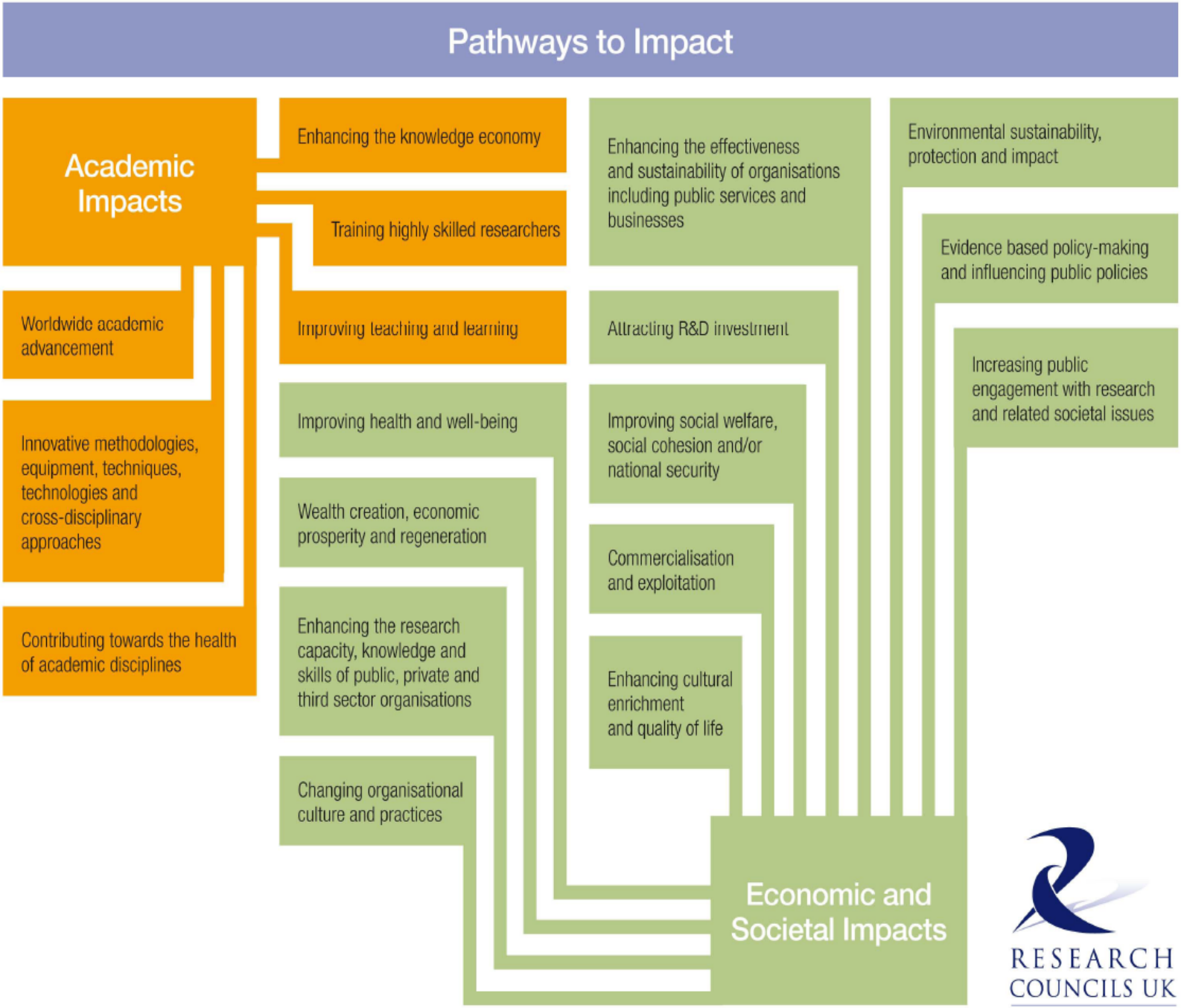
Images/content courtesy of University of Nottingham

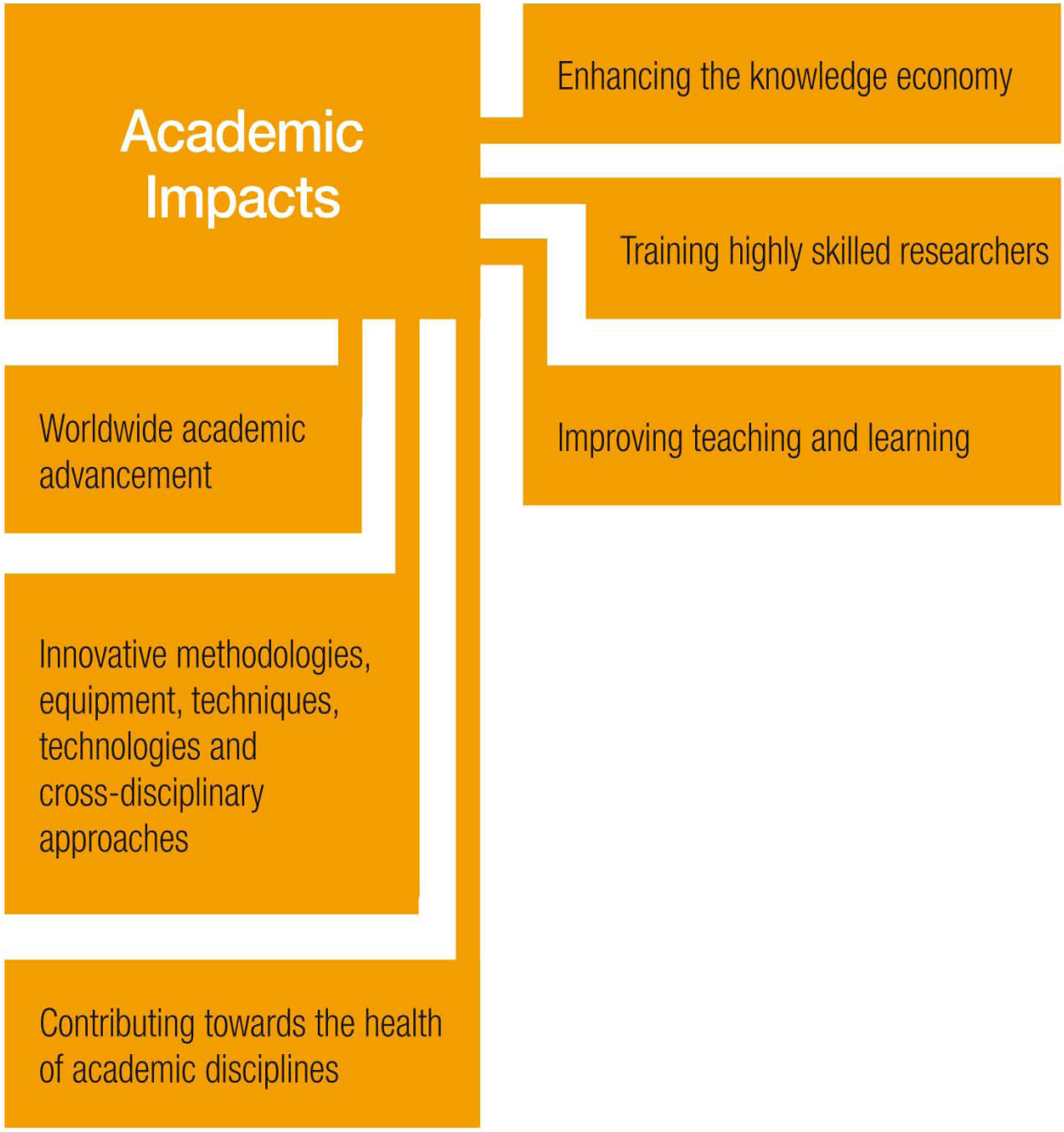
Research and Pathways to Impact Delivery (RAPID)

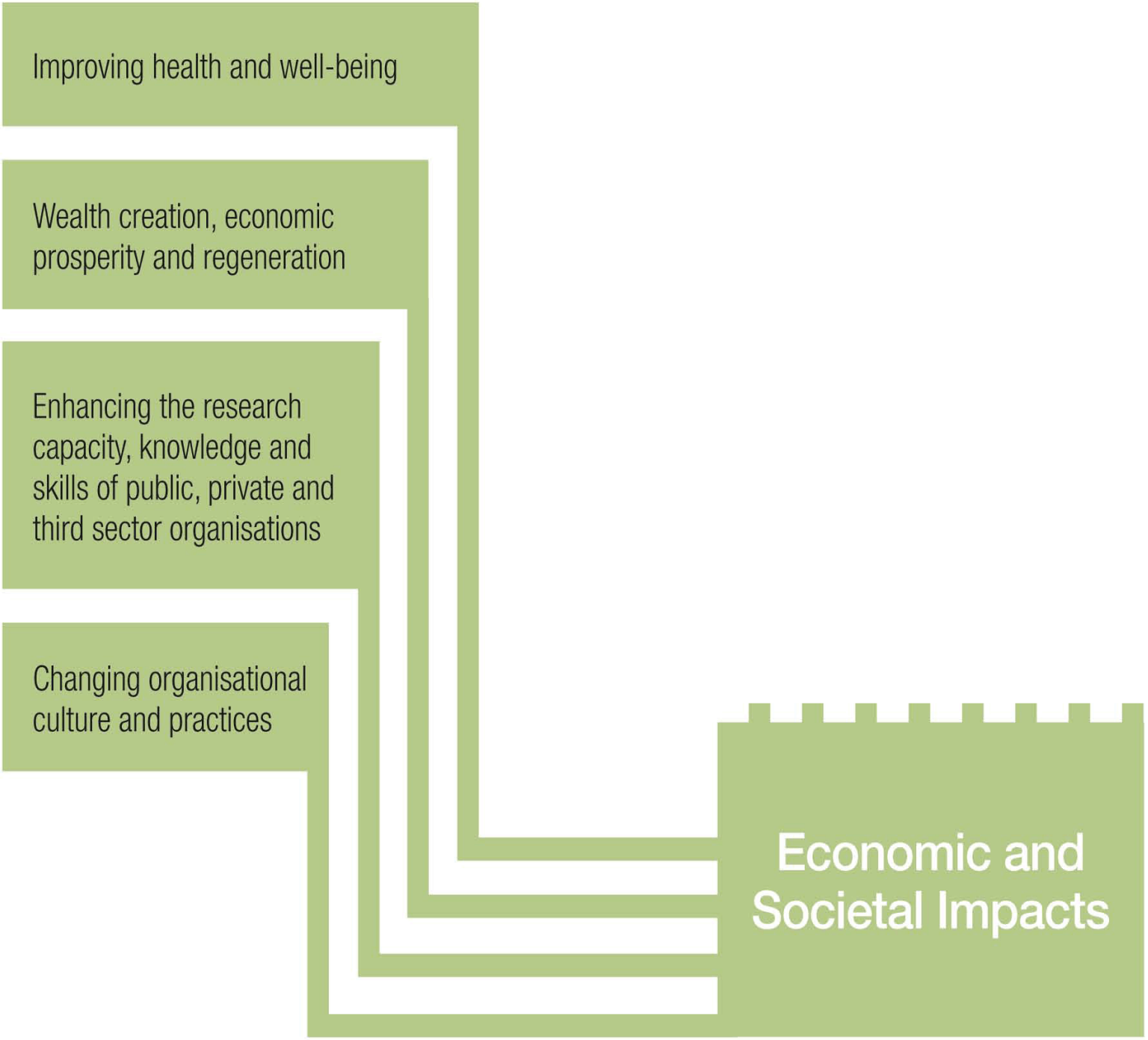
- The RAPID process will run throughout the course of the UKCCSRC
- Led by the Research Area Champions and gathering input from a wide range of academic, industry and other stakeholders.
- Results summarised in a RAPID Handbook.
- The first draft of the Handbook will be published after an intensive 4 month exercise at the project outset
- Handbook will be updated annually.

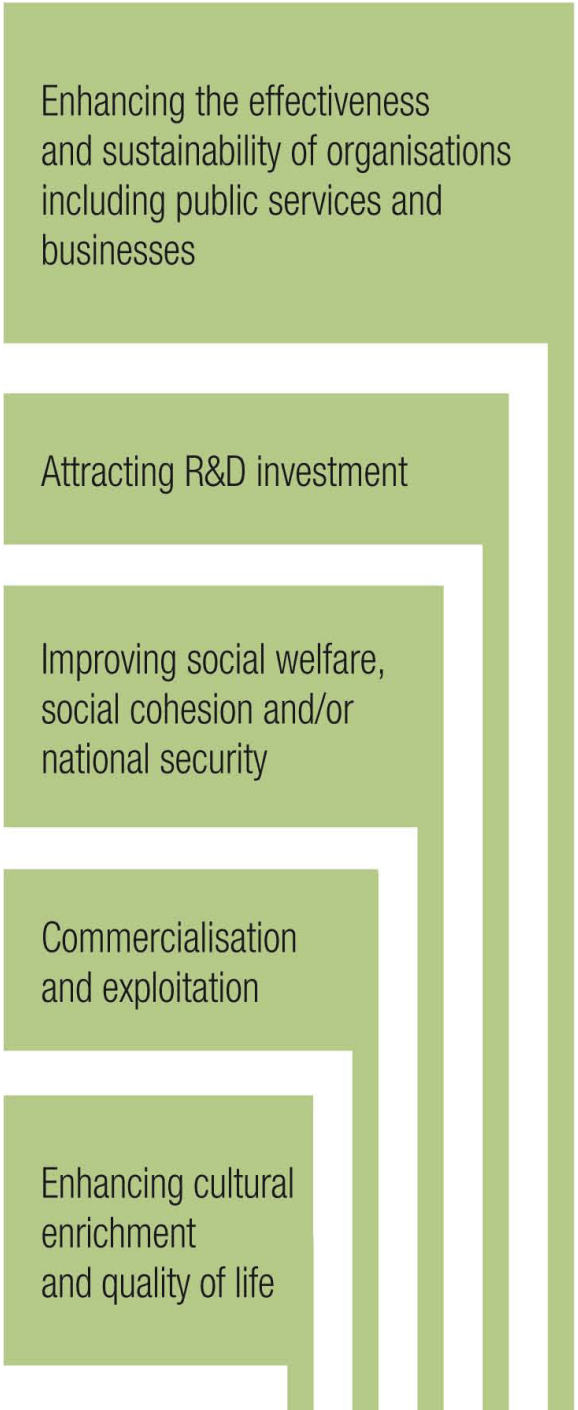



Financial
Environment
Safety
Complete chains taking CO_2 from source to secure geological storage
Capture
Transport
Storage
Interfaces + Interactions + Interoperability
Post
Pre
Oxy
Industry
Pipeline
Ship
Hydro-carbon
Aquifer
Gas
Coal
Biomass
Gas
Coal
Biomass
Gas
Coal
Biomass
Hydrocarbons
Cement
Iron &steel
Point to point
Cluster
Long/short distance
Gas
Oil
Open
Closed
Solvent
Solid
Membrane
Solvent
Solid
Membrane
CO_2 processing
Oxygen production
Low carbon energy
Gas phase
Dense phase
Buffer storage
Buoy transfer
Monitoring
Capacity assessment
Injection engineering
Public acceptance
Regulation


Pathways to Impact
Academic Impacts
Worldwide academic advancement
Innovative methodologies, equipment, techniques, technologies and cross-disciplinary approaches
Contributing towards the health of academic disciplines
Enhancing the knowledge economy
Training highly skilled researchers
Improving teaching and learning
Improving health and well-being
Wealth creation, economic prosperity and regeneration
Enhancing the research capacity, knowledge and skills of public, private and third sector organisations
Changing organisational culture and practices
Enhancing the effectiveness and sustainability of organisations including public services and businesses
Attracting R&D investment
Improving social welfare, social cohesion and/or national security
Commercialisation and exploitation
Enhancing cultural enrichment and quality of life
Environmental sustainability, protection and impact
Evidence based policy-making and influencing public policies
Increasing public engagement with research and related societal issues
Economic and Societal Impacts
RESEARCH COUNCILS UK


Academic Impacts
Enhancing the knowledge economy
Training highly skilled researchers
Improving teaching and learning
Worldwide academic advancement
Innovative methodologies, equipment, techniques, technologies and cross-disciplinary approaches
Contributing towards the health of academic disciplines


Improving health and well-being
Wealth creation, economic prosperity and regeneration
Enhancing the research capacity, knowledge and skills of public, private and third sector organisations
Changing organisational culture and practices
Economic and Societal Impacts


Enhancing the effectiveness and sustainability of organisations including public services and businesses
Attracting R&D investment
Improving social welfare, social cohesion and/or national security
Commercialisation and exploitation
Enhancing cultural enrichment and quality of life

Environmental sustainability, protection and impact

Evidence based policy-making and influencing public policies

Increasing public engagement with research and related societal issues

CRF Research Needs - The key R,D&D challenges include:

- **Improve the efficiency of coal fired power generation with effective removal of conventional pollutants such as SOx, NOx particulates and trace metals.**
- **Improve the use of more advanced steam cycles, for which the need to improve performance through materials selection is critically important.**
- **Improve plant integration, together with enhanced fuel and operational flexibility.**
- **Establish near zero emissions systems such that CO_2 can be prevented from being released to atmosphere, with any adverse technical impacts on such efficiency and environmental performance being minimised in as cost effective manner as possible. This will require large scale demonstrations of the first generation CO_2 capture systems and offshore CO_2 storage within a complete CCS chain.**
- **Improve effectiveness and costs of the first generation CO_2 capture systems and the development of second generation systems that will overcome some of the inherent disadvantages of the first.**
- **Gain a better understanding of the properties of CO_2 to ensure the provision of robust transport systems.**
- **Improve assessment and modelling of CO_2 storage capacity in various geological formations, together with the development of improved monitoring and verification techniques.**

THINGS THAT ARE NEEDED TO MAKE CCS HAPPEN

Perceived need for CCS

Plans that include CCS

Money to pay for CCS

Legal cover for CCS Permitting, Regulation and Leasing

Project liability protection

Environmental sustainability

Public acceptance

Industry to produce and capture CO_2

CO_2 transport systems

CO_2 storage sites -

CCS Hardware

CCS-related Services

Operating/managing CCS systems in real time and day-to-day

UNDERPINNING RESEARCH ACTIVITIES

UKCCSRC + other research input

PROCESSES AND POSSIBLE EXAMPLES OF STAKEHOLDERS INVOLVED IN MAKING CCS HAPPEN

Global climate change agreement

Understanding role of CCS

UK energy & climate policy

Global CCS development organisations: CSLF, GCCSI, IEAGHG, Clean Energy Ministerial CCUS

Electricity market planners –DECC, Ofgem, National Grid, utilities

Financial instruments to support CCS – government grants, EMR, carbon price, clean energy standards etc.

CCS safety regulators - HSE

Plant permitting – EA, SEPA

Crown Estates

Offshore storage site permitting & leasing

Onshore pipeline permitting

Offshore pipeline routing and leasing

Government participation in storage liability

CCS project/process insurance

Process emissions

Lifecycle emissions

Site impacts

Remediation options

Media

Opinion formers

Local groups

Special interest groups

Electricity utilities
Merchant generators

Steel with CCS
Cement with CCS
Refining with CCS

Hydrocarbon extraction and processing with CCS
Synthetic fuels with CCS

National Grid

Onshore pipeline developers and operators

Offshore pipeline developers and operators

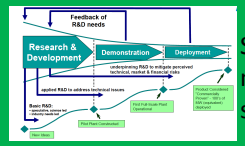
Pipeline T&S project developers

Shipping T&S project developers

Storage site developers & operators

CO_2 EOR developers & operators

Oil &gas companies (many roles)



See next slide

Many stakeholders in technology 'funnel' - R&D doers, funders, VCs, OEMs etc

Input to project development, feasibility and FEED studies etc.

Consultants: e.g. engineering, sub-surface, legal, environment

EPC Contractors

Electricity market operators – National Grid, utilities

T&S system operators – National Grid + others

Research organisations & communities

Ideas

Facilities

Evidence

Impact support

Engagement

Know-how

Skilled people

High-level ---------- Very specific

Long term ---------- Immediate

Demonstrable ---------- Potential

Big ---------- Small

Multiple impacts ---------- Focussed impact

Intentional ---------- Serendipitous

UKCCSRC involved ---------- 3rd party

Plan preceded research ---------- Plan followed research

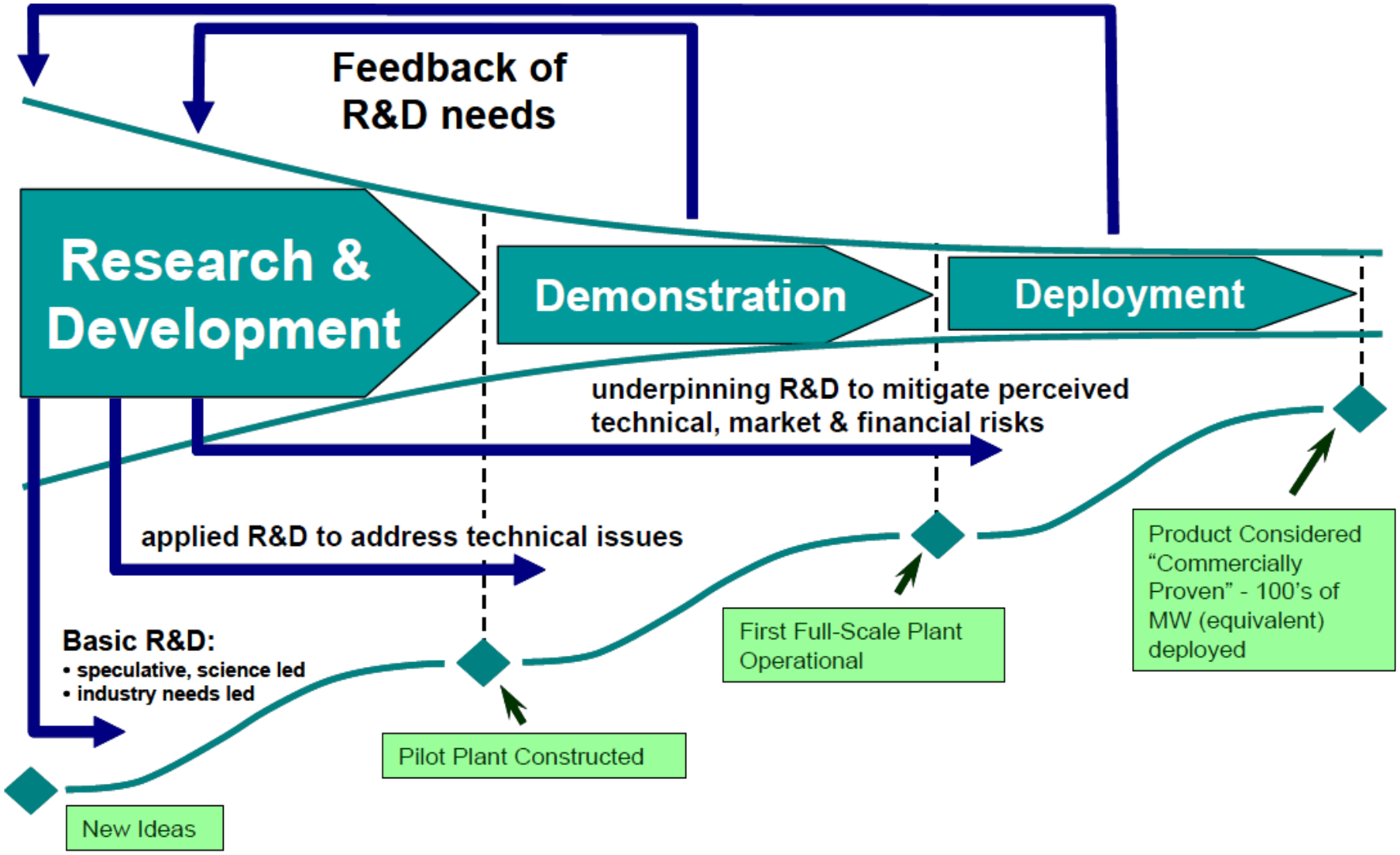
Research impact ---------- Deployment impact

Tangible vehicle ---------- Intangible vehicle

Publishable ---------- Confidential

Clear Attribution ---------- Debatable

Energy Innovation Chain



CATs R+D - an Industrial Viewpoint, Mike Farley, APGTF 8th CATS Workshop, 27 February 2008
http://www.apgtf-uk.com/files/documents/8thWorkshop2008/09JMFIndustryAPGTF%20Forum27Feb08.pdf