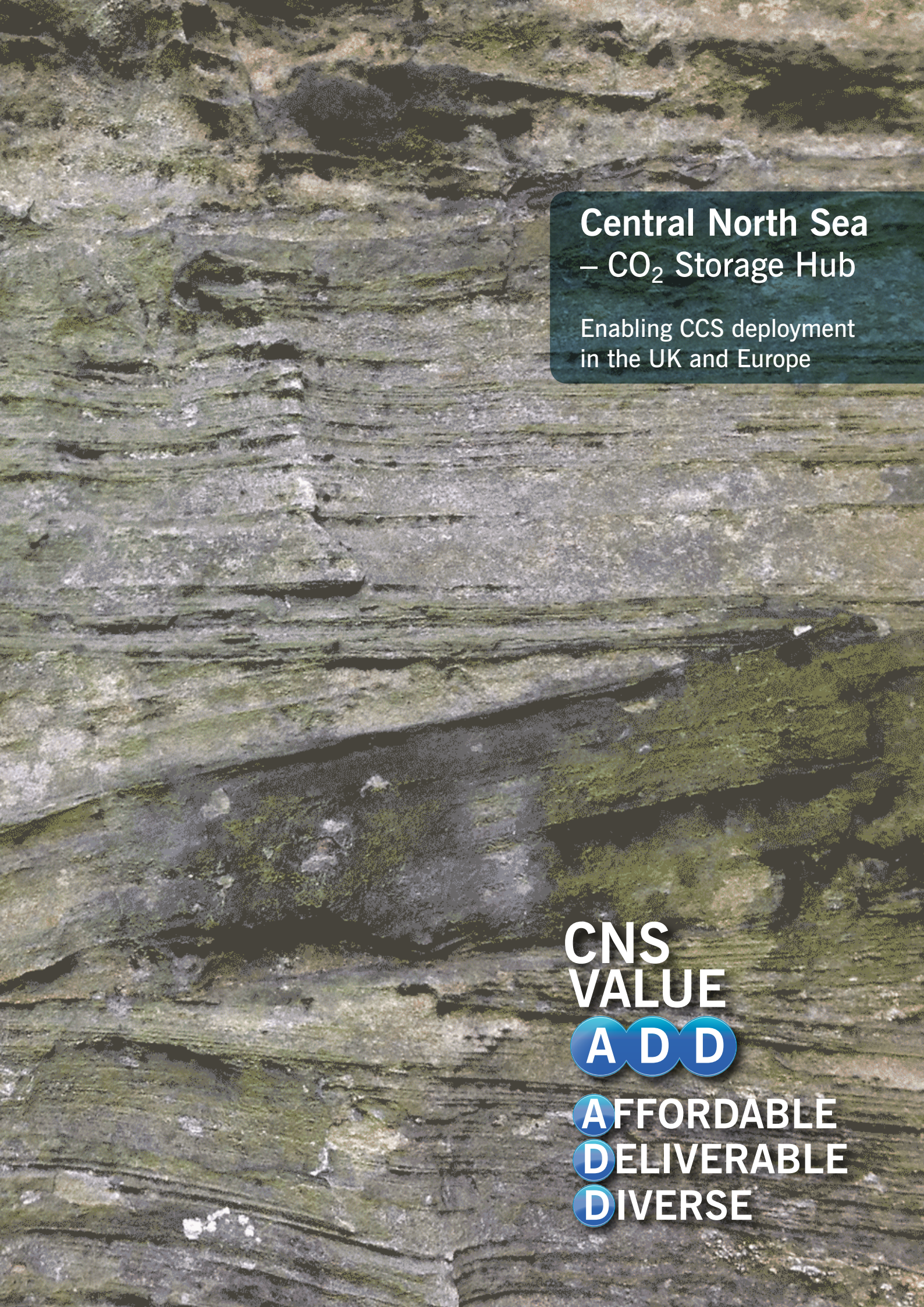


Central North Sea – CO_2 Storage Hub

Enabling CCS deployment in the UK and Europe

CNS VALUE ADD

AFFORDABLE
DELIVERABLE
DIVERSE

Central North Sea – CO_2 Storage Hub

Enabling CCS deployment in the UK and Europe

Some CO_2 capture technologies are commercially available today and the majority can be applied across different sectors, although storage issues remain to be resolved

International Energy Agency
Energy Technology Perspectives 2012

Experience worldwide, and throughout history in developing new technologies shows that rapid learning and cost-reduction comes from constructing and operating a series of medium-sized projects.

Bigger is not better, as that has the same learning, but for more cost and more scale-up risk. The Central North Sea can produce multiple CCS projects more quickly than anywhere else in the UK. Accessing the Central North Sea is easiest from Scotland, Teesside and Yorkshire. The CNS fulfils the UK's own needs, and also opens a gateway to Europe, to safeguard high value jobs in the UK and provide long-term taxable revenue.

Professor Stuart Haszeldine OBE,
University of Edinburgh, Research Director SCCS

Peterhead Power Station - Courtesy of SSE

1

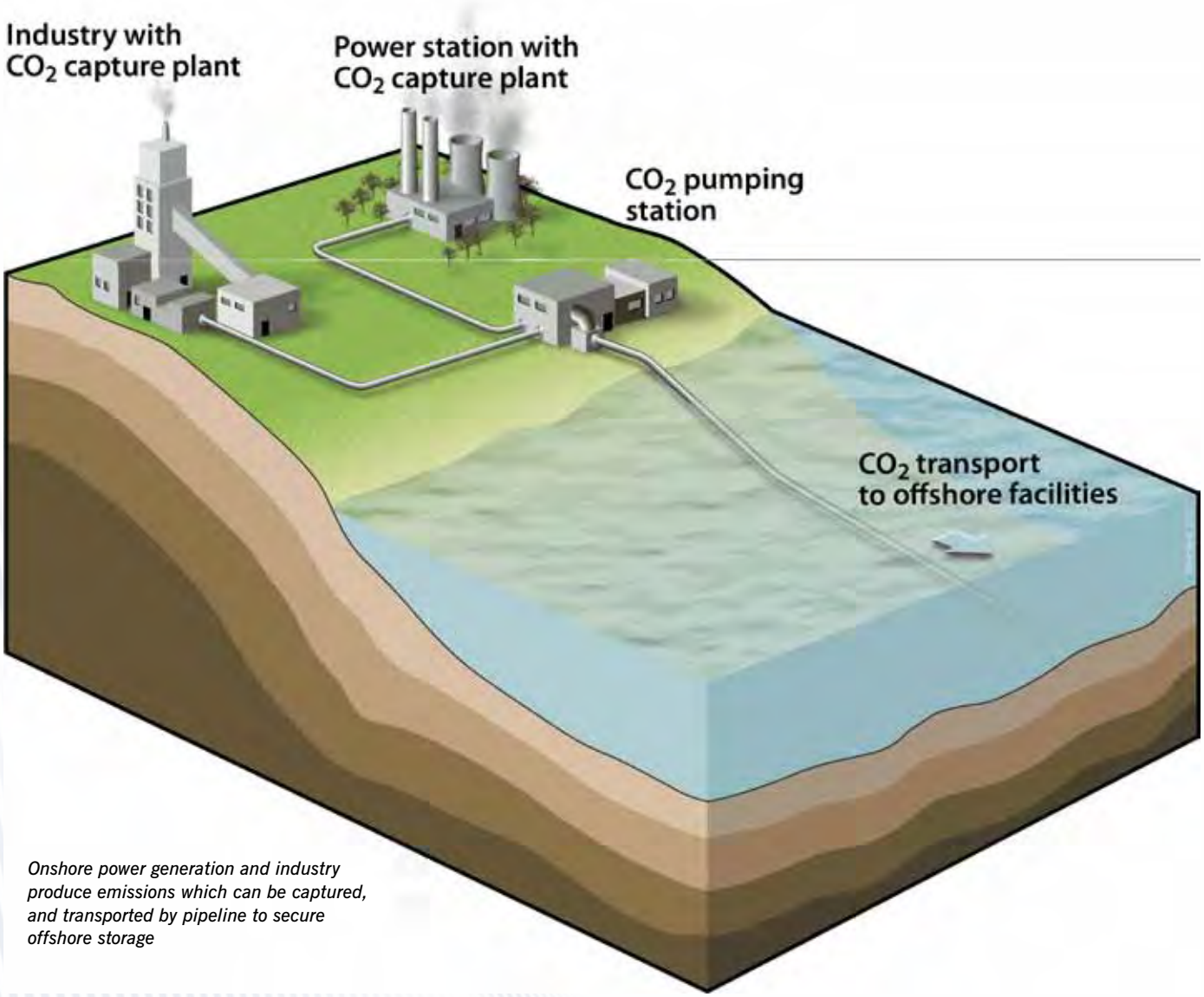
The need for CCS

Carbon Capture & Storage is widely recognised as a vital technology which will play a significant role in the generation of low carbon electricity. CCS has the potential to reduce the carbon emissions of fossil fuelled power stations by as much as 90% as well as offering the only realistic solution to heavy industrial emitters such as steel mills, petrochemical refineries and cement manufacturing plants.

Projects which can combine capture of emissions from power generation as well industrial emitters will enable the development of CO_2 transport infrastructure which can act to safeguard existing employment in carbon-intensive industries within the UK and EU. CCS development zones can also attract new energy intensive industries to locate into an area with an established network of CO_2 pipelines. That means low marginal costs to connect into a guaranteed network for transportation and storage of captured CO_2.

Recent studies examining the levelised cost of electricity have consistently demonstrated that CCS will be competitive with renewable generation technologies such as offshore wind. CCS provides a low-carbon solution to the issue of intermittency which is inevitable with wind power, thereby helping to address the need for energy security in a future which will see a growth in the percentage of power generation from renewable sources. Fossil fuels will be part of the energy and industry system for many decades to come. CCS is the only viable option for abating those CO_2 emissions.

The creation of a CCS industry in the UK will provide opportunities for economic growth through the retention of many thousands of high-value jobs, creation of thousands of new jobs, increased manufacturing activity, as well as retention of the UK's world leading oil & gas supply chain for home investment and billions of pounds in export services.



Onshore power generation and industry produce emissions which can be captured, and transported by pipeline to secure offshore storage

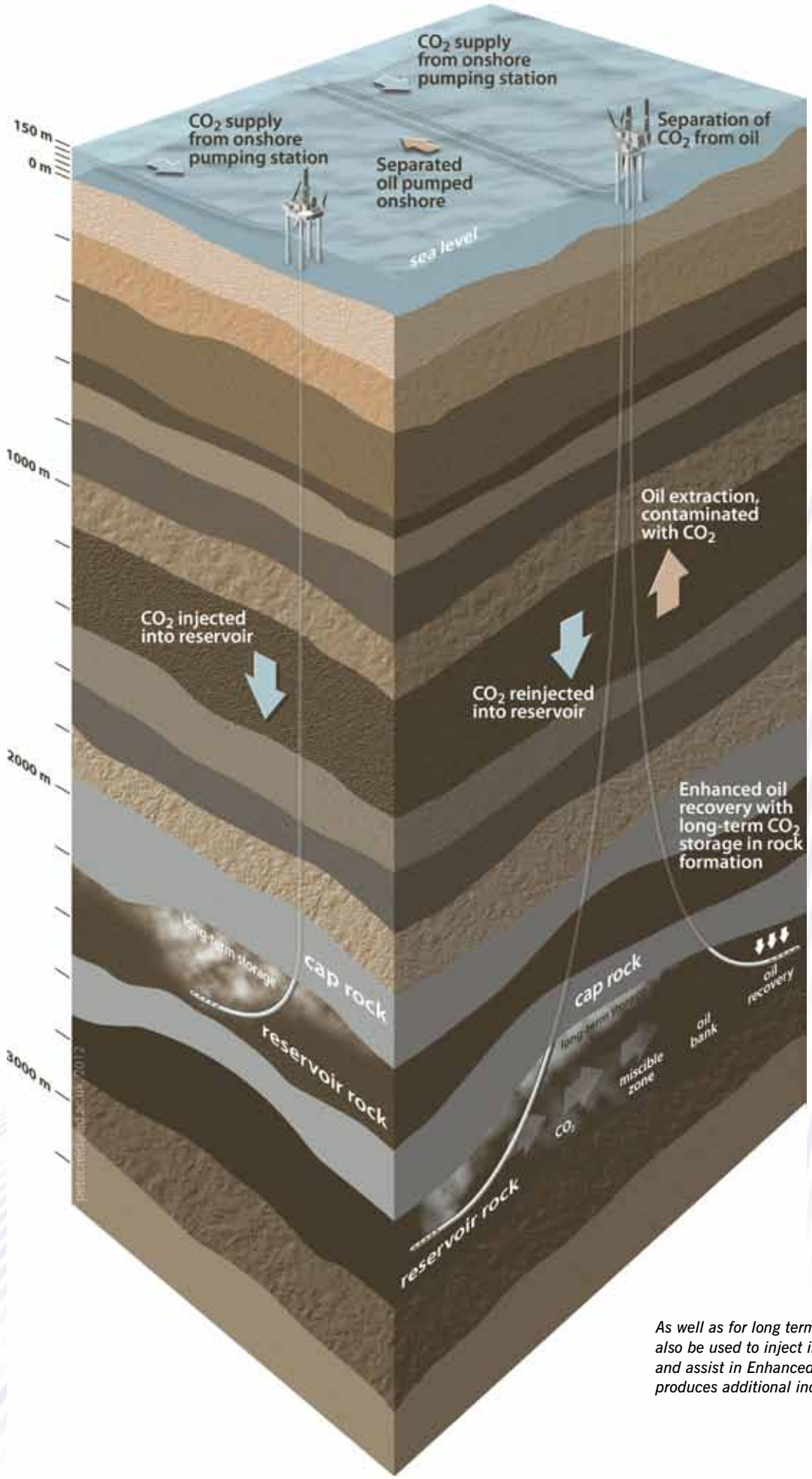
Business innovation is supported by Scotland's world leading research universities. Networked together in the Energy Technology Partnership, there are 600 energy researchers, with global standards of research excellence, training diversity, and proven commercialisation success.

UK based companies such as Doosan Power Systems, Wood Group and Mott MacDonald have already been involved in the successful delivery of manufactured goods and technical services for the fledgling CCS industry across the world.

UK offices of major international organisations (Amec, Arup, Alstom, PB Power, Costain, BP, Shell, Petrofac) are also strongly committed to CCS technology development and business innovation.

Coupled with Enhanced Oil Recovery, which is a commercial opportunity much stronger in the CNS (Central North Sea) than elsewhere, the CCS industry will generate billions in additional tax revenue (initial estimates suggest up to £9bn[1]) for government over a number of decades.

[1] http://www.scottish-enterprise.com/~/media/SE/Resources/Documents/DEF/Economic%20Potential%20of%20CO2%20EOR%20in%20Scotland.pdf



As well as for long term storage, CO_2 can also be used to inject into depleted oilfields, and assist in Enhanced Oil Recovery which produces additional income.

1

Why the Central North Sea

When it comes to making CCS a reality, the UK has an unmoveable and unique advantage. Nowhere else in the EU is as close to the geologically near-perfect, and technically diverse, sub-surface CO_2 storage sites available within Central North Sea. Deep beneath the waters of the Moray Firth, the Captain Sandstone alone has already been shown to have enough capacity to safely store the next fifty years of emissions from UK fossil fuelled power plant. Nearby, another ten reservoirs can easily hold one hundred years worth of Europe's CO_2 emissions [2, 3].

The CNS can be confidently described as a Value ADD proposition:

	Now	Future
Affordable	Characterised storage sites Power/Industrial cluster potential Employment safeguarding and creation Existing expert supply chain Significant existing and reusable infrastructure Best Value for Money option for UK	Long term export opportunity Low cost storage solution for wider CCS deployment Reuse of depleting hydrocarbon fields and paid for infrastructure Potential to enable wider CCS deployment across EU
Deliverable	Multiple stakeholder support Supply chain capability and capacity Geological appraisal of numerous storage sites completed World leading academic/industry collaboration	World leading demonstration of CCS Increased supply chain capability and export growth EU scale storage capacity
Diverse	Hydrocarbon reservoirs linked to wider aquifer storage capacity EOR potential providing increased tax revenue Fit with DECC ambition to extend production life of North Sea Oil & Gas Shipping infrastructure potential	Scaleable to provide storage solutions for EU CCS projects Increased storage/EOR potential from depleting hydrocarbon fields

[2] www.sccs.org.uk/scottish-regional-study
[3] www.sccs.org.uk/progress-to-co2-storage-scotland

CNS VALUE ADD

AFFORDABLE
DELIVERABLE
DIVERSE

Value

Projects proposing to utilise the CNS for storage will demonstrate excellent value for money and can provide the same amount of learning for less cost when compared with projects elsewhere.

Affordable

Much of the infrastructure needed to develop CCS is already in place thanks to the legacy of North Sea Oil & Gas.
The skilled people are already available, because the UK has a uniquely long and diverse history of energy innovation, coupled with a present-day renewable energy revolution. Throughout the UK, there are companies which can fulfil every aspect of the CCS supply chain – quickly, reliably and innovatively whilst providing excellent value-for-money.

Deliverable

A CCS Cluster in the Forth Estuary will be closest to the CNS CO_2 storage hub at St Fergus and Peterhead, with access also easily achievable from high emissions clusters in Teesside and Yorkshire. There's a genuine 'can do' culture already evident at local, regional and national level. By recently leading one of the world's most detailed FEED studies for commercial CCS, organisations from government to industry and regulator throughout the CCS chain have developed an unmatched body of knowledge[4]. These working practices provide practical assurance, which continues to attract CCS project developers to the region.

Diverse

The scalability, connectivity and diversity of storage opportunities in the CNS region mean that businesses of all sizes can participate in the process at different stages along the chain. With the region's geology comes a naturally diverse opportunity which will provide multiple operators with a range of storage options for many years to come. With diversity comes reduction of risk; storage in other parts of the UK will rely on single geological types which means vulnerability to single-point-failure. The CNS has multiple geological styles as geological backup to reduce such worries. With the added opportunity for CO_2 - Enhanced Oil Recovery[5], the CNS can help prolong the UK's strategic hydrocarbon reserves and sustain the North Sea Oil & Gas industry for many years into the future, protecting and creating jobs, generating revenue and building a globally competitive UK supply chain which can deliver CCS, and CO_2 - EOR projects elsewhere.

[4] www.sccs.org.uk/cassem
http://www.decc.gov.uk/en/content/cms/emissions/ccs/ukccscomm_prog/feed/scottish_power/scottish_power.aspx
[5] www.sccs.org.uk/censeor-co2
http://www.pet.hw.ac.uk/research/hrm/index.cfm

3

Investment and Funding

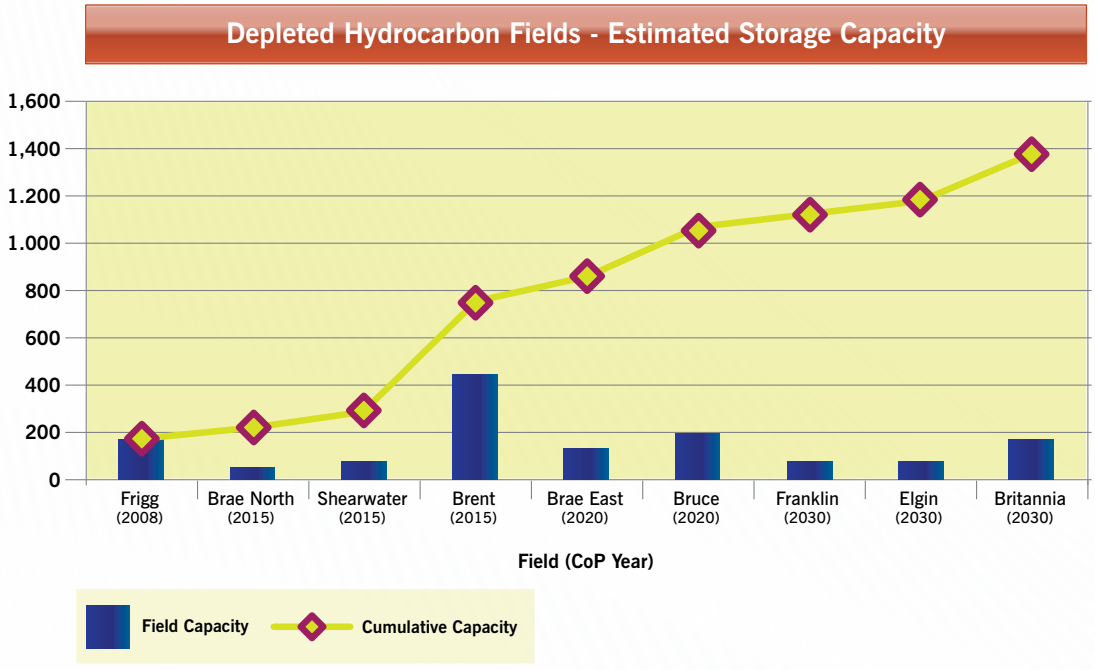
In April 2012, the UK Government launched the CCS Commercialisation Programme which will provide up to £1bn in competitive capital funding to support the design and construction of practical systems for the demonstration of CCS at commercial scale. Amongst the aims of the programme are:

- Delivery of cost effective CCS in the UK by the mid 2020s
- Communication of the key learnings "from doing" commercially viable, cost competitive CCS
- Developing a UK CCS infrastructure to establish a cost competitive CCS industry for the UK

Projects which intend to utilise storage assets in the Central North Sea can provide the UK taxpayer with value for money against all of the above criteria by utilising existing infrastructure, opening up networks which can be used by future projects and establishing the first round of storage sites that are linked to a longer term opportunity sufficient for storing CO_2 on a European scale.

Real progress is already being made to develop the CNS and the Captain Aquifer as the ideal storage hub from the United Kingdom. In mid-2012, the UK's first agreement for lease (AfL) for the permanent storage of CO_2 was signed by The Crown Estate and the Peterhead CCS Project regarding storage of CO_2 at the offshore depleted Goldeneye gas field.

In addition to this an AfL relating to CO_2 storage in the Aspen storage site, also within the Captain Aquifer, is in the process of being finalised for signature later in 2012 between The Crown Estate and the Captain Clean Energy Project. This "first-mover" activity clearly demonstrates that the CNS is the right place for the UK to put its CO_2.



Depleted hydrocarbon fields offer an easily accessible, and geologically well known suite of opportunities for CO_2 storage. This graph shows Millions of tonnes CO_2 storage capacity available in selected large oilfields, with their projected dates of availability (data from SCCS 2009).
These storage estimates are based on existing conditions, ie with no additional EOR. If CO_2 - Enhanced Oil Recovery occurs to assist financing, that will create additional "space" enabling more CO_2 to be stored.

The CCS Commercialisation Programme also identifies a need to establish networks for the future to allow industrial emitters to capture CO_2 from their processes. Early deployment of CCS on power stations adjacent to existing transportation infrastructure can be the starting point for the development of such emitter CCS clusters. The creation of a CNS CO_2 storage hub will reduce the entry costs for industrial capture projects. Investment by some of the proposed €10bn EU Energy Infrastructure Package, can build pipes and ports linked to commercially proven storage, and allow member states to store their captured emissions in the CNS; this investment will provide a long term opportunity for the UK Oil & Gas sector by capitalising on the world leading offshore supply chain expertise that already exists.

A recent study commissioned by Scottish Enterprise[6] details a number of technically viable options for importing CO_2 via Peterhead Port in North-East Scotland to allow onward transport of CO_2 via existing or new pipeline infrastructure to storage sites in the CNS. With an estimated range of capital expenditure between £64 million and £100 million to allow the importation of up to 4 Mt CO_2/year initially, this will provide an affordable and flexible value for money early solution to ship CO_2 from distant CCS projects to share the storage sites which are developed in the CNS during construction of the first UK demonstration projects.

In addition, it is estimated that the development of such an import facility would lead to the creation of over 500 jobs and additional GVA in excess of £140 million. The import facility is scalable, to accept shipping of much greater import tonnages. Legacy pipelines are already available for offshore transport to the Norwegian border. Additional legacy or new pipelines will rapidly add to this offshore network, taking CO_2 to profitable CO_2-EOR site clusters or to low cost storage in shared saline aquifers.

The CNS offers diverse oilfields as storage sites, with well understood reservoirs. Even without CO_2-EOR (Figure opposite), these can accommodate CO_2 storage startups totalling 1,400Mt CO_2. This is equivalent to 5 large coal plant, plus 14 gas plant for 20 years of operation. Deploying CO_2-EOR to assist with financing, will increase these storage tonnages by a factor of 3.

[6] http://www.scottish-enterprise.com/~/media/SE/Resources/Documents/PQR/PeterheadCO2ImportationStudyPreliminaryFindings.pdf

4

The CNS CO_2 Storage Hub pathway : learning fastest

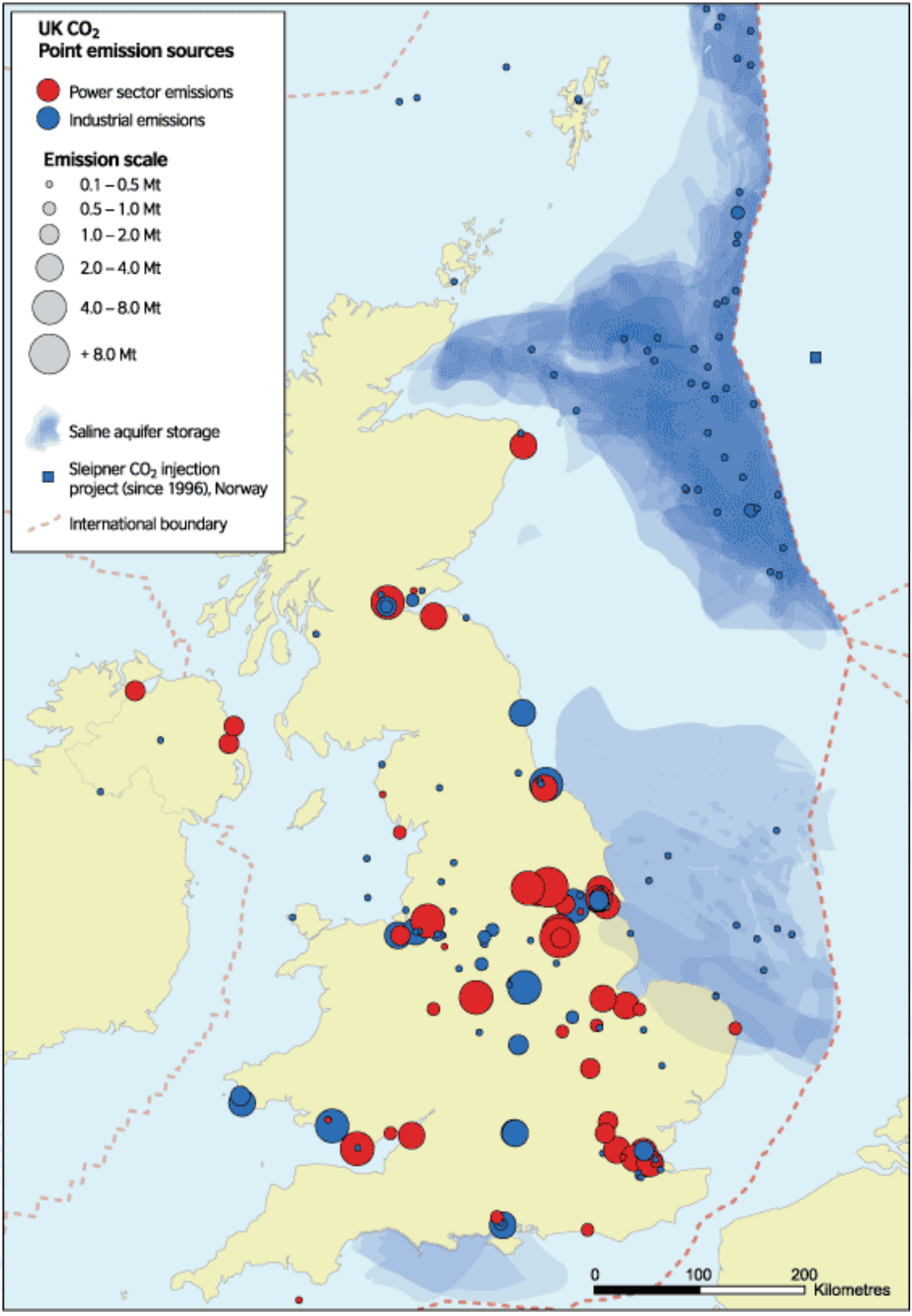
Why CNS? It is well known where the CO_2 emissions arise in the UK, and it's clear that the east of the UK, particularly Yorkshire and Tees-side, have a lot of CO_2. But where can all that CO_2 go to? Although saline aquifers are undoubtedly part of the CCS future, how do those sites get developed cost-effectively and securely? All the oil is in the CNS and northwards, so that is a more attractive business and tax target than saline aquifers. The answer lies in the CNS, which is unique in offering well-researched, reduced pressure, gas fields as secure entry points closely located to oilfields suitable for CO_2-EOR and intimately interconnected to saline aquifers for many decades of future CO_2 tonnages.

One objective of UK investment in CCS is to enable cost-reduction for future CCS projects. Can this be delivered by investing in the CNS? Yes it can. To achieve cost-reduction for newly developing technologies, it is well established that accumulation of experience in designing and building leads to cheaper pricing. Doubling the number of units built typically reduces costs by 10 -15%. So it is clear that learning will be fastest by building several small projects in sequence.

If the "lessons learned" are effectively transmitted to the next project, then each new project will be cheaper than the one before. For CCS, a series of small power plant and industry projects will learn to reduce costs faster than one big project.

Building three CNS projects in series can reduce costs for 2025 projects by 15 - 30% and commercially prove multiple types of storage. CNS offers the best UK opportunity to connect-in diverse small projects onshore, whilst also testing a diversity of storage options offshore.

Map opposite shows the present day CO_2 arisings on shore and offshore from power generation and industry. It is clear that most of the UK's CO_2 lies within 100km of the east coastline. Offshore shading shows the shapes of the multiple saline aquifer storage regions, which comprise 95% of the UK's CO_2 storage. When these lie on top of each other, a darker blue colouring results. Those dark blues are also the place to go for diversity of secure geology, and for cost-reductions in shared evaluation, shared access, shared monitoring, and in income from oil recovery. It is clear that the great abundance of CO_2 storage, as well as the oil, lies beneath the CNS. Some of this storage has already been proven and exploited commercially since 1996, by the Sleipner CCS project in Norway (blue square). How to develop these UK sites, is shown on pages 17-21.


UK CO_2
Point emission sources
Power sector emissions
Industrial emissions
Emission scale
0.1 – 0.5 Mt
0.5 – 1.0 Mt
1.0 – 2.0 Mt
2.0 – 4.0 Mt
4.0 – 8.0 Mt
+ 8.0 Mt
Saline aquifer storage
Sleipner CO_2 injection project (since 1996), Norway
International boundary
0
100
200
Kilometres

CNS is accessible to CO_2 from large oil refineries, from Forth, Tees and Yorkshire - helping to preserve and secure thousands of jobs.

5

The CNS CO_2 Storage Hub pathway :focusing on cost and risk

Scotland is offering CCS on a number of medium-sized power projects now, with the prospect of more similar projects in the near future. That means Government grants and Contracts for Difference can buy the same learning, in each of two or three small projects, that is gained by spending all of the money on one large or expensive project. That's delivering value now.

Which parts of the chain do we need to learn? Those engaged with CCS would agree that the main cost lies with capture and the greatest gains are to be made in making that more efficient. The main uncertainty lies with storage, and providing that predictions will be validated, the gains will come from injecting large enough CO_2 volumes to prove a storage site is functioning. The main risk lies in the business partners and funding model holding together.

A CNS CO_2 Storage Hub can utilise existing pipework. That greatly reduces costs and time associated with new planning consents which consequently reduces construction times as well as project risk. The learning investment is focused on different CCS plant and capture types – including both gas and coal fuels; focused on testing several types of storage, including CO_2 - EOR, which are close together for mutual support in case unforeseen events require a change of plan; and focused on the diverse experiences of different management teams.

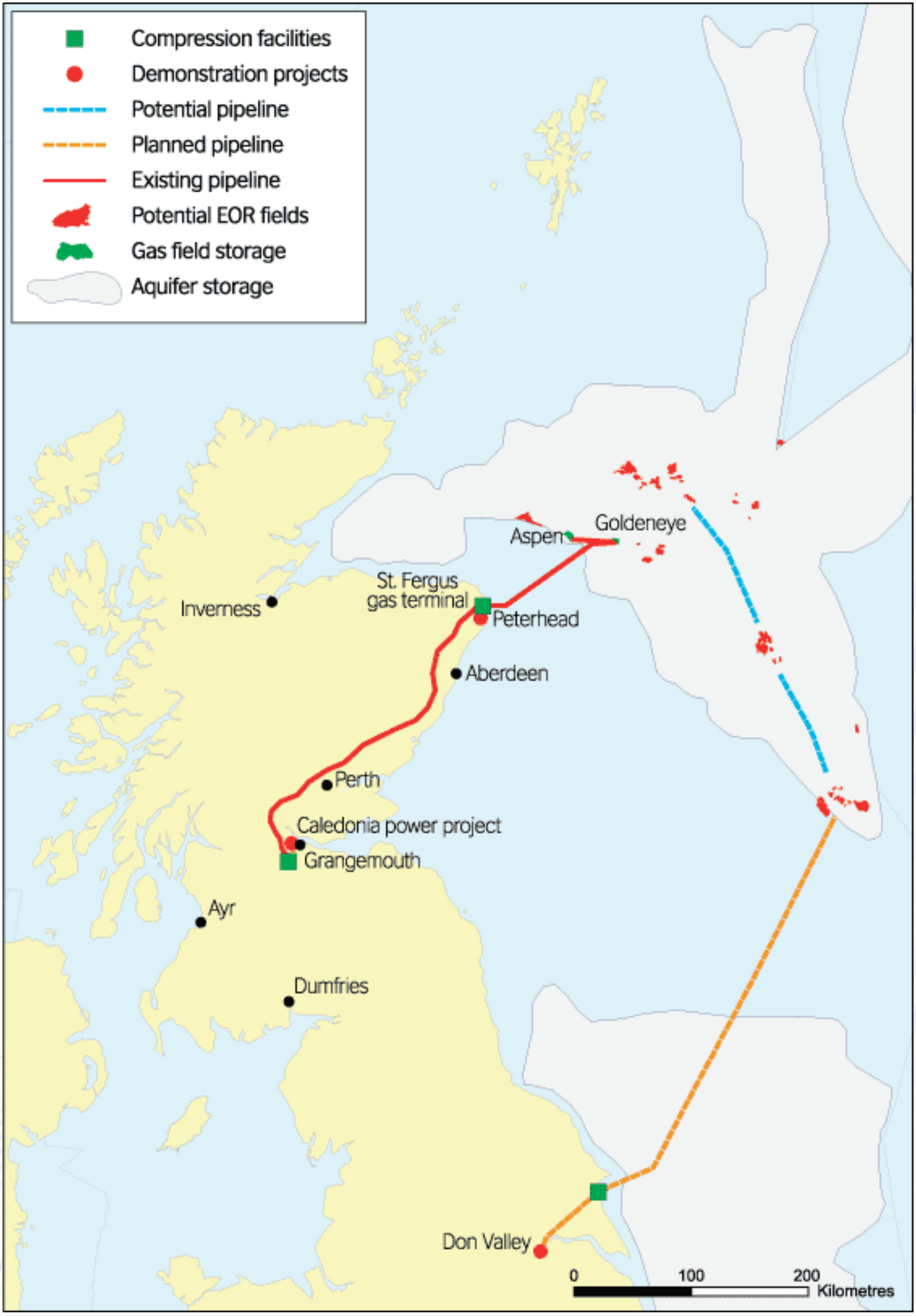
6

The CNS CO_2 Storage Hub pathway :now and future evolution

2020

In the 2012 DECC Competition, the CNS is an integral part of projects spanning the CCS fuel and capture range: post-combustion capture on gas (Peterhead), pre-combustion capture on gasification of coal (Captain Clean Energy Project) and CO_2 - EOR (Don Valley). These form the foundations of a durable and highly scalable cluster, which can service all UK needs and has European impact.

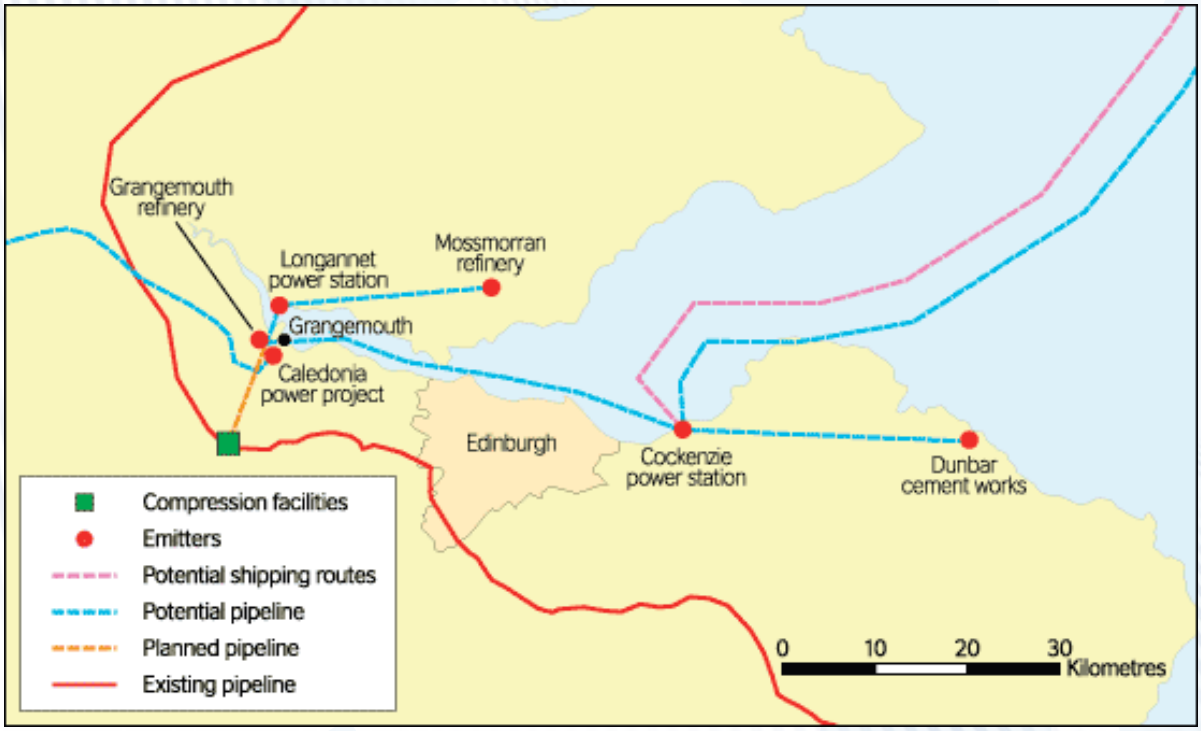
These power plants can be connected into a pipeline network which largely exists. Current industrial CO_2 emissions can be added in to this network at an early date. An offshore "A to B" pipeline starts to develop CO_2 - EOR. ***Total storage 5 - 10Mt CO_2/year***

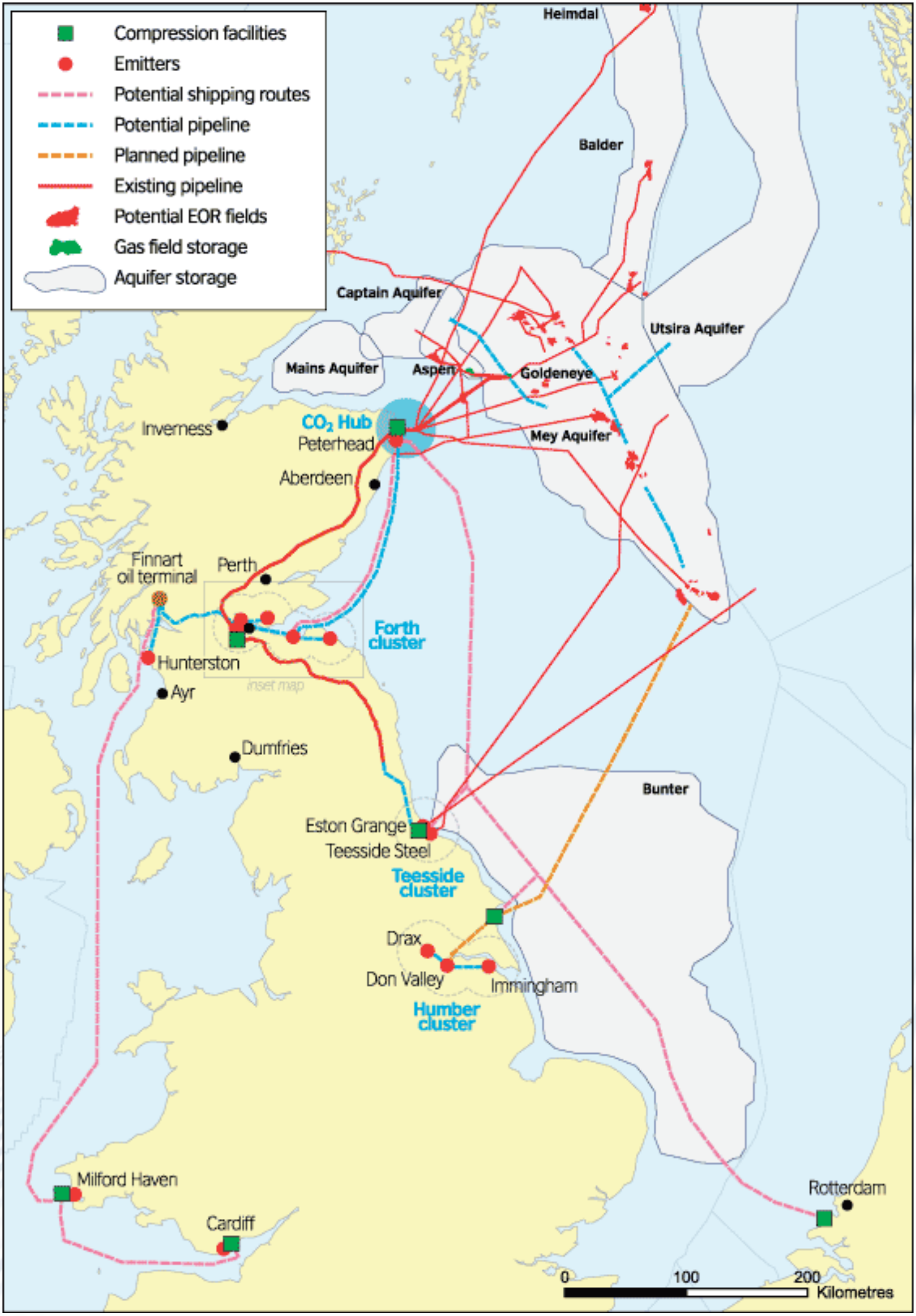

Compression facilities
Demonstration projects
Potential pipeline
Planned pipeline
Existing pipeline
Potential EOR fields
Gas field storage
Aquifer storage
Aspen
Goldeneye
St. Fergus
gas terminal
Peterhead
Inverness
Aberdeen
Perth
Caledonia power project
Grangemouth
Ayr
Dumfries
Don Valley
0
100
200
Kilometres

2030

New gas or coal plants will have been developed on existing brownfield sites at Cockenzie and Longannet, with minimal marginal cost to connect into the existing under-used pipeline capacity. Large carbon-intensive industries also have easy connection (Grangemouth Refinery, Mossmorran Ethylene, Dunbar Cement). A CO_2 shipping hub is developed at Peterhead deepwater port, enabling 20,000 tonne and larger tankers to import CO_2 from Rotterdam, Teesside, the Forth cluster, and decentralised parts of the UK.

These are attracted by 15 to 20 CO_2 - EOR developments in the UK and multi-user aquifer storage, proven and guaranteed to commercial quality by more than 10 years of injection experience. Development of the existing tanker terminal at Finnart enables flexible shipping import of CO_2 from the UK west coast to help many stranded assets; a short link pipe, already planned, expands links into the Forth Cluster. Cross-border transport develops Norwegian CO_2-EOR and aquifers. ***Total storage 100 Mt CO_2/year.***

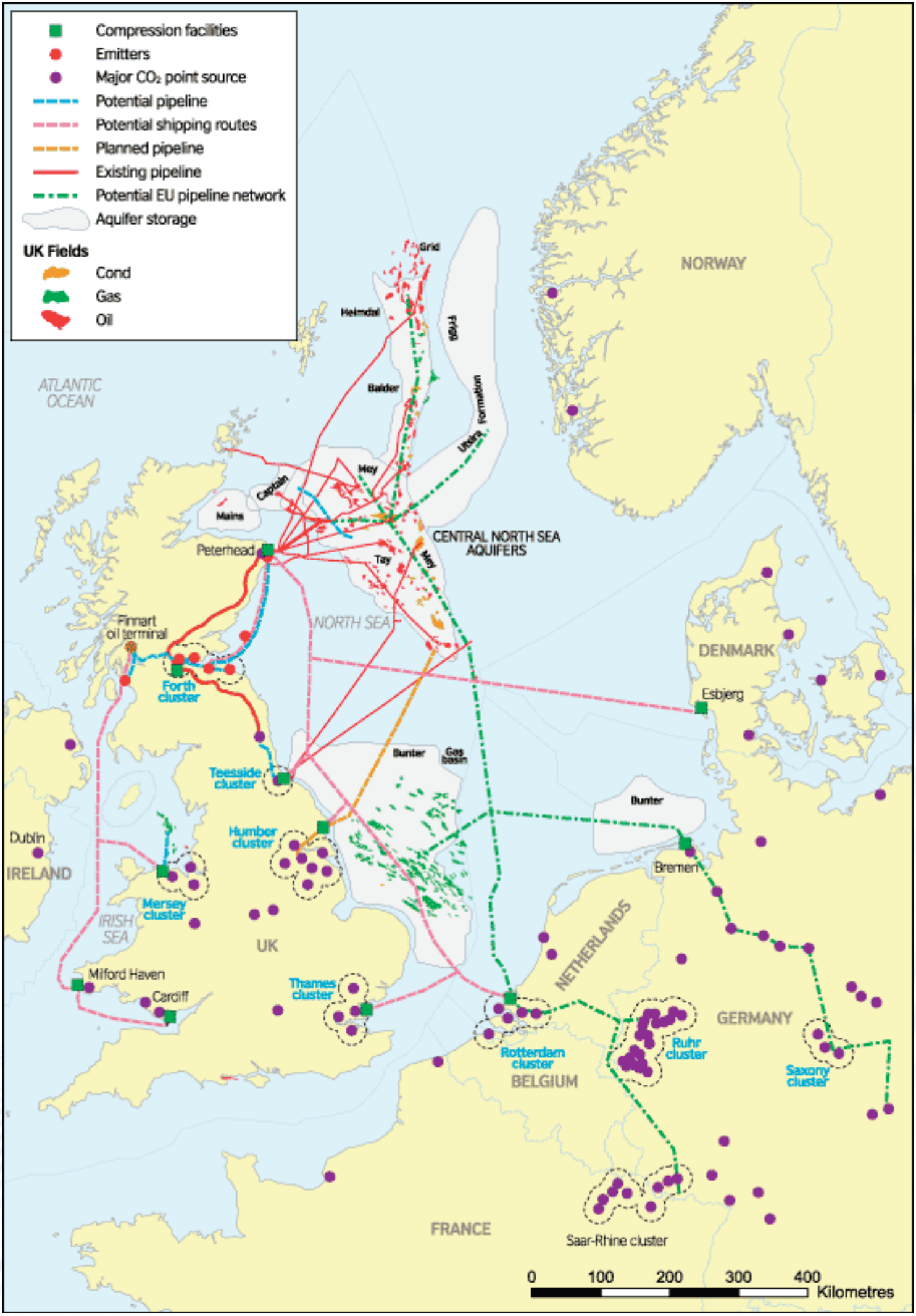



Compression facilities
Emitters
Potential shipping routes
Potential pipeline
Planned pipeline
Existing pipeline
Potential EOR fields
Gas field storage
Aquifer storage
Heimdal
Balder
Captain Aquifer
Utsira Aquifer
Mains Aquifer
Aspen
Goldeneye
Mey Aquifer
Inverness
CO2 Hub
Peterhead
Aberdeen
Finnart
oil terminal
Perth
Forth
cluster
Hunterston
inset map
Ayr
Dumfries
Bunter
Eston Grange
Teesside Steel
Teesside
cluster
Drax
Don Valley
Immingham
Humber
cluster
Milford Haven
Cardiff
Rotterdam
0
100
200
Kilometres

2050

New gas plant could be located in Scotland based on the short transport circuit between pipeline gas import from Norway, CCS on the coast and export of CO_2 to proven sites. These development costs are incentivised by CCS being cheaper than high carbon prices, which far outweigh the electricity transmission charges into the UK market. Interconnector cables from Peterhead to England and from Hunterston to England become fully utilised by synergistic balancing between intermittent wind power with 33% availability exporting southwards to the European grid, and flexible gas generation with CCS running for the remaining 66% of capacity. European pipelines from Rotterdam gather CO_2 from multiple onshore power plant and industrial sources and shipping imports are received into Peterhead from Scandinavia and mainland Europe, and into Finnart from England, Wales and potentially Ireland. Co-operation with Norway has increased to enable storage development northwards.

Total storage 500Mt CO_2/year (equivalent to approx. 25% of total EU power and industrial emissions in 2007)


Compression facilities
Emitters
Major CO_2 point source
Potential pipeline
Potential shipping routes
Planned pipeline
Existing pipeline
Potential EU pipeline network
Aquifer storage
UK Fields
Cond
Gas
Oil
NORWAY
ATLANTIC OCEAN
Grid
Heimdal
Frigg
Balder
Forties
Ula
Mey
Captain
Mains
Peterhead
Tay
CENTRAL NORTH SEA AQUIFERS
NORTH SEA
Finnart oil terminal
Forth cluster
DENMARK
Esbjerg
Bunter
Gas basin
Teesside cluster
Bunter
Humber cluster
Dublin
IRELAND
Bremen
Mersey cluster
IRISH SEA
UK
NETHERLANDS
Milford Haven
Cardiff
Thames cluster
GERMANY
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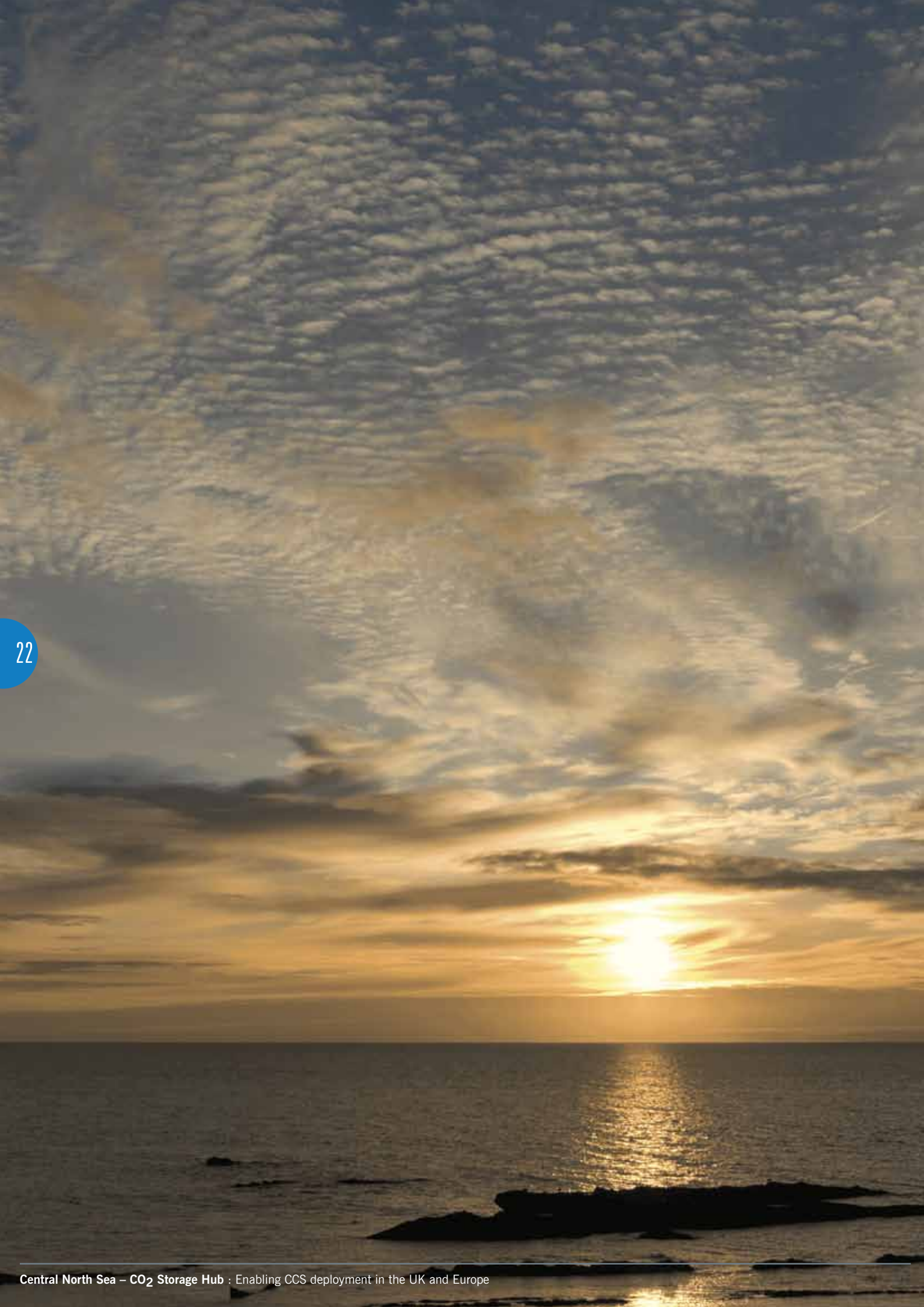
Ruhr cluster
Saxony cluster
BELGIUM
FRANCE
Saar-Rhine cluster
0
100
200
300
400
Kilometres



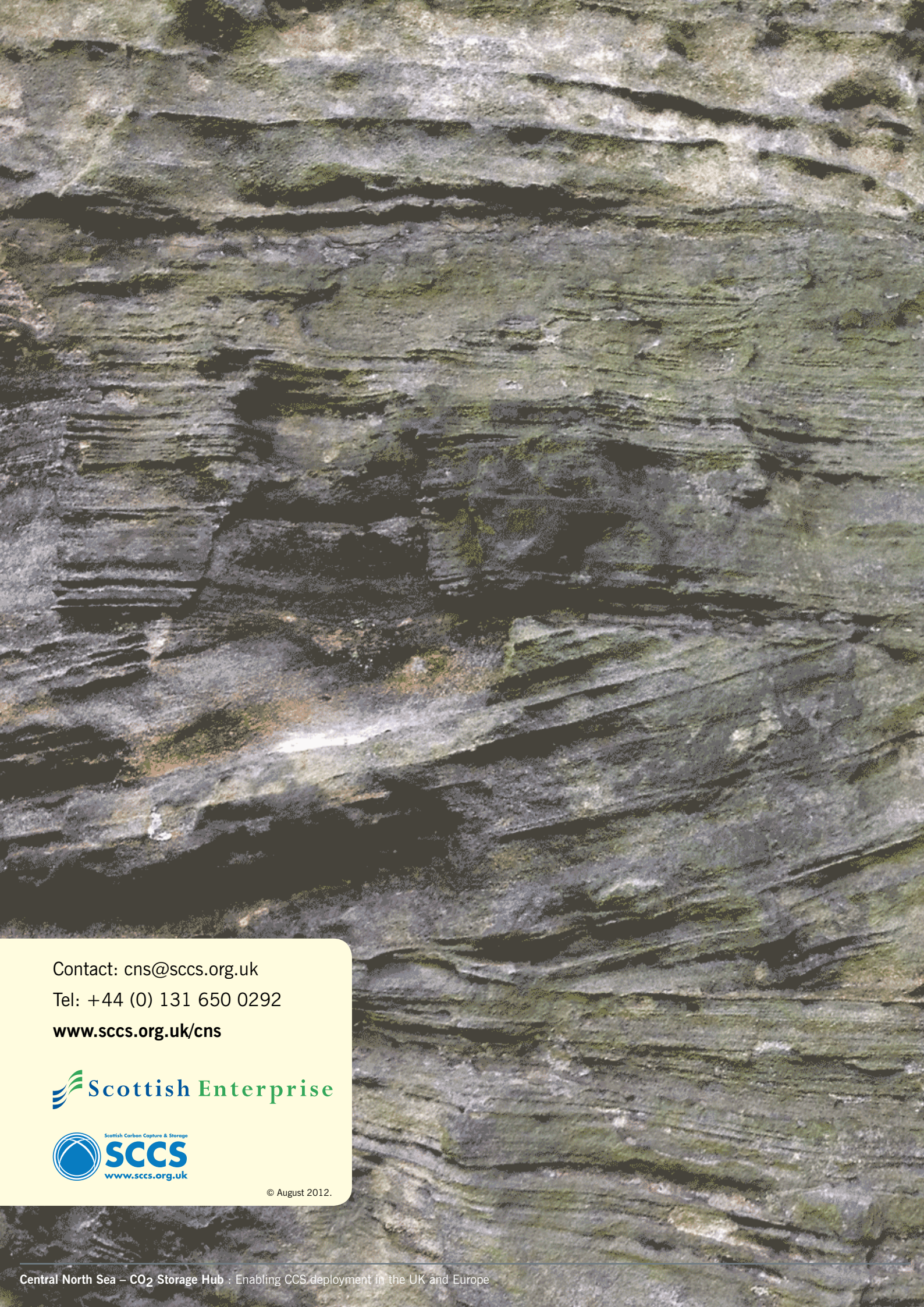
7 In Conclusion

The International Energy Agency has stated in a recent publication[7] that **CCS remains critical in the long term** *and* is the only technology on the horizon today that would allow industrial sectors (such as iron and steel, cement and natural gas processing) to meet deep emissions reduction goals. The publication also states that **"Some CO_2 capture technologies are commercially available today and the majority can be applied across different sectors, although storage issues remain to be resolved".** The UK Energy Technologies Institute cite CCS as enabling 20% of UK power production by 2050.

The Central North Sea presents the UK Government CCS Commercialisation Programme, through unrivalled transportation and storage assets, with a unique, value for money and affordable opportunity to address these unresolved issues. Through its diversity of storage sites, the CNS can provide CCS project developers and investors with certainty that CO_2 will be permanently sequestered and reused in a way that prevents it from re-entering the atmosphere. This will lead to the rapid and sequential development of a number of "rightsized", projects around existing pipelines which will have ready access to this tremendous CO_2 storage resource. Multiple medium and small sized projects will retain flexibility and produce rapid serial learning, much more so than one or two very large projects relying on un-proven storage sites of low diversity which are vulnerable to critical point failure as a common cohort. Finally, the learning available from these multiple projects will lead to a sustained reduction in the cost of CCS after 2025, and open up infrastructure which can be used by projects across Europe to contribute towards the challenging emissions reduction targets set by the EU and its member states.

In short, a decision by the UK Government to provide capital support to projects in the CNS will represent the first step in the faster route to a commercially viable, cost competitive CCS industry in the UK and a future-proof storage asset for Europe.

[7] Energy Technology Perspectives 2012 (http://www.iea.org/Textbase/npsum/ETP2012SUM.pdf)



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Scottish Enterprise

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SCCS
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