Introduction

Global energy security throughout the next century will continue to depend significantly on fossil fuel and nuclear whilst unlocking the potential of renewable as well as unconventional sources. The UK government's industrial strategy highlights the importance of continuing support for the oil and gas and nuclear sectors.

The British Geological Survey (BGS) in association with DECC has completed an estimate for the resource (gas-in-place) of shale gas in part of central Britain in an area between Wrexham and Blackpool in the west, and Nottingham and Scarborough in the east. The estimate is in the form of a range to reflect geological uncertainty. The lower limit of the range is 822 trillion cubic feet (tcf) and the upper limit is 2281 tcf, but the central estimate for the resource is 1329 tcf (Andrews, 2013)

This shale gas estimate is a resource figure (gas-in-place) and so represents the gas that we think is present, but not the gas that might be possible to extract. The proportion of gas that it may be possible to extract is unknown as it depends on the economic, geological and social factors that will prevail at each operation. Shale gas clearly has potential in Britain but it will require geological and engineering expertise, investment and protection of the environment. It will also need organisations like the BGS to play their part in providing up-to-date and accurate information on resources and the environment to the public, industry and Government.

To facilitate the above we propose an infrastructure "the Energy Test Bed" to allow the subsurface to be monitored at time scales that are consistent with our use of the subsurface, to increase efficiency and environmental sustainability but also to act as a catalyst to stimulate investment and speed new technology energy options to commercialisation.

It will thus act as a bridge from ideas to application and would attract support and possible co-funding from oil and gas companies, utilities and energy and environment consultancies

Method and/or Theory

The BGS is taking a central role in shale gas research in the UK and also across Europe as follows:

- undertaking a baseline groundwater survey of methane concentrations and other relevant chemical indicators in groundwaters across Great Britain;
- evaluating the spatial relationship between different potential shale gas source rocks and the principal aquifers in England and Wales;
- researching the induced seismicity that may be related to fracking; studies of the organic content and the organic make-up of the shales to improve the understanding

of how much shale gas they might produce and how the gas is stored within the rocks;
- understanding the distribution and correlation of shale and how the shale layers behave in response to depositional and tectonic controls;
- advice and guidance for Government in trying to understand the amount of gas that may be both in place and possibly recoverable within the shales in the UK.

Our future use of the subsurface, particularly for energy (subsurface gas storage, compressed air energy storage, shale gas, coal bed methane, underground coal gasification, enhanced oil recovery, geothermal) and waste disposal relating to energy (carbon capture and storage, radwaste) – depends on much greater understanding of subsurface flow and processes. This is particularly pertinent to low-carbon energy because the feasibility of three low carbon energy solutions rely on understanding of subsurface geological containment or flow: carbon capture and storage (CCS), shale gas and radwaste. Lack of understanding and uncertainty feeds through to lack of confidence amongst policy makers and industrial investors, and most of all to lack of public confidence.

An integrated multicomponent sub-surface monitoring infrastructure linked with the European Plate Observing System (EPOS) and the European Carbon Capture and Storage Laboratory Infrastructure (ECCSEL) will allow research into:

1. the impact of deep shale gas drilling and hydraulic fracturing on shallow groundwater and surface water, on seismic activity, and on ground stability and subsidence;
2. processes relating to the containment, confinement, and rates of solution and carbonation of subsurface stored CO2 in carbon capture and storage;
3. processes relating to the containment and confinement of subsurface nuclear and other types of waste; movement of fluids (gas, water, solutes);
4. studies on the impact of coal combustion products on the environment both from surface and subsurface operations (e.g. underground coal gasification);
5. the role of biological mediation in the subsurface in shallow to deep environments;
6. processes at basin and reservoir scale in reservoir stimulation and enhanced oil recovery (EOR);
7. ground deformation and induced seismicity associated with enhanced geothermal systems in hot-rock-dry-rock environments.

The UK would develop a unique package of monitoring capability where monitoring at the surface and in the critical zone will be coupled with deep borehole monitoring of variables such as pressure, temperature, heat flow, seismicity, tilting, strain accumulation, fluid chemistry, pH and biological properties. Monitoring will also include satellite and remote sensed data such as InSAR (Interferometric synthetic aperture radar) and gravity, electrical, spectral and magnetic data.

Infrastructure that underpins research into subsurface activity will make us better at monitoring and managing these new and continuing activities safely and sustainably, including optimising exploration practices. Industry would benefit in being able to access

state-of–the–art monitoring data to maximise efficiency of extraction and subsurface management, as well as maximising environmental sustainability.

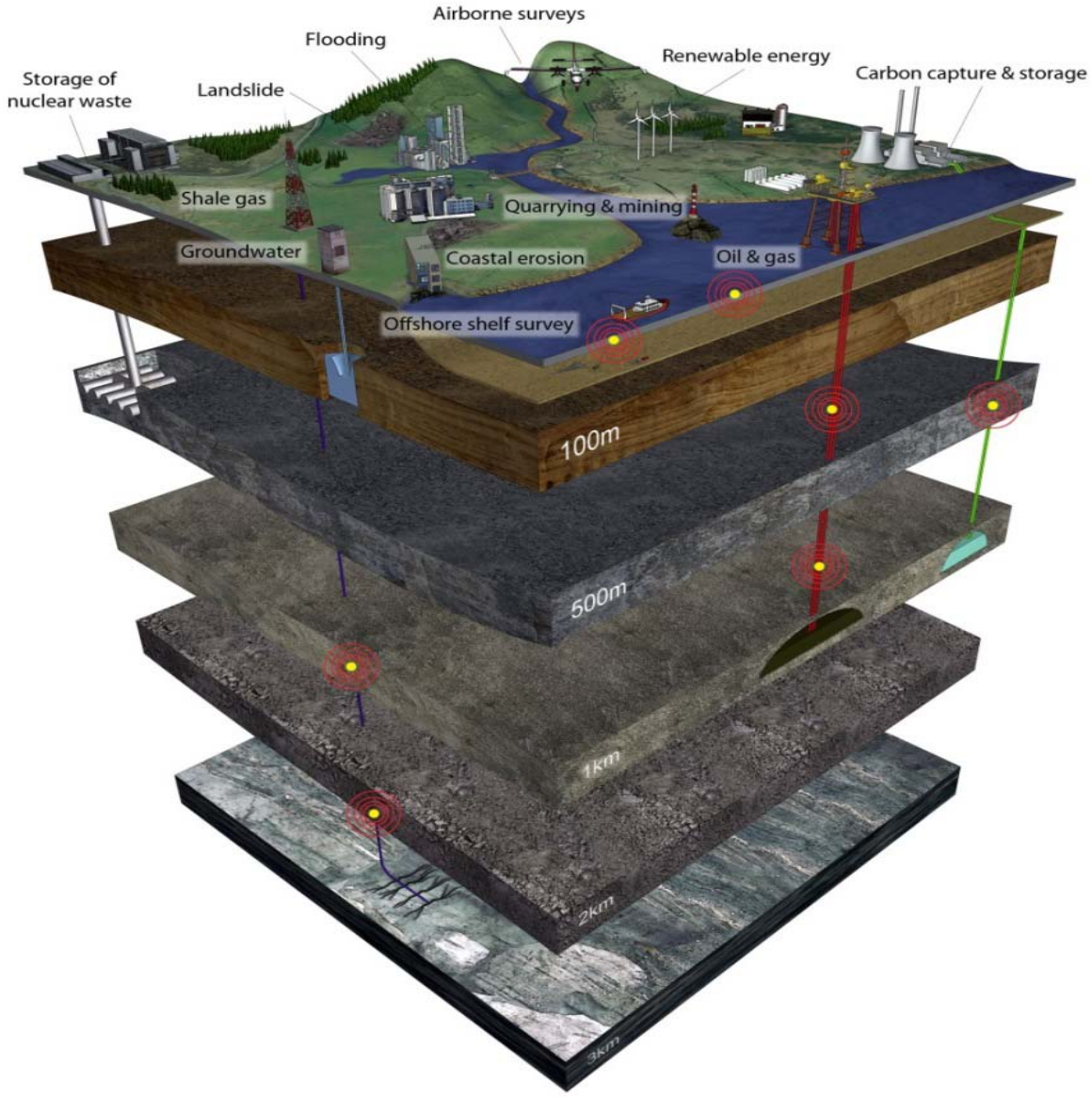

Figure 1 Schematic model of the "energy test bed"

The knowhow and data would also stimulate outside investment and speed new technology energy options to commercialisation, for example compressed air energy storage (CAES) and underground coal gasification (UCG). This would become a competitive advantage in developing British expertise for use in the international energy market.

Conclusion

The research infrastructure will underpin the UK energy industry building on and linking with HEI and industry and existing distributed RIs for example EPOS, ECCSEL.

The European Plate Observing System (EPOS) is the integrated solid earth sciences research infrastructure (RIs) approved by the European Strategy Forum on Research Infrastructures (ESFRI). EPOS is a long-term integration plan of national existing RIs. The EPOS Preparatory Phase (EPOS PP) is the planning phase of this research infrastructure and e-science for data and observatories on earthquakes, volcanoes, surface dynamics and tectonics.
[1]

The ECCSEL consortium teams up selected Centres of Excellence on Carbon Capture and Storage research (CCS) from 10 countries across Europe. The mission is to develop a European distributed, integrated Research Infrastructure (RI), involving the construction and updating of CCS research facilities

The **economic impact** is potentially very large in developing (1) untapped energy resources like shale gas, CBM, UCG, geothermal; (2) methods to sustain fossil fuel reserves e.g. EOR; (3) understanding of storage processes including CCS, gas storage and radioactive waste disposal; and (4) subsurface energy storage such as compressed air energy storage (CAES). Economic value will also stem from management and minimisation of environmental impacts which will protect the environment, ecosystem services, property and infrastructure.

Greater understanding of subsurface processes, if communicated properly, will also allow better public buy-in to subsurface usage and therefore more efficient, streamlined development.

The **scientific impact** of this new infrastructure will be far reaching, including understanding of subsurface flows, geochemistry and physics of rock matrices, and the interaction of surface carbon and other geochemical cycles and subsurface flows.
The new infrastructure will act as a catalyst for industry both onshore and offshore to stimulate investment and speed new technology options to commercialisation, for example CAES and UCG. It will thus act as a bridge from ideas to application and would attract support and possible co-funding from oil and gas companies, utilities and energy and environment consultancies.

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