**RSC response to the House of Commons Select Committee on Science and Technology inquiry into Carbon Capture and Storage Technology.**

The Royal Society of Chemistry (RSC) welcomes the opportunity to comment on the House of Commons Select Committee on Science and Technology inquiry into Carbon Capture and Storage Technology.

The RSC is the largest organisation in Europe for advancing the chemical sciences. Supported by a network of 43,000 members worldwide and an internationally acclaimed publishing business, our activities span education and training, conferences and science policy, and the promotion of the chemical sciences to the public.

This document represents the views of the RSC and has been put together by our Environment, Sustainability and Energy Forum in consultation with the Energy Policy working group. The RSC's Royal Charter obliges it to serve the public interest by acting in an independent advisory capacity, and we would therefore be very happy for this submission to be put into the public domain.

The document has been written from the perspective of the Royal Society of Chemistry consequently our comments relate to only parts of the consultation document. However, the chemical sciences and chemical scientists will play an essential role in driving forward technological breakthroughs in the capture, storage and conversion of carbon dioxide.

The evidence submitted was in the most part published in an RSC report entitled "Chemical Science Priorities for Sustainable Energy Solutions" [www.rsc.org/Gateway/Subject/EnvEnergy/].

The response can essentially be divided into 4 key sections:

1. State of the art in trapping and storing $CO_2$
2. Research and development priorities for trapping and storing $CO_2$
3. Chemical conversion of $CO_2$ in chemicals and fuels
4. Key funding needs

## EXECUTIVE SUMMARY

1 Carbon capture and storage is something that Nature has been doing throughout the Earth's history. For example, huge quantities of atmospheric carbon are captured and stored by the oceans each year.

2 Among the so-called 'greenhouse gases' that contribute to global warming the most important is carbon dioxide ($CO_2$). This $CO_2$ is what humans breathe out every day and produce by burning fossil fuels or in other ways.

3 This Select Committee inquiry is all about how best to deal with the additional carbon dioxide that is being produced by human activity.

4 Although the inquiry is called *Carbon Capture and Storage* this is incomplete. It's also important to consider *Carbon Conversion* i.e. converting carbon dioxide into something not harmful to the atmosphere.

5 The science of chemistry and the skills of the chemical sciences will be vital to our success, especially in the *conversion* of carbon dioxide.

6 One of the vital issues in global warming is how much carbon dioxide ($CO_2$) is released into the atmosphere.

7 There is a general consensus that the world needs to do much more to limit or reduce the amount of carbon dioxide in the Earth's atmosphere produced by human activity.

The key questions are how to achieve this.

8 This is why the Select Committee's new inquiry into *Carbon Capture and Storage* is so timely and important. If we can do more to 'capture' carbon and 'store' it away somewhere – or transform it into something else that isn't harmful - then it means that less carbon dioxide will be released into the atmosphere.

THE CAPTURE OF CARBON

9 Capturing carbon is a critical component of all schemes designed to reduce or eliminate carbon emissions into the atmosphere.

10 A number of different ideas are being actively researched and developed and although these are technically quite complicated they boil down to trying to do one or more of the following:

- Systems for absorbing the carbon into something else
- Systems for separating the carbon out from something else
- Getting rid of the carbon before it's used as a fuel
- Burning fossil fuels in a specific way to produce $CO_2$ that is easier to deal with compared to existing burning methods
- Converting $CO_2$ into something inert and thus not harmful
- Converting $CO_2$ into something useful (and potentially commercially viable in the future)

THE STORAGE OF CARBON

11 One of the potential areas which we need to be exploring now is the idea of storing carbon under the vast oil and gas fields of the North Sea – but we can't afford to wait too long as the existing infrastructure of the oil industry will begin to be phased out as the oil/gas runs out.

12 Other potential storage options for the UK include deep level saline aquifers such as those that can be found in the North Sea.

13 For this innovative under-the-sea storage solution to work we will need much more collaborative research – combining chemists, geologists and engineers – looking into key technical issues like:

- The long-term sealing of oil fields (e.g. in the North Sea)
- The long term integrity of storing carbon under the sea
- How to maximise the amount of carbon you could store
- The best monitoring and surveillance of the stored carbon

14 Some of these ideas have been proven to work but others are only at the research stage – and all the ideas for carbon capture and storage may have disadvantages that also need to be considered.

## Summary

*In $CO_2$ capture and storage, capture technologies constitute a critical component of zero emission power generation schemes. The major thrust of research is in the optimisation of solvent absorption systems, development of new separation systems (membranes and adsorption systems), a move to achieving more concentrated gas streams by way of, for example, pre-combustion decarbonisation or flue gas recirculation with oxygen addition ('oxyfuel') and research into the conversion of $CO_2$ into inert or commercially viable materials. $CO_2$ storage in North Sea oil and gas fields must be addressed now, as this sector moves into the decline phase, to avail of this storage mechanism. Areas which will warrant further attention include collaborative research by chemists, geologists and engineers into: corrosion of well completions and long-term sealing; geochemical and geomechanical impact on the reservoir cap rock and overlying seals (long-term integrity); maximising storage potential and surveillance and monitoring.*

## 1. State of the art

This section summarises the state of the art and discusses those gaps in technology that should be addressed to encourage greater deployment of $CO_2$ capture and storage (CCS). Much of the following is based on discussions and documented outputs of the CO2NET thematic network on carbon capture and storage sponsored by the EU Framework Programme and published in more detail at www.co2net.com.

### 1.1 $CO_2$ Capture

$CO_2$ capture is a well-known technology in different sectors to separate $CO_2$ from flue gas, natural gas and hydrogen (in syngas). Captured $CO_2$ is vented, used for enhanced oil recovery or purified to produce high purity $CO_2$ for niche market applications (e.g. the food and beverage industry). Three process routes are available:

- pre-combustion;
- post-combustion;
- oxyfuel combustion.

#### 1.1.1 Pre-combustion capture

In pre-combustion capture, $CO_2$ is captured from a gas mixture which is produced by partial oxidation of natural gas, coal oil residuals or biomass. This gas mixture contains predominantly $H_2$ gas and $CO_2$ (15– 40%) at a high pressure (15–40 bar). Separating $CO_2$ from $H_2$ is the main task in pre-combustion capture. Physical absorption is the leading option (when partial pressure is sufficiently high), but membranes and cryogenics might become interesting alternatives in the future.

### 1.1.2 Post-combustion capture

In post-combustion capture, $CO_2$ is captured at low pressure and low $CO_2$ content from flue gas by separation from $N_2$ and $O_2$. This technology can be applied to large power plants such as pulverized coal plants and natural gas turbine fired combined cycles, cement kilns and industrial boilers and furnaces. The leading technology in post-combustion capture is chemical absorption using monoethanolamine. Alternative options to capture $CO_2$ from flue gasses are adsorption, cryogenics and membranes, but these options are still relatively expensive.

Pre-combustion capture is considered to be a key technology for the production of hydrogen from fossil fuels, especially in integrated coal gasification combined cycle plants, where $CO_2$ capture could be cheaper and more efficient compared to capture at pulverized coal plants.

### 1.1.3 Oxyfuel combustion

A concentrated stream of carbon dioxide can be produced by the exclusion of nitrogen before or during the combustion/conversion process. The difference with previous process routes is that here the separation is targeted to produce oxygen from air (i.e. separation of oxygen from mainly nitrogen), thereby avoiding the need for $CO_2$ separation. Cryogenic separation is the conventional technology to produce pure oxygen, separating air into liquid oxygen and gaseous nitrogen, argon (which can be sold) and some trace components. Fossil fuels are then burned in an atmosphere of pure or enriched oxygen. A part of the flue gas, which consists mainly of $CO_2$ and $H_2O$, is recycled to the combustion chamber to enhance the $CO_2$ content for subsequent removal. This also helps to control the flame temperature, since current materials applied in the power industry cannot handle such high temperatures. Finally, water is condensed from the flue gas that is not recycled and $CO_2$ is removed by compression. Since the volume of inert gas in the boiler is lower than conventional systems, the boiler efficiency is increased.

This technology has already been applied in some glass, steel and iron industries but has yet to be widely deployed due to the high costs and the energy requirements of the oxygen separation technologies.

### 1.1.4 Biological Capture and Mineralisation

About 90 gigatonnes of carbon are exchanged between the ocean and the atmosphere each year with a net uptake by the ocean of 2.2 gigatonnes. The upper warmer ocean layer contains about 1030 gigatonnes of carbon whereas the deeper ocean stores around 38,100 gigatonnes, drawing 1.7 gigatonnes from the surface layer each year. Acceleration of mineral formation from dissolved $CO_2$ in a controlled manner would enhance the capacity of the ocean as a $CO_2$ sink without the potentially damaging ecological impacts of elevated $CO_2$ concentrations. Wright has suggested that microbial consortia mediate precipitation of a range of carbonates including dolomite and magnetite in ephemeral, highly saline lakes that occur in arid parts of the world. The way in which iron reducing bacteria convert atmospheric carbon dioxide to calcite, aragonite and siderite in ash collection ponds is being examined by Oak Ridge under US DOE funding as a means of sequestering $CO_2$. This has the added advantage of stabilising fly ash into a stable mineral. Several claims are made for this research including combination with agricultural and food processing waste treatment to provide energy for microbial growth.

### 1.1.5 Direct Capture of $CO_2$ from the Atmosphere

In 2001, Lackner, Grimes and Ziock argued that it is technically feasible to capture $CO_2$ from natural airflow at a rate that far exceeds natural photosynthesis. Their idea is based on the construction of many 300 metre tall, 115 metre diameter convection towers, where a down draft is created by cold water pumped to the top of the tower. Air flowing out of the bottom of the tower would pass 9,500 tonnes of $CO_2$ per day through a $Ca(OH)_2$ absorbent. The absorbent would then be regenerated to release a concentrated stream of $CO_2$ for disposal. The authors estimate that the process would cost $10–15 per tonne of $CO_2$. The focus of their paper is to suggest a viable and cost effective alternative to changing the transportation infrastructure to non-carbonaceous fuels and they conclude that all of the $CO_2$ produced by the consumption of transportation fossil fuels could be captured for $0.09–0.14 per gallon of gasoline. Additional costs would be incurred to store or sequester the captured $CO_2$.

### 1.2 Carbon Storage

An example of $CO_2$ storage is the Sleipner West natural gas field production operated by Statoil, in the Norwegian sector of the North Sea. In order to meet market specifications, the $CO_2$ content in the natural gas has to be reduced from 9 % to 2.5 %. Rather than emit this $CO_2$ to the atmosphere, as is a normal practice, Statoil decided to store the $CO_2$ underground. Since 1996, Statoil have been storing approximately 1 megatonne of $CO_2$ per year in a saline aquifer. The saline aquifer is similar to a sandstone reservoir, that contains oil and/or gas, but contains saline porewater instead.

Another example is the Weyburn oilfield in Saskatchewan, Canada. Here, Encana, the field operator, is injecting $CO_2$ to enhance oil recovery (EOR). $CO_2$ is a good solvent for oil that allows the oil to move more easily through the reservoir, aided by a slight increase in the oil volume and improved sweep efficiency of the $CO_2$. The $CO_2$ for this EOR operation is supplied from flue gas from the Dakota Gasification Company in North Dakota. At the end of the EOR operation the $CO_2$ will be left behind in the reservoir. The oil industry, especially in the onshore oilfields of Texas, has been using $CO_2$ for EOR for several decades. Hence the technologies and experience of injecting $CO_2$ underground are already well established.

There are three broad options for $CO_2$ storage: depleted oil and gas fields; deep saline aquifers; and unmineable coal seams. The potential for storage in unmineable coal seams is very small in the UK and will not be considered further in this document. Depleted oil and gas fields offer the advantages of having, by definition, a proven trapping mechanism (though some fields do allow hydrocarbons to migrate out of the main reservoir, occasionally to the surface). Also, due to the exploration and production history, much is known about these traps in terms of their geology, size, storage capacity, sealing caprocks etc. In contrast, saline aquifers have not been studied previously and although their theoretical storage capacity is very large, geologists have not had opportunities to establish this absolutely.

## 2. Research and development issues in $CO_2$ capture and storage

### 2.1 Capture

Amine scrubbing is currently the most widely used process for $CO_2$ capture and has been used, for example, in the Sleipner plant since 1996 to remove $CO_2$ from natural gas. Considerable technical experience exists with respect to generation of relatively small amounts of food-grade $CO_2$ and for relatively low volume industrial purposes such as cooling and fire fighting equipment. However, the process is costly and inefficient when used with the dilute streams of $CO_2$ found in the stack gases from the current generation of fossil fuel power plants. It accounts for more than 80% of the overall cost of the carbon capture and storage (CCS) chain. The development of other more cost effective methods of $CO_2$ capture is one of the key issues relating to CCS (along with public acceptance of geological storage).

Alternatives to amine absorption currently under development include polymers such as polyethyleneimine impregnated on high surface area silicas,  activated carbons or fly ashes that are effective and regenerable adsorbents. The key issues for adsorption separation are to develop an adsorbent with high $CO_2$ separation selectivity and adsorption capacity.  A significant programme on adsorption has been established at the University of Nottingham.

Other methods are under examination (e.g. membrane or cryogenic separation), but the major thrust of research is aimed at achieving more concentrated gas streams by way of, for example, pre-combustion decarbonisation or ‘oxyfuel’ i.e. use of a low nitrogen, high carbon dioxide gas stream for combustion.

More specifically, further research is needed into post-combustion decarbonisation technologies, with a view to validation of absorption technologies in integrated pilot plants and development of novel chemical solvents and associated process technologies with significantly reduced capture costs and energy consumption. Other separation processes to be investigated include membranes, adsorption, high temperature solid sorbents, as well as cryogenic approaches. Similarly, within the field of pre-combustion decarbonisation there is a need for validation of absorption technologies in integrated pilot plants as well as the development of novel reactor concepts for $H_2/CO_2$ separation (e.g. membrane, adsorption and absorption for the enhanced reforming/ gasification process).

Some concepts for generation of multiple products, including $CO_2$ capture, warrant further study. Validation of de-nitrogenation/oxyfuel technologies in integrated pilot plants is also essential, as are novel concepts for oxygen production or oxygen transfer. Further development of fuel conversion technologies should focus on drastic improvements in capture processes or avoidance of separation processes.

Capture technologies constitute a critical component of zero emission power generation schemes. It is necessary to work on the development and validation of new integrated processes providing near complete $CO_2$ capture, while at the same time trying to achieve higher energy efficiencies and/or lower costs. This could also include incorporation of biomass co-combustion and partial $CO_2$ capture as well as multi-pollutant removal concepts addressing, for example, sulphur components, NOX and trace metals.

It is essential that the development of capture processes is properly integrated into complete $CO_2$ mitigation chains, providing enhanced uptake through:

- integration with improved combustion technologies;
- and synergistic approaches for $CO_2$ capture and $CO_2$ storage.

### 2.2 Storage in Oil and Gas Fields

The $CO_2$ storage capacity of old and current oil and gas fields in Western Europe amounts to approximately 37 billion tonnes. Although this is only a few percent of the estimated storage capacity of aquifers, these fields offer a potentially useful test bed and niche market for larger-scale commercial sequestration. If the injection of $CO_2$ into such reservoirs can generate a marketable by-product, through EOR, the net costs of $CO_2$ sequestration could be reduced and this might encourage oil companies with substantial prior experience to participate in the programme. Additional information gained with this type of application will also be relevant for the more general aquifer storage of $CO_2$. Regulatory issues are also likely to be simpler and potential sites could become available earlier than for aquifers.

Most experience of $CO_2$ EOR has been gained onshore in the US and Canada. Operating offshore in the North Sea is a more difficult proposition, though much of the on-shore experience is still relevant. There is, however, an issue of timing. Already many of the large early discoveries in the North Sea are in the decline phase, as is the entire British offshore sector, and the Norwegian and Danish North Sea sectors are predicted to move into the decline phase within a few years. A concern is that older oil and gas fields may be decommissioned before $CO_2$ EOR and enhanced gas recovery (ERG) projects can be implemented.

Many of the major international oil companies, needing a rate of return of 12%, are moving their interests to lower risk areas elsewhere in the world and leaving the North Sea to smaller independent operators. These low cost operators can operate at the end of the maturity line of a field, by operating at a rate of return of 8%, but this leaves little tolerance on such tight margins for new technology in the North Sea. Small operators cannot afford or risk using new technology, as the major operators could. The window of opportunity is therefore shortening.

Issues for which further R&D is either necessary or desirable to optimise storage potential as opposed to the present norm of minimising $CO_2$ generation include the following:

- Geophysical and geotechnical explorations of potential wells
- Corrosion of well completions and long term sealing;
- Geochemical and geomechanical impacts on the reservoir cap rock and overlying seals (long term integrity);
- Maximising storage potential;
- Surveillance and monitoring;
- Technology transfer.

### 2.3 Aquifer Storage

Deep saline aquifers constitute by far the greatest potential for geological storage of $CO_2$, being capable, in principle, of storing several hundred years' worth of Europe's power plant-derived $CO_2$. Suitable aquifers are, however, unevenly distributed throughout Europe, with the majority of the theoretical storage potential located in the North Sea, far away from the main power plants and other major emission points. It should be noted that the UK has one of the largest capacities in Europe for offshore $CO_2$ storage in aquifers. Very considerable aquifer potential does still exist onshore and near-shore, but detailed assessment of the aquifer potential at any given location is a prerequisite to understanding the regional, national or local storage capacity. The information available about saline aquifers is often scant and considerable effort is required to assess the capacity and suitability of various aquifers.

Although a number of technical issues dealing with storage safety, monitoring and longevity are still outstanding, the public acceptance of geological storage is probably the overriding issue. To address public acceptance, it is important to carry out a number of onshore geological storage pilot projects, selected to represent a geographical spread and a range of geological conditions. The European Commission's 6th Framework Programme will provide the first such small scale demonstration. Following these projects, there will be a need for several other small projects, as well as a few concerted projects at greater scale, bringing European policies and the main players together in one or just a few activities.

The rolling out of geological storage demonstrations across Europe is perceived to constitute the main scientific bottleneck to the successful deployment of CCS. In other words, it does not matter how much $CO_2$ can be captured, and at what cost, if geological storage cannot obtain public acceptance as a safe, long term $CO_2$ abatement method.

With respect to subsurface processes, further research requirements include laboratory experiments to improve knowledge of the behaviour and physical properties of $CO_2$ at reservoir conditions that include increased temperatures, pressures, and salinities, and account for the presence of other fluids and organics. These complex conditions can affect the chemistry of $CO_2$/rock/reservoir fluid interactions and compromise the sealing capacities of overlying caprocks. In conjunction with the improved knowledge at the small-scale, it is essential that *in-situ* field experiments are conducted. These should aim to elucidate the effects of different geological settings, geological variance, $CO_2$ migration and long term processes using and integrating natural analogues and laboratory experiments, as well as identifying suitable sites for demonstrations. In addition, research should focus on the potential impacts on both offshore and onshore ecosystems of spatially restricted but very high concentration $CO_2$ leaks, thereby helping to define site performance and safety criteria. Methodologies and protocols should be developed for long term performance assessment of storage sites. These will integrate much of the disparate research needs and knowledge described above into long-term predictions of probable risks and potential impacts of $CO_2$ leaks.

In the field of material and equipment development, the utilisation of aquifers requires further development of corrosion resistant material (e.g. pipes, pumps, cements) and cheap, long-life measuring sensors for down-hole (e.g. leak detection, pressure and temperature gauges) as well as surface uses (e.g. gas sniffers, seismology and compaction sensors). There is also a need for the further development of new cheap, high resolution $CO_2$ plume monitoring methodologies.

### 2.4 The chemistry of $CO_2$ / rock /reservoir fluid interactions.

There is a growing literature regarding the long-term interactions between $CO_2$ and the minerals present in the receiving reservoir both as solids and in solution. These interactions will play a major role in determining the eventual form of the stored $CO_2$ and hence the risks associated with leakage and escape to the atmosphere. The long-term geochemical interactions in both the reservoir and caprock, which prevents the fluid ($CO_2$, hydrocarbons or water) moving upwards, are very important in CCS. Predicating these reactions over geological timescales with confidence can be challenging since increased temperatures, pressures, and salinities, must be accounted for. If the $CO_2$ could be more permanently locked up through precipitation as a carbonate within the reservoir this would increase the security of storage. In addition saline porewaters saturated with $CO_2$ are denser than the surrounding porewaters so they would tend to 'sink' rather than the 'pure' supercritical $CO_2$ fluid which has much lower density and hence naturally buoyant and wants to rise up, increasing the risk of leakage. One of the key issues for storage is the stability of cements over long (geological) periods used to seal the boreholes. Low pH porewaters resulting from injected $CO_2$ can readily dissolve cements, which therefore necessitate an investigation into the pH evolution of porewaters, since pH essentially controls the precipitation of carbonates as well.

## 3. Conversion of carbon dioxide into chemicals and fuels

It is important to note that the majority of the technologies discussed so far involve trapping and storage of $CO_2$, however, from a chemical science perspective $CO_2$ can also be seen as potential feedstock for the manufacture of useful chemicals and as such chemical conversion of significantly large amounts of carbon dioxide to inert or commercially useful material is an option that **cannot be ignored**. This is a key challenge that the chemical sciences will rise to meet if a framework of continued and dedicated funding is in place to reflect the significant research effort that is required. In this section a number of ongoing research projects are detailed.

A substantial amount of research has been carried out to find an economic route to the preparation of carbon monoxide (CO), methane and methanol by chemically reducing carbon dioxide. For example, $CO_2$ will react with hydrogen over a nickel catalyst in the Sabatier reaction to generate methane, and the reverse water-gas shift reaction can be used to convert $CO_2$ to carbon monoxide as a feedstock for higher hydrocarbon production. These two reactions have both been explored for space exploration as a means of recycling $CO_2$. Syn gas may also be generated by reforming natural gas with $CO_2$ as well as with steam.

Less conventional routes have also been proposed for the reduction of $CO_2$. In 2002 Nakamichi Yamasaki of the Tokushima Industrial Technology Center in Japan claimed that carbon dioxide and hydrochloric acid in the presence of iron powder at 300ºC and 100 atmospheres will yield substantial amounts of methane, ethane, propane and butane. However, these promising observations don't seem to have led to anything yet.

The search for catalysts that will unlock a commercial route to the activation of $CO_2$ will no doubt continue and is founded on a growing body of published literature.

More recently there has been growing interest in understanding the photochemical processes by which plants algae and certain bacteria are able to utilise light to drive charge separation processes within the cell that eventually lead to the reduction of carbon dioxide and the synthesis of carbohydrates.

Over the last 15 years, much research effort has been devoted to finding ways of mimicking the mechanism of photosynthesis for conversion of $CO_2$. One approach has been to construct artificial photocatalytic systems, which are able to use light energy for the reduction of $CO_2$. However, there is a need for fundamental research to overcome the key problems that still remain to be solved in this very complex area of photocatalytic $CO_2$ activation, particularly understanding how to increase the present unsatisfactory efficiency both with respect to the value of the reduction products of $CO_2$ (usually C1 products) and also to the oxidation products of the sacrificial electron donor. The University of Nottingham is currently looking into developing catalyst materials that can mediate the photochemical reduction of $CO_2$ with water using near UV/visible light to produce fuels. This holds promise to develop systems that can mediate $CO_2$ photoreduction with sunlight. Substantial progress has already been made in this field with the demonstration of photo-reduction of $CO_2$ to methanol using a variety of transition metal complexes.

An alternative electrochemical route is being pursued by CSIRO who are investigating the use of a 200 nm porous Au electrode, supported on a polymer membrane, for electrochemically reducing $CO_2$ to carbon monoxide (CO) at near-ambient pressures.

Finally, another potential chemical approach to sequestration is the transformation of $CO_2$ into inert, long-lived materials, such as magnesium carbonate. This process is known as mineral carbonation and mimics the natural weathering of silicate rocks. Although the reaction is thermodynamically favoured, it is extremely slow and the challenge is to increase the reaction in order to be able to design an economically viable process.

At this stage it is clear that the transformation of $CO_2$ into useful chemicals can be achieved either by chemical processes or by moving towards artificial photosynthesis. There are considerable scientific and economic challenges to be overcome in this area of research before such processes are feasible on a large-scale, but it is important to note that this research offers a **genuine use for $CO_2$ rather than a "storage option"**. With the correct funding and political framework in place this research could lead to a future scenario where significant quantities of fuels and chemicals are synthesised from $CO_2$.

## 4. Key funding needs:

- Government needs to put into place a framework to provide incentives (most likely fiscal incentives such as R&D tax credits) to promote R&D associated with sustainable energy technologies.
- Significant long-term funding is required for fundamental chemistry and application specific chemistry to stimulate and encourage energy related research; innovative, ground-breaking energy related R&D will rely on a strong chemical science base (e.g. materials chemistry, catalysis and combustion chemistry) in the UK.
- Significant and continued funding for the chemical science research and demonstration of technologies for the chemical conversion of $CO_2$ into inert or useful chemicals is required if the opportunities for utilising trapped $CO_2$ is to be realised.
- Incentives are required to recruit and retain outstanding, internationally competitive scientists to work on energy related research in the UK. Incentives to attract international researchers to work in these areas are required to ensure that R&D happens now.
- Funding is needed for pilot studies of the above $CO_2$ sequestration methods. These pilot studies are required in order to assure public acceptance and praise once the required fundamental research is complete.