2013 CSLF
Technical Group Meeting

April 16-19, 2013
Rome, Italy

carbon sequestration leadership forum

Carbon Sequestration Leadership Forum
www.cslforum.org

CSLF Technical Group Meeting
and
CO_2 Monitoring Interactive Workshop

Rome, Italy
16-20 April 2013

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Carbon Sequestration Leadership Forum

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CSLF-T-2013-01
Draft: 10 April 2013
Prepared by CSLF Secretariat

AGENDA
CSLF Technical Group Meeting
Hotel Palatino
Rome, Italy
17 April 2013

08:00-09:00 **Registration**
Foyer outside Sala Cesarini

09:00-10:45 **Technical Group Meeting**
Sala Cesarini

1. **Opening Remarks**
   Trygve Riis, Technical Group Chair, Norway
2. **Host Country Welcome**
   Marcello Capra, Ministry of Economic Development, Italy
3. **Introduction of Delegates**
   Delegates
4. **Adoption of Agenda**
   Trygve Riis, Technical Group Chair, Norway
5. **Review and Approval of Minutes from Perth Meeting** CSLF-T-2012-20
   Trygve Riis, Technical Group Chair, Norway
   John Panek, Acting Director, CSLF Secretariat
6. **Review of Perth Meeting Action Items**
   John Panek, Acting Director, CSLF Secretariat
7. **Report from Secretariat**
   John Panek, Acting Director, CSLF Secretariat
8. **CO_2 Storage Science Development and Application in Italy**
   Salvatore Lombardi, University of Rome, Italy
9. **Italian Law on CO_2 Storage**
   Francesca Cappelletti, Ministry of Economic Development, Italy

10:45-11:00 **Refreshment Break**
at hotel's bar area

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11:00-12:30 **Continuation of Meeting**

10. Report from Projects Interaction and Review Team
Christopher Consoli, Acting PIRT Chair, Australia

11. Approval of Projects Nominated for CSLF Recognition

- Uthmaniyah EOR Project
  Ali Meshari, Overall Carbon Management Coordinator, Saudi Aramco, Saudi Arabia
- Alberta Carbon Trunk Line Project
  Farid Remtulla, Senior Vice President, Enhance Energy Inc., Canada
- UNIS CO_2 Lab
  Alvar Braathen, Professor, University Centre in Svalbard (UNIS), Norway

12:30-13:30 **Lunch**
at hotel's restaurant

13:30-15:00 **Continuation of Meeting**

12. Report from 2013 CSLF Technology Roadmap Steering Committee
Trygve Riis, Technical Group Chair, Norway

13. Report from Technical Challenges for Conversion of CO_2 EOR to CCS Task Force
Stefan Bachu, Task Force Chair, Canada

14. Report from CO_2 Utilization Options Task Force
Mark Ackiewicz, Task Force Chair, United States

15. Report from Reviewing Best Practices and Standards for Geologic Storage and Monitoring of CO_2 Task Force
Lars Ingolf Eide, Task Force Chair, Norway

15:00-15:15 **Refreshment Break**
at hotel's bar area

15:15-16:30 **Continuation of Meeting**

16. Report from Technology Opportunities and Gaps Task Force
Christopher Consoli, Acting Task Force Chair, Australia

17. Report on Activities of the United Kingdom's CCS Cost Reduction Task Force
Philip Sharman, United Kingdom

18. Status of Activities / Discussion of the Need for New Technical Group Task Forces
Trygve Riis, Technical Group Chair, Norway

19. Update from the IEA Greenhouse Gas R&D Programme
Tim Dixon, IEA GHG

20. New Business
Delegates

21. Action Items and Next Steps
John Panek, Acting Director, CSLF Secretariat

22. Closing Remarks/Adjourn
Trygve Riis, Technical Group Chair, Norway

19:00-22:30 Dinner Event
Visit to Capitoline Museums [19:00-20:30]
Dinner at Ristorante TABERNA ULPIA (located adjacent to the Rome Forum historical site) [20:30-22:30]
Short bus tour of Rome following dinner (on the way back to the hotels)

Note: This document is available only electronically.
Please print it prior to the CSLF meeting if you need a hardcopy.

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Carbon Sequestration Leadership Forum
www.cslforum.org

CSLF CO_2 Monitoring Interactive Workshop

Hotel Ambasciatori Palace
Sala Ambasciatori

Rome, Italy

18 April 2013

09:00-09:15

Plenary Session

Workshop Introduction and Background

John Panek, Deputy Director, CSLF Secretariat

Welcoming and Keynote Address

Sergio Persoglia, International Collaboration Director, OGS, Italy

09:15-12:30

Session 1: Monitoring CO_2 Storage in Deep Saline Aquifers and Oil Reservoirs

Session Chair:

Ahmed Aleidan, Petroleum Engineer, Saudi Aramco, Saudi Arabia

Project sponsors will detail their experience and intentions for utilizing CO_2 monitoring technologies at commercial scale.

- **Illinois Basin – Decatur Project**
  Rob Finley, Illinois State Geologic Survey, United States
- **Quest CCS Project**
  Sean McFadden, Shell Canada
- **Zero Emission Porto Tolle (ZEPT) Project**
  Silvana Iacobellis, ENEL, Italy
- **SECARB Early Test at Cranfield Project**
  Susan Hovorka, Gulf Coast Carbon Center, University of Texas, United States
- **Bell Creek CO_2-EOR Project**
  Edward Steadman, University of North Dakota Energy and Environmental Research Center, United States

Facilitated Discussion amongst Project Participants *(comparing and contrasting monitoring plans, experience, and methodologies)*

Audience Interaction *(following discussion between Project Participants)*

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12:30-14:00
Lunch

14:00-16:30
Session 2: Monitoring CO_2 at Controlled Release Projects in Shallow Subsurface

Session Chair:
Trygve Riis, Special Adviser, Research Council of Norway

Project sponsors will detail their experience and intentions for utilizing CO_2 monitoring technologies in controlled release experiments and projects in shallow subsurface.

- **CO_2 Field Lab Project**
  Maria Barrio, SINTEF Petroleum Research, Norway
- **Montana State University Shallow Release Experiments**
  Lee Spangler, Montana State University, United States
- **Australia Controlled Experiments on CO_2 Release in Shallow Subsurface**
  Andrew Feitz, Geoscience Australia / CO2CRC
- **CO2ReMoVe**
  Ton Wildeborg, TNO, Netherlands

Facilitated Discussion amongst Project Participants *(comparing and contrasting monitoring plans, experience, and methodologies)*

Audience Interaction *(following discussion between Project Participants)*

16:30-17:00
Workshop Conclusions

Session Chair:
Stefan Bachu, Distinguished Scientist, CO_2 Storage, Alberta Innovates – Technology Futures, Canada

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Workshop Concept
- Each project representative will give a 20-minute presentation emphasizing CO_2 monitoring aspects and technologies, followed by 10 minutes of immediate Q&A discussion.
- Following all presentations in the session, there will be an additional discussion among the panelists facilitated by the session chair.
- Following the panelist discussion, there will be an Audience Interaction Q&A session.

Note: This document is available only electronically
Please print it prior to the Workshop if you need a hardcopy.

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Carbon Sequestration Leadership Forum

www.cslforum.org

CSLF Technical Group Meeting
Rome, Italy
16-19 April 2013

	Tuesday 16 April Hotel Ambasciatori Palace	**Wednesday 17 April Hotel Palatino**	**Thursday 18 April Hotel Ambasciatori Palace**	**Friday 19 April Latera Caldera**
Morning	CSLF Projects Interaction and Review Team (PIRT) *Sala Ambasciatori* *10:00-12:00*	Meeting Registration *08:00-09:00* *Sala Cesarini Foyer* CSLF Technical Group *Sala Cesarini* *09:00-12:30*	**CO_2 MONITORING WORKSHOP** Plenary Session *Sala Ambasciatori* *09:00-09:15* Session 1: Monitoring CO_2 Storage in Deep Saline Aquifers and Oil Reservoirs *Sala Ambasciatori* *09:15-12:35*	Site visit to Latera Caldera *Bus departs TBA*
	Lunch *12:00-14:00*	Lunch *12:30-13:30*	Lunch *12:30-14:00*	Lunch
Afternoon	Technical Challenges for Conversion of CO_2 EOR to CCS Task Force *Sala Ambasciatori* *14:00-15:00* Reviewing Best Practices and Standards for Geologic Storage and Monitoring of CO_2 Task Force *Sala Ambasciatori* *15:00-16:00* CO_2 Utilization Options Task Force *Sala Ambasciatori* *16:00-17:00* Technology Opportunities and Gaps Task Force *Sala Ambasciatori* *17:00-18:00*	CSLF Technical Group *Sala Cesarini* *13:30-16:30*	**CO_2 MONITORING WORKSHOP** Session 2: Monitoring CO_2 at Controlled Release Projects in Shallow Subsurface *Sala Ambasciatori* *14:00-16:30*	Site visit to Latera Caldera and visit to historical site *Bus returns 20:00* *(Earlier bus returns to airport after lunch)*
Evening		Dinner Event *17:30-22:30*		

Meeting documents will be available only electronically. Please print them prior to the meeting if you need hardcopies.

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About Wednesday 17 April

The meeting of the CSLF Technical Group will take place at Palatino Hotel (Via Cavour, 213/m). A bus will leave from Ambasciatori Palace Hotel (Via Veneto, 62) at 8.00 a.m. .

The program of the evening provides:

- A guided visit at the **"Musei Capitolini"** (Piazza del Campidoglio 1), the most ancient publicly-owned museum in the world (see *"Musei Capitolini annex*")
- The Social Dinner at the **"Taberna Ulpia"** Restaurant (Via Foro Traiano 1/B), in front of the Imperial Traiano Markets (see *"Social Dinner annex"*)

Musei Capitolini and Campidoglio are quite close to the Palatino Hotel, about 1 Km, 15 minutes walking (see the map).
The participants will be divided in two groups at the meeting registration desk.
The appointment for the first group will be at 17.30 in front of the Musei Capitolini booking office.
The appointment for the second group will be at 17.50.
The visit will have the duration of 1 hour and 15 minutes.
The guides will attend the participants in front of the booking office of the Museum, and then they will take them to the restaurant, at about 20.00.
After dinner a bus will leave from the Restaurant for the Hotels

About Friday 19 April

About the site visit to **Latera Caldera**, an interesting area characterized by high and localized CO_2 emissions due to the final part of volcanic activity, the bus will leave from Ambasciatori Palace Hotel at 8.00 a.m. . After lunch the return will be organized at 14.00, for Fiumicino Airport and Rome Hotels. For more information see the *"Excursion to Latera Caldera"* annex

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The Capitoline Museums

*The **Capitoline Museums** (Italian **Musei Capitolini**) are a group of art and archeological museum in Piazza del Campidoglio, on top of the Capitoline Hill .*

The museums are contained in three palazzi surrounding a central trapezoidal piazza in a plan conceived by Michelangelo Buonarroti in 1536 and executed over a period of more than 400 years.
The statue of a mounted rider in the centre of the piazza is of Emperor Marcus Aurelius. It is a copy, the original being housed on-site in the Capitoline museum.
The history of the museums can be traced to 1471, when Pope Sixtus IV donated to the Roman People a group of ancient artefacts that had previously been housed in the Lateran, amongst which are the She-Wolf, the city's own symbol, the colossal head of Constantine with hand and globe, the Spinarius and the Camillus.
This first nucleus of artefacts was displayed at the Palazzo dei Conservatori, the original headquarters of the homonymous Roman legal-bench, with the precise goal of allowing everyone to enjoy these ancient bronzes, following a revolutionary concept aimed at providing the Roman People and visitors to the Eternal City with the pleasure deriving from the ancient artefacts enshrined in private collections and palaces and destined to the admiration of an extremely narrow elite of high-lineage people.
Since this first acquisition, the Capitoline collection obtained a clear and peculiar definition of connection to the prerogatives granted by the city's charters to the Conservatori, regarding the conservation of antiques: everything they safeguard is indeed from Rome or from its outskirts, and relates to Rome's ancient history.
The relocation of artefacts to the Capitoline, ordered by popes and cardinals, continued throughout the end of the 15th and the 16th centuries, with a marked intent of emulating predecessors or of explicit appropriation of the Roman hill's symbolic value.
The positioning of ancient sculptures in the Museum reflects a change in concept which intervened during the 16th century. From an initial exhibition underneath the porch in the Palazzo dei Conservatori, the artefacts were moved inside the building, in a balanced distribution along the route to the Piano Nobile, up to the Apartment halls destined to public and secret counsel reunions, where Lux in Arcana will be held.
This new concept of an open museum, originated from a regained awareness of the ancient grandeur of Rome, accrued together with the building's renewal.
In 1568 a reconstruction was started of the facade and the inner and outer porches; subsequently the halls on the first level were reorganised, and the furnishing and frescoes were completely remade: the Conservators decided for an iconographic programme derived from the tales of ancient Roman history, with the explicit aim of celebrating the virtues of the magistrates by commemorating ancient exemplary episodes.

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During the 17th century a second twin-building was commenced; it was subsequently destined to housing a museum of ancient sculpture, called Palazzo Nuovo.
During this period the Conservators made every effort to build, at their own expense, the bases and pedestals for sculptures who had already got to the Capitol, with a twofold outcome: that of offering a correct exhibition of the artefacts and that of perpetually binding their name to them by means of inscriptions. The exhibition route proceeds inside the halls of the Conservators' Apartment, the magnificent boardrooms where the Roman court met and exercised the duties linked to its public role.
All the rooms are decorated with important frescoes dating back to the 16th and 17th centuries that are characterised by iconographic programmes which exalt ancient civic values and the best-known and most significant examples from Roman history.

The exhibition starts at the monumental staircase to the Palazzo's Piano Nobile, whose walls are decorated with important figure-like Roman friezes; subsequently, the route proceeds towards the magnificent Hall of the Horatii and Curiatii, painted between the end of the 16th and the beginning of the following century by Cavalier d'Arpino.

Following is the Hall of the Captains, frescoed by Tommaso Laureti between 1587 and 1594, where the Conservatori's tribunal sat.
Next is the Hall of the Triumphs, so-called due to the 1569 fresco by Michele Alberti and Iacopo Rocchetti representing the triumph of consul Lucius Aemilius Paullus over Perseus; the renowned "Sala della Lupa" and, not far, the Hall of Hannibal, the only one in the Apartament to preserve all of its original frescoes.

Carried out by Iacopo Ripanda's circle, the episodes are inspired by the Punic wars. Even the wooden roof is one of the oldest in the building, dating back to a period between 1516 and 1519.
From this latter room the visitor reaches the 16th century Palatine Chapel, where one can easily see the grid that allowed the Conservatori to attend Mass directly from the Hall of the Captains.
Lastly, the Hall of the Tapestries owes its name to the precious tapestries reproducing pictures of Roman history preserved in the Capitoline picture gallery. In 1770 the hall was renewed in order to house the papal throne's imposing canopy.

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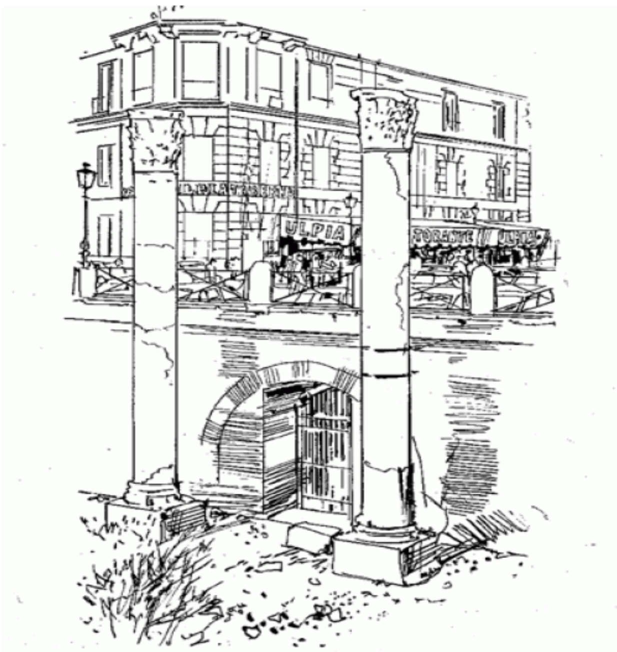
CSLF
Technical Group Meeting

GALA DINNER



TABERNA VLPIA RESTAURANT

WEDNESDAY 17TH APRIL 2013

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A place of history, with columns, capitals, statues and sculptures everywhere. Looking onto the charming Traiano Markets, it is located in the sixteenth-century palace of the Marquis of Gallo di Roccagiovine, which was built on the ruins of the second-century Basilica Ulpia.

The ancient Roman taberna below, complete with a stretch of imperial road, has remained unchanged, as have the historic Traiano and Impero rooms.

Since 1880, Taberna Ulpia Restaurant in Rome has been serving traditional Roman food to the great and the good, ordinary Romans, and even the not-so-good.

The menu features all the traditional Roman favourites, with fine service. This is a huge, popular place and a national monument.

MENU'

L'APERITIVO DI BENVENUTO CON SALATINI

IL MISTO DI AFFETTATI ITALIANI

CON

LE VERDURE GRIGLIATE

RIGATONCINI ALL'AMATRICIANA

MEZZE MANICHE ALLA CARBONARA

I SALTINBOCCA ALLA ROMANA

CON

PATATE AL ROSMARINO E CICORIA SALTATA

IL DOLCE DELLA CASA

IL CAFFÈ

L'ACQUA MINERALE

IL VINO BIANCO E ROSSO VULPIA IN BOTTIGLIA

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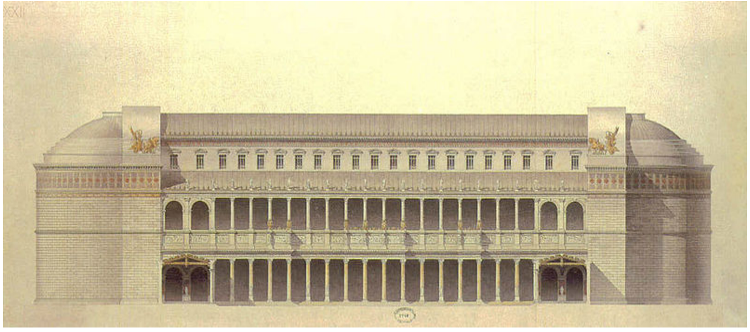
The Basilica Ulpia was an ancient Roman civic building located in the Forum of Trajan. The Basilica Ulpia separates the temple from the main courtyard in the Forum of Trajan with the Trajan's Column to the northwest. It was named after Roman emperor Trajan whose full name was Marcus Ulpius Traianus

It became perhaps the most important basilica after two ancient ones, the Basilicas Aemilia and Julia. With its construction, much of the political life moved from the Roman Forum to the Forum of Trajan. It remained so until the construction of the Basilica of Maxentius and Constantine.

Unlike later Christian basilicas, it had no known religious function; it was dedicated to the administration of justice, commerce and the presence of the emperor. It was the largest in Rome measuring 117 by 55 meters (385 x 182 ft).

The Basilica Ulpia was composed of a great central nave with four side aisles with clerestory windows to let light into the space divided by rows of columns and two semicircular apse, one at each of the ends with the entry to the basilica located on the longitudinal side. The columns and the walls were of precious marbles; the 50 meter (164 ft) high roof was covered by gilded bronze tiles.



Reconstruction of the basilica

This dinner is sponsored by

BD

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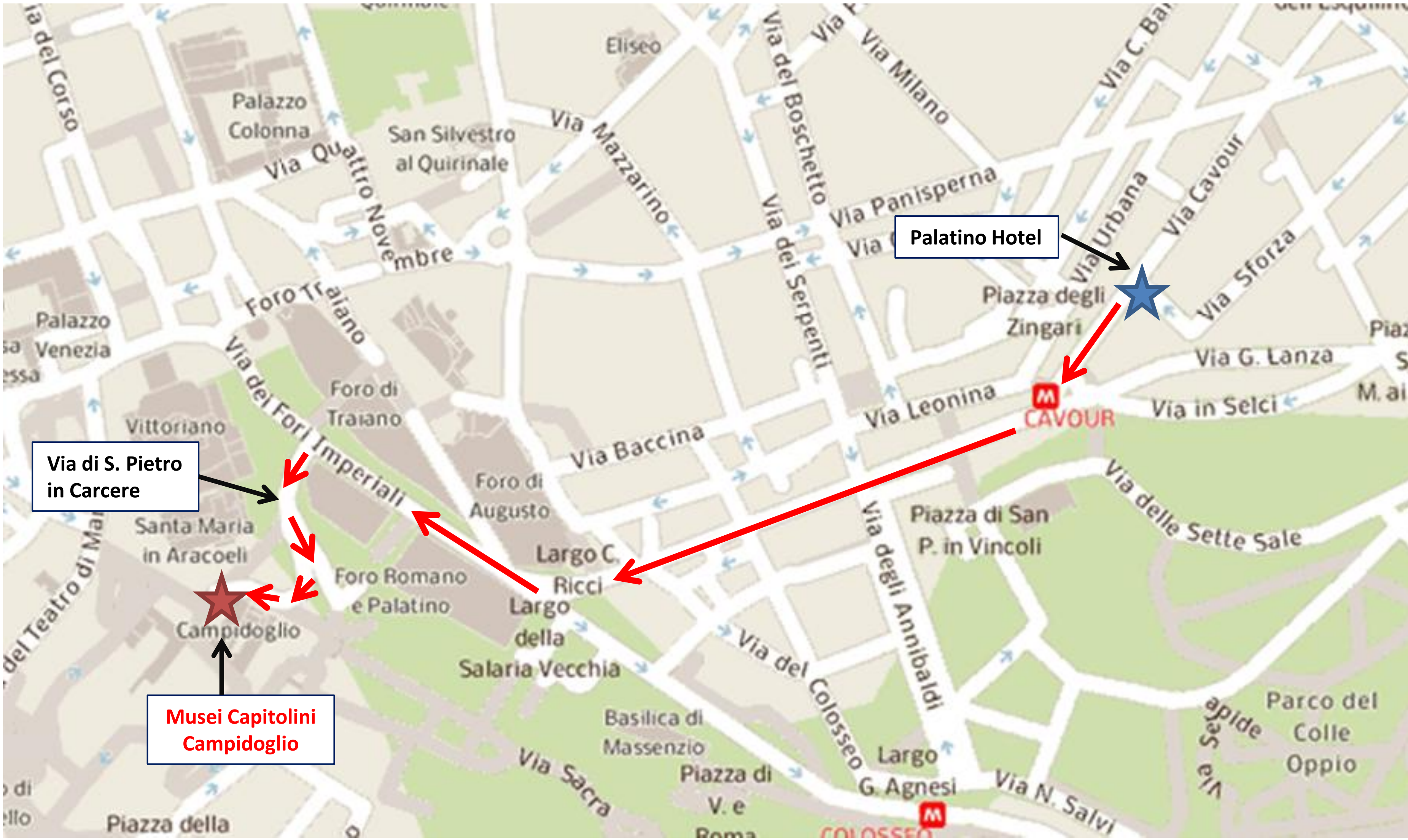
From Palatino Hotel to Musei Capitolini – Piazza del Campidoglio, 1



From Palatino Hotel to Musei Capitolini about 1 Km

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Carbon Sequestration Leadership Forum – Rome – 19 April 2013

Excursion to Latera Caldera (about two hours and a half from Roma)

The Latera Caldera and the Vulsini Volcanic District belongs to the Roman Magmatic Province, localized on the Tyrrhenian coast of Italian peninsula. The development of this volcanic activity is connected to a post-Miocene extensional tectonics, which determined the opening of the Tyrrhenian basin, and dissected the previous fold and thrust belt by NW–SE and N–S trending normal fault systems. This area is characterized by high and localized CO_2 emission due to the final part of volcanic activity.

The Latera Caldera. View from East

Program

Leaving from Rome (Ambasciatori Hotel) around 8.00.
Arrival at 11.00 and visit at the Latera Caldera.

What to observe:

- Impact on local population and human activities (agricultural and sheep farming)
- Main characters of natural leakage of CO2 (gas vents)
- Migration pattern of gas through fault zones

Gas vent in Latera Caldera

Normal fault, trending N40°E in a quarry in the Latera Caldera. The yellow to brown materials constitutes the non cohesive cataclasites within the fault zone

12,30 - 13.00 / 14.00 - Lunch
Return to Fiumicino Airport or Rome Hotels

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Carbon Sequestration Leadership Forum
www.cslforum.org
CSLF-T-2012-20
Draft: 31 December 2012

TECHNICAL GROUP

Revised Draft
Minutes of the CSLF Technical Group Meeting

Perth, Australia
25 October 2012

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Carbon Sequestration Leadership Forum
www.cslforum.org

CSLF-T-2012-20
Draft: 31 December 2012

MINUTES OF THE CSLF TECHNICAL GROUP MEETING
PERTH, AUSTRALIA
25 OCTOBER 2012

Note by the Secretariat

Background

The Technical Group of the Carbon Sequestration Leadership Forum held a business meeting on 25 October 2012, in Perth, Australia. Initial draft minutes of this meeting have been compiled by the CSLF Secretariat and were circulated to the Technical Group delegates for comments. Comments received were incorporated into this revised draft. Presentations mentioned in these minutes are now online at the CSLF website.

Action Requested

Technical Group delegates are requested to approve these revised draft minutes.

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Carbon Sequestration Leadership Forum
www.cslforum.org

CSLF-T-2012-20
Draft: 31 December 2012
Prepared by CSLF Secretariat

REVISED DRAFT

Minutes of the Technical Group Meeting

Perth, Australia
Thursday, 25 October 2012

LIST OF ATTENDEES

Technical Group Delegates

Australia:	Clinton Foster (Vice Chair), Richard Aldous
Canada:	Stefan Bachu, Eddy Chui
China:	Jiutian Zhang
European Commission:	Jeroen Schuppers
France:	Didier Bonijoly
Italy:	Giuseppe Girardi
Japan:	Ryozo Tanaka
Korea:	Young Cheol Park, Chong Kul Ryu
Netherlands:	Paul Ramsak
Norway:	Trygve Riis (Chair), Jostein Dahl Karlsen
Saudi Arabia:	Ahmed Aleidan
South Africa:	Tony Surridge (Vice Chair)
United Kingdom:	Philip Sharman
United States:	Darren Mollot, George Guthrie

Representatives of Allied Organizations

Global CCS Institute:	Peter Grubnic

CSLF Secretariat

John Panek, Richard Lynch

Invited Speakers

Wayne Calder, Department of Resources, Energy and Tourism, Australia
Dominique Van Gent, Department of Mines and Petroleum, State Government of Western Australia
Maureen Clifford, Department of Primary Industries, Energy & Earth Resources Group, State Government of Victoria, Australia

Observers

Australia:	Chris Consoli, Peter Cook, Declan Kuch, Bruce Murphy, Claire Richards
Chinese Taipei:	Chi-Wen Liao, Shoung Ouyang
Norway:	Nils A. Røkke
United States:	Arthur Lee

1. Chairman's Welcome and Opening Remarks

The Chairman of the Technical Group, Trygve Riis, called the meeting to order and welcomed the delegates and observers to Perth.

Mr. Riis provided context for the meeting by mentioning that the CSLF has been planning for the next Ministerial Meeting, which will take place in late 2013, and prior to that there would be another Technical Group meeting in the second quarter of 2013. Several items on the agenda for this meeting are relevant to these upcoming meetings. In regards to next year's Ministerial Meeting, the Policy Group has requested that the Technical Group consider how the CSLF can become more relevant – how it can increase its visibility and have greater influence on the Ministers who will be attending the meeting.

Mr. Riis concluded his remarks by mentioning that the current meeting would include a presentation on Australia's carbon capture and storage (CCS) projects, two presentations from sponsors of projects that have been proposed for CSLF recognition, an update on the 2013 CSLF Technology Roadmap, and progress reports from the Technical Group's Task Forces.

2. Host Country Presentation

Clinton Foster, Chief Scientist for Geoscience Australia, welcomed the Technical Group to Perth and provided a brief overview of the Australia's CCS policy drivers and projects. At July 2012, the price for CO_2 was set at A$23 per tonne. After three years there will be a transition to a flexible price that the market will determine through a cap-and-trade system. This price for CO_2 is not expected to be high enough to commercialize CCS in Australia, but it will be sufficient to put CCS on the agenda at the corporate level. Placing a price on carbon emissions will provide a commercial incentive for emissions-intensive industries to utilize CCS to reduce their carbon price liability.

Dr. Foster stated that CCS is a very important component of Australia's strategy for addressing climate change. Currently, Australia is heavily reliant on fossil fuels for domestic energy demand, with several high-emitting industries that could be made much less so if retrofitted with CCS technology. There are several large projects that are underway or in planning, including the South West Hub Geosequestration Project in southwestern Australia, the CarbonNet Project in southeastern Australia, and the Gorgon CO_2 Injection Project in northwestern Australia. Each of these will store millions of tonnes of CO_2 annually. South West Hub and CarbonNet have been designated as Flagship Projects by the Australian Government and have been proposed for CSLF recognition, while Gorgon is already a CSLF-recognized project.

Dr. Foster closed his remarks by conveying the following message from Australia's Minister of Resources and Energy, The Honourable Martin Ferguson AM MP: "I wish you a successful meeting, and encourage you to exchange ideas and discuss practical ways to accelerate the development and deployment of CCS."

3. Introduction of Delegates and Observers

Technical Group delegates and observers present for the session introduced themselves. Fourteen of the twenty-five CSLF Members were present at this meeting, including representatives from Australia, Canada, China, the European Commission, France, Italy, Japan, Korea, the Netherlands, Norway, Saudi Arabia, South Africa, the United Kingdom, and the United States. Observers representing Australia, Chinese Taipei, Norway, and the United States were also present.

4. Adoption of Agenda

The Agenda was adopted with the small change that the report from the CO_2 Technology Opportunities and Gaps Task Force would be heard immediately after the discussion on the 2013 Technology Roadmap.

5. Approval of Minutes from Bergen Meeting

The Technical Group minutes from the June 2012 meeting in Bergen, Norway, were approved as final with no changes.

6. Review of Action Items from Bergen Meeting

John Panek provided a brief update on the twelve action items from the Bergen meeting. Exploration is still underway on whether the Phase II Report from the now discontinued Risk Assessment Task Force will be published as a journal article. The option of forming a new Best Practices Knowledge Sharing Task Force was up for discussion later in the meeting as part of the update on the Technical Group Action Plan. Mr. Panek stated that the remaining ten action items have all been completed.

7. Report from CSLF Secretariat

John Panek gave a brief presentation that summarized CSLF activities that had occurred since the June Technical Group meeting in Bergen, including the July 2012 Risk and Liability Workshop in Paris and Capacity Building activities in Brazil in late July and early August. The capacity building event was the first of four planned courses in Brazil to focus on carbon capture, utilization and storage (CCUS) and featured five days of presentations and discussions from global experts.

The Risk and Liability Workshop was a two-day event and included sessions on how geologic risks are measured by geologists and geological engineers; how business risks and potential liabilities are evaluated for business decisions; how risks are valued and how the insurance industry and banking sectors address liabilities; issues encountered by governments in addressing liability and their approaches to risk and liability; what will make the public be and feel safe and comfortable with CCUS; and what will make investors comfortable.

Mr. Panek also gave a short update on the CSLF-recognized projects. As of the beginning of October there are 23 active and 11 completed projects in the portfolio. The most recent project to be completed is the Demonstration of an Oxyfuel Combustion Project, located in the United Kingdom. Mr. Panek stated that the Secretariat has redesigned the 'Projects' page of the CSLF website to include a map of the locations of all the active and completed projects.

8. CCS in Australia

Wayne Calder, General Manager of the Low Emissions Coal and CO_2 Storage Branch of Australia's Department of Resources, Energy and Tourism, gave a presentation that described Australia's priorities and policy framework for CCS, and some of the projects that are now underway. Currently, Australia's electricity generation is predominately driven by fossil fuels, with about 90% of its electricity generated from coal and natural gas. Australia is also very committed to address climate change, and has set CO_2 emissions reduction goals of 5% by 2020 and 80% by 2050 (based on year 2000 emissions). To get there, substantial investment in low emissions technologies, including CCS, will be needed.

Mr. Calder described some of the actions taken by the Australian government to address the dual challenge of meting these ambitious CO_2 reduction goals while maintaining a strong economy that is heavily dependent on fossil fuels. Development of renewable energy is being accelerated and a new Clean Energy Finance Corporation has been created and allocated with A$10 billion in funding, which will be leveraged with private sector investments for large-scale clean energy technology projects. Australian government funding for CCS includes the CCS Flagships Program (A$1.7 billion funding), the National Low Emissions Coal Initiative (A$370 million funding), the National CO_2 Infrastructure Plan (A$61 million funding), and the Global CCS Institute (A$315 million funding).

Mr. Calder stated that the carbon price that was instituted earlier in 2012 is just one policy-driven step toward widespread implementation of CCS. The policy framework for CCS in Australia includes legislative certainty, storage issues, research and development, project demonstration and financing (from pilot scale to large-scale demonstrations), stakeholder engagement, and knowledge sharing. Community acceptance is also paramount to success, and involves two different aspects: assurance of safety and resolving land use issues associated with CCS, and achieving a broadly-based community attitude that CCS is a necessary technology for addressing climate change. A “CCS Communication and Awareness Strategy” has been implemented that incorporates these outreach perspectives.

Mr. Calder ended his presentation by briefly describing some of the individual project activities that are ongoing in Australia, including the previously-mentioned Gorgon, South West Hub, and CarbonNet projects. In addition, the pilot-scale Callide Oxyfuel Project in Queensland State will capture and store CO_2 from a 30 megawatt unit at Callide Power Station that has been retrofitted with oxycombustion technology. A revised Queensland Flagship CCS project is also under development. Mr. Calder reinforced that demonstrating CCS at commercial scale is critical to future deployment, and that implementing demonstration projects requires consideration of all elements of the CCS puzzle.

9. Report from the CSLF Projects Interaction and Review Team (PIRT)

The PIRT Chair, Clinton Foster, gave a brief presentation that summarized the previous day’s PIRT meeting. There were two major outcomes from the meeting:

- There was consensus for simplification of the CSLF Gaps Analysis Checklist, reducing it in length from seven pages down to a single page.
- Two projects were approved by the PIRT for Technical Group action: the South West Hub Geosequestration Project (nominated by Australia and supported by the United States and Canada) and the CarbonNet Project (nominated by Australia and supported by the United States).

After brief discussion, the Technical Group reached consensus that it will henceforward use the PIRT’s simplified and more concise version of the Gaps Analysis Checklist.

10. Approval of Projects Nominated for CSLF Recognition

South West Hub Geosequestration Project (nominated by Australia, United States, and Canada)

Dominique Van Gent, Coordinator of Carbon Strategy for the State Government of Western Australia's Department of Mines and Petroleum, gave a presentation about the South West Hub Project. This project will implement a large-scale "CO_2 Hub" for multi-user capture, transport, utilization, and storage of CO_2 in southwestern Australia near the city of Perth. The project is one of Australia's "Flagship" projects for large-scale demonstration of CCS technologies. Several industrial and utility point sources of CO_2 will be connected via a pipeline to a site where the CO_2 can be stored deep underground in the Triassic Lesueur Sandstone Formation. The project initially plans to sequester 2.4 million tonnes of CO_2 per year and has the potential for capturing approximately 6.5 million tonnes of CO_2 per year. A separate and unique feature of the project is that an additional approximately one quarter million tonnes of CO_2 per year will be permanently chemically stored in bauxite residue as part of an environmentally beneficial amelioration program. The project will also include reservoir characterization and, once storage is underway, measurement, monitoring and verification (MMV) technologies.

After brief discussion, there was consensus by the Technical Group to recommend to the Policy Group that the South West Hub Geosequestration Project receive CSLF recognition.

CarbonNet Project (nominated by Australia and United States)

Maureen Clifford, Communications & Stakeholder Engagement Manager for the State Government of Victoria's Energy & Earth Resources Group at the Department of Primary Industries, gave a presentation about the CarbonNet Project. This project will implement a large-scale multi-user CO_2 capture, transport, and storage network in southeastern Australia in the Latrobe Valley. The project is another of Australia's "Flagship" projects for large-scale demonstration of CCS technologies. Multiple industrial and utility point sources of CO_2 will be connected via a pipeline to a site where the CO_2 can be stored in depleted oil and gas fields in the offshore Gippsland Basin. The project initially plans to sequester approximately 1 to 5 million tonnes of CO_2 per year, with the potential to increase capacity significantly over time. The project will also include reservoir characterization and, once storage is underway, measurement, monitoring and verification (MMV) technologies.

After brief discussion, there was consensus by the Technical Group to recommend to the Policy Group that the CarbonNet Project receive CSLF recognition.

11. Update on 2013 CSLF Technology Roadmap (TRM)

Trygve Riis provided a brief status update on the 2013 CSLF TRM. At the June 2012 Technical Group meeting in Bergen, there was consensus that the next TRM would be a deliverable at the 2013 CSLF Ministerial Meeting and that the time horizon of the TRM would run to the year 2030, with the year 2020 being an important milestone. This is to be a major TRM revision, but it will be much shorter than the current version and with emphasis on presenting clear and concise messages to Ministers and policy makers. To that end, a Steering Committee was formed, led by the Technical Group Chair and including the Technical Group Vice Chairs, Task Force Chairs, and Secretariat, and has responsibility for all aspects of the new TRM, including the scope, content, and process for completion.

Mr. Riis stated that the Steering Committee held a preliminary meeting in Bergen, followed by several teleconference meetings, and then an in-person meeting in Perth. This has resulted in a scoping document which describes the objectives and scope of the TRM as well as the process (including a proposed timeline) for completion. An initial draft of the TRM's status and assessment will be ready by mid December, and by early January there will be a first draft of the TRM's priorities for research, development and demonstration (RD&D) activities. A complete initial draft of the 2013 TRM is expected to be available for review by the Technical Group prior to its next meeting in the 2nd quarter of 2013. Mr. Riis mentioned that the Steering Committee will have a one-day meeting in conjunction with the next Technical Group meeting to review the initial draft. An advanced draft, incorporating comments from Technical Group delegates, is expected in June 2013, and this would be followed by review by both the Technical Group and Policy Group. Any comments and revisions would then be incorporated into the final version of the 2013 TRM. There was consensus to accept this schedule.

Mr. Riis mentioned that he had met with Ellina Levina of the International Energy Agency (IEA), who is working on IEA's CCS Roadmap and reached informal agreement that work on the two Roadmaps should be coordinated. There was also agreement that the two Roadmaps should convey consistent messages to policy makers, and be presented in a form that can influence priorities in some countries. The IEA has established an Advisory Board to oversee its CCS Roadmap, but the technical sections have not yet been written. Therefore, the upcoming draft of the TRM's status and assessment would be valuable to the IEA, and Ms. Levina is quite interested in getting technical input from the CSLF.

Concerning the process for completion of the TRM, Mr. Riis stated that he had contacted Norway's Ministry of Petroleum and Energy (MPE), which agreed to help support the CSLF TRM work by providing funding to hire a consultant for this work. SINTEF has been contracted for this support, and three consultants from SINTEF will work with Lars Ingolf Eide of the Research Council of Norway, who will be the editor. The TRM Steering Committee will be consulted as needed on a continuing basis.

Philip Sharman noted that there is an inherent linkage between the Technical Group's TRM activities and the new Technical Group Task Force on CO_2 Technology Opportunities and Gaps. Because of this, there was consensus for that Task Force to give its report next.

12. Report from CO_2 Technology Opportunities and Gaps Task Force

The Task Force Chair, Richard Aldous, gave a brief update on the Task Force and its activities. The Task Force would undertake a comprehensive look at the key technologies in play around CCS and CCUS with a view toward identifying scientific and technology gaps and opportunities which have the potential to significantly impact CCS and CCUS demonstration and deployment. Reports from the Task Force would provide recommendations on how the global technology development pathway could be sped up or enhanced to further drive down costs and enhance efficiency for these technologies.

Dr. Aldous stated that the Task Force would go into a somewhat deeper level of detail than the TRM, but would have the same framework as the TRM since information from the Task Force would be a TRM input. The Task Force results can be reported in spreadsheet format, perhaps using technology readiness level methodologies. Phase 1 work will review existing reports and other work that has been done in this area by outside organizations, and will decide on an assessment methodology. The interim

Phase 1 Report will include identification of high-level gaps and opportunities. Phase 2 of the Task Force's activities will include an analysis of these high level gaps and opportunities. A draft of the interim Phase 1 Report is expected in time for the next Technical Group meeting. The Task Force is currently comprised of Australia (as Chair), Korea, Norway, and the United States.

Ensuing discussion focused on the timelines for development of the TRM and of the Task Force. Stefan Bachu and Philip Sharman both observed that even though the timelines mostly were in synch, some of the results from the Task Force may still come too late to be inputs for the 2013 TRM. However, the two initiatives should still proceed in parallel, as there will be future versions of the TRM.

13. Update on Technical Group Action Plan

John Panek provided a brief summary of the Action Plan. At the September 2011 CSLF Ministerial Meeting in Beijing, the Technical Group approved a new multi-year Action Plan to identify priorities and provide a structure and framework for conducting Technical Group efforts through 2016. Twelve individual actions were identified, and Task Forces have been formed to address four of these twelve actions. Reports from these four new Task Forces are part of the Perth meeting. Mr. Panek stated that activity on another action, Competition of CCS with Other Resources, had been deferred pending the forthcoming IEA Greenhouse Gas R&D Programme (IEA GHG) study related to that topic. As for the action on the Best Practices Knowledge Sharing action, activity had also been deferred, as the Global CCS Institute has been involved in that area.

In response, Peter Grubnic stated that the Global CCS Institute's position was that its members have provided the feedback that knowledge sharing must be a key focus for the Institute and that the Institute should, as much as possible, make its knowledge systems available to other organizations. Mr. Grubnic mentioned that the Institute welcomes the opportunity to work with other organizations, and is already involved with the European Commission's demonstration projects network as well as its Japanese and Korean members, for dissemination of CCS-related learnings. This kind of collaboration reduces duplication, stretches resources, and increases efficiency.

Trygve Riis observed that the Global CCS Institute is already performing knowledge sharing more broadly and comprehensively than the CSLF probably could ever do, and questioned the need for forming a new Task Force or undertaking any other activities in this area. However, Stefan Bachu noted that all of the large CSLF-recognized projects that receive government support have requirements for knowledge sharing, and could effectively do so through a new or existing CSLF Task Force. Clinton Foster suggested that the PIRT would be the logical Technical Group point of contact, for knowledge sharing purposes, with project representatives and also the Global CCS Institute. Information obtained by the PIRT from the projects would be used to populate the Institute's knowledge sharing platforms. There was agreement to proceed in this fashion, and for the PIRT to have main responsibility for the "Best Practices Knowledge Sharing" action. Dr. Foster noted that this approach, combined with the series of successful Technical Workshops that have been organized by the Technical Group, are the beginnings of a technical communication strategy for disseminating knowledge and information.

Stefan Bachu also noted that two other actions in the Action Plan are already being addressed. The action on "Risk and Liability" is being covered by the new Joint Policy and Technical Group Task Force on this topic, while the IEA GHG will soon be publishing a report that appears to address the "Competition of CCS with Other Resources" action. There was agreement that the Technical Group would not address the "Risk and Liability" actions, and would continue to defer any activity toward the "Competition of CCS with Other Resources" action pending review of the IEA GHG report.

Philip Sharman suggested that two other actions in the Action Plan were also being addressed. The Clean Energy Ministerial (CEM) and the IEA are producing a high-level appraisal paper on how industrial emissions relate to CCS, and this would relate to the action on "CCS with Industrial Emissions Sources". This appraisal paper may well establish the basis for a new Technical Group Task Force, but it was proposed and agreed that the Technical Group should defer action in this area so as not to preempt the CEM report. Concerning the action on "Energy Penalty Reduction", Mr. Sharman stated that the United Kingdom's Department of Energy and Climate Change (DECC) already has a Cost Reduction Task Force that is in the final stages of completing a report on this topic, and that it also could be the basis for future Technical Group activities, if necessary. Mr. Sharman was requested to send a copy of the DECC report to the Secretariat, once it is available, so that the Secretariat can disseminate it to the Technical Group delegates. There was agreement to defer any activity in this area pending review of the report.

Mr. Riis noted that, as a result of activities undertaken by various organizations, including CSLF Task Forces, 9 of the 12 actions in the Action Plan are now being addressed. Mr. Panek reminded delegates that the Technical Group's Action Plan is a living document and is open to amendment for new actions. Ideas for additional actions and Task Forces are always welcome.

14. Report from Technical Challenges for Conversion of CO_2-EOR to CCS Task Force

The Task Force Chair, Stefan Bachu, provided a short summary about the Task Force and its activities. At the 2011 CSLF Ministerial in Beijing, there was renewed emphasis on CO_2 utilization, and adoption of the new Technical Group Action Plan resulted in creation of this Task Force and also the CO_2 Utilization Options Task Force. The latter covers all other forms of CO_2 utilization except enhanced oil recovery (EOR), which is being addressed by this Task Force. The most prevalent form of CO_2 utilization, CO_2-EOR, is a proven technology with more than 120 operations worldwide. Dr. Bachu stated that the Task Force's mandate was to review, compile and report on technical challenges that may constitute a barrier to the broad use of CO_2 for EOR and to the conversion of CO_2-EOR operations to CCS operations. Economic and policy barriers would be outside the scope of the Task Force.

Dr. Bachu stated that the Task Force will produce a report that identifies these technical challenges and also any regulatory issues that involve technical aspects. An initial draft will be ready in time for the next Technical Group meeting, in the 2nd quarter of 2013. After comments from the Technical Group have been incorporated, a finalized version of the report will be ready for the 2013 CSLF Ministerial Meeting. Topics to be covered by the report include characteristics of CO_2-EOR operations (objectives, suitability, operational aspects, monitoring & surveillance, regulatory requirements), characteristics of CO_2 storage operations (objectives, suitability, operational aspects, monitoring & surveillance, regulatory requirements), and transitioning from CO_2-EOR to CCS (commonalities and differences, operational scenarios, storage integrity, monitoring and regulatory requirements). Dr. Bachu also mentioned the composition of the Task Force, with confirmed representation from Brazil, Canada (as chair), China, Mexico, Norway, Saudi Arabia, and the United States.

15. Report from CO_2 Utilization Options Task Force

The Task Force Chair, Darren Mollot, gave a brief summary of the Phase 1 Task Force report and outlined Phase 2 activities. The Task Force is focused on all forms of CO_2 utilization except CO_2-EOR, and the mission is to identify/study the most economically promising CO_2 utilization options that have the potential to yield a meaningful, net reduction of CO_2 emissions, or facilitate the development and/or deployment of other CCS technologies. The Task Force is currently comprised of China, Germany, the Netherlands, Saudi Arabia, South Africa, the United Kingdom, and the United States (as Chair).

Dr. Mollot stated that the Task Force activities are being done in two phases. Phase 1 is completed and has resulted in a report that summarizes current knowledge of the use and re-use of CO_2 and provides a broad listing of CO_2 utilization opportunities. During the course of the meeting, the Task Force selected eight technologies as a first cut of those that would undergo further evaluation as part of Phase 2. These technologies fall into three categories: resource recovery (enhanced gas recovery; shale gas recovery; fracturing using CO_2), non-consumptive (urea production; algal fuels; use in greenhouses), and consumptive (synthetic aggregates / supplementary cementitious material; CO_2-assisted geothermal power production). Each technology selected had at least one Technical Group delegate who will champion and lead the assessment effort. The Phase 2 activities will focus on the most attractive CO_2 utilization options, based on economic promise and CO_2 reduction potential, and will include an assessment of current and potential economic viability, estimation of CO_2 reduction potential at various price points, examination of the potential for co-production, and a discussion of RD&D needs. The Task Force's Phase 2 report is planned for completion in time for the next Technical Group meeting, in the 2nd quarter of 2013.

Ensuing discussion centered on the Task Force's Phase 2 activities. Jeroen Schuppers stated that the European Commission is sponsoring several related studies that could be relevant to the Task Force's discussion on RD&D needs. Dr. Schuppers agreed to provide Dr. Mollot the relevant results from these studies, once confidentiality requirements have been addressed. Jostein Dahl Karlsen inquired if the Task Force set its scope to coincide with the year 2020 time horizon of the TRM. Dr. Mollot replied that the Task Force is looking at both near-term and longer-term options and is not necessarily limiting itself to a 2020 cut-off date.

16. Report from Monitoring Geologic Storage for Commercial Projects Task Force

Trygve Riis, speaking on behalf of Task Force Chair Lars Ingolf Eide, gave a brief update on the Task Force and its activities. The Task Force mandate is to perform initial identification and review of standards for storage and monitoring of injected CO_2. Economic and policy issues would be outside the scope of the Task Force. Task Force membership currently includes representation from China, Denmark, the European Commission, France, Germany, the IEA GHG, the Netherlands, Norway (as Chair), the United Kingdom, and the United States.

Mr. Riis stated that the current work plan includes identification and review existing standards for geological CO_2 storage and monitoring (on an annual basis); identification of shortcomings and/or weaknesses in standards/guidelines; communication of findings to the Technical Committee on CCS of the International Organization for Standardization (ISO); producing annual summaries of new as well as updated standards, guidelines and best practice documents regarding geological storage of CO_2 and monitoring of CO_2 sites; and following the work of other organizations related to CO_2 storage. However, the Task Force is not yet scheduled to go beyond 2013, and the future of the Task Force will be decided at the 2013 CSLF Ministerial Meeting.

Mr. Riis reported that the Task Force is on a timeline that will produce its first annual report before the end of 2012. A draft version of the report has already been completed and includes an initial compilation of standards, best practices, and guidelines for storage and monitoring of injected CO_2. Preliminary conclusions are that site selection, monitoring / verification, and risk assessment are best covered by existing standards, Best Practices Manuals (BPMs), or guidance documents, but none of the BPMs reviewed by the Task Force covered all topics of interest.

Ensuing discussion focused on the overall scope of the Task Force. Stefan Bachu mentioned that the original scope of the Task Force, as decided at the Bergen meeting, was only for monitoring of stored CO_2 and not of other issues such as storage capacity estimation and site selection. Mr. Riis stated that he would inform Mr. Eide of this concern and that the Task Force membership would need to resolve it. Jeroen Schuppers mentioned that the European Commission has several projects, most notably the recently-completed ReMoVe Project, that examined monitoring/verification best practices and technologies. Dr. Schuppers mentioned that results from these projects would be a good input to the Task Force and agreed to provide Mr. Eide relevant information as it becomes available. As for coordinating Task Force activities with the ISO, Dr. Bachu stated that the ISO and its committees proceed at a completely different and necessarily much slower pace than the CSLF. It would therefore be very unlikely that the Task Force would get any useful information from the ISO in time for the 2013 CSLF Ministerial Meeting. Ahmed Aleidan inquired if outcomes from the Task Force would be binding in any way, and Mr. Riis responded that the Task Force was formed only to review existing standards, not to create new ones.

17. Status of Proposed CSLF Liaison with the ISO

John Panek provided a brief summary of the CSLF's request to the ISO for liaison status. At the Bergen meeting, the Task Force on Monitoring Geologic Storage for Commercial Projects had recommended that the CSLF request a formal liaison with the ISO Technical Committee on CO_2 Capture, Transportation and Geological Storage (ISO/TC 265). To that end, the CSLF Policy Group Chair, in August, sent a letter to the ISO/TC 265 Secretariat that requested liaison status. Mr. Panek stated that a response was received that requested additional information about the CSLF, and this was provided to the ISO/TC 265 Secretariat in late September.

Stefan Bachu, who is a member of the ISO/TC 265, added that he had received an email announcement the previous day that had requested the ISO/TC 265 membership to vote on the proposed admission of the CSLF to liaison status. However, Dr. Bachu did not know when the result would be announced.

Trygve Riis noted that the CSLF had requested liaison as a "Category A" organization, which is the most active status, and asked who would participate on behalf of the CSLF if liaison status is approved. Mr. Panek responded that the Secretariat would coordinate with the Technical Group Executive Committee in that regard, and that both the United States delegation and the Secretariat have expressed willingness to participate as necessary on behalf of the CSLF. Mr. Panek also stated that the Secretariat would notify Technical Group delegates concerning the outcome of its application, once it is known.

18. Review of 2013 CSLF Ministerial Concept Paper

Trygve Riis stated that a draft Concept Paper had been prepared by the CSLF Secretariat for the upcoming 5th CSLF Ministerial Meeting, and that the Technical Group had been asked to review it. A robust discussion ensued, with many delegates providing their comments on various parts of the document. In the end, there was consensus that the paper needed a major rewrite and that the following recommendations be provided to the Policy Group.

- The proposed theme for the Ministerial Conference, "The Business Case for CCUS: Carbon Utilization to Meet Energy Sustainability, for Economic Development and to Fight Poverty", should be re-thought. In particular, "…to Fight Poverty" is outside the scope of the CSLF and is therefore not credible.
- There is confusion in use of the terms "CCS" and "CCUS" in the paper. The terms are not interchangeable, and should not be used interchangeably.
- CO_2-EOR is an important bridge to CCS but it is not applicable to all countries. The Concept Paper should not give exclusive emphasis to CO_2-EOR, as this may be a disincentive for some Ministers to participate.
- Technical Group activities should be featured more prominently. These include the TRM, the new Task Forces that are addressing the Action Plan, and collaboration with outside organizations.
- The Concept Paper should convey the following messages:
  - CO_2 storage is the issue, not EOR. Therefore, "The Business Case for CCUS…" is not appropriate for the proposed theme.
  - Geologic storage of CO_2 is safe with proper operation.
  - There is a need for large-scale demonstration CO_2 storage projects.
  - There is a need for policy and regulatory clarity regarding CO_2 storage.

19. Dates and Locations of Future CSLF Technical Group Meetings

Giuseppe Girardi stated that Italy would like to host the next CSLF Technical Group meeting in Rome during the week of April 15-19, 2013. The meeting would include a Technical Workshop and a visit to a site near Rome where natural emissions of CO_2 occur. The Technical Group offered its thanks and accepted the offer.

Mr. Panek also stated that he had been notified by Korea's delegation that it would like to host the 2014 Technical Group meeting. Possible dates for the meeting would be forthcoming later. The Technical Group again offered its thanks and accepted the offer.

20. Planning for 2013 Technical Workshop

John Panek reported that planning for next year's Technical Workshop will be coordinated with the Italian hosts. This will be a Monitoring-themed Workshop and Stefan Bachu has agreed to provide his assistance in developing ideas for the Workshop sessions and in suggesting possible participants from the portfolio of CSLF-recognized projects. Mr. Panek stated that as soon as details firm up, the Secretariat would inform the Technical Group.

21. Election of Technical Group Chair and Vice Chairs

Trygve Riis requested that John Panek oversee the meeting for this agenda item. Mr. Panek stated that according to the CSLF Terms of Reference and Procedures, CSLF Chairs and Vice Chairs will be elected every three years. The previous election of the Technical Group Chair and Vice Chairs was at the London meeting in October 2009, and it was now time for another election.

By consensus, Norway was re-elected as Chair, and Australia, Canada, and South Africa were elected as Vice Chairs.

22. New Business

There was no new business.

23. Review of Consensuses Reached and Action Items

Consensus was reached on the following:

- The Technical Group will henceforward use a simplified and more concise version of the Gaps Analysis Checklist for use by projects requesting CSLF recognition.
- The South West Hub Geosequestration Project and the CarbonNet Project are recommended by the Technical Group to the Policy Group for CSLF recognition.
- The schedule for producing the 2013 TRM is accepted.
- The PIRT will act as main Technical Group point of contact, for knowledge sharing purposes, with CSLF-recognized projects and the Global CCS Institute, and will be responsible for any activities on the Action Plan for "Best Practices Knowledge Sharing".
- The Technical Group will not address the Action Plan on "Risk and Liability", as there is a Joint Policy and Technical Group Task Force that has been formed to address this topic.
- The Technical Group will defer addressing the Action Plan on "Competition of CCS with Other Resources" until after publication and review of a report by the IEA GHG related to this topic.
- The Technical Group will defer addressing the Action Plan on "CCS with Industrial Emissions Sources" until after the publication and review of a report by the Clean Energy Ministerial on this topic.
- The Technical Group will defer addressing the Action Plan on "Energy Penalty Reduction" until after the publication and review of a report by the United Kingdom's Cost Reduction Task Force on this topic.
- The Technical Group recommends that the draft of the Ministerial Concept Paper be rewritten.
- Italy will host the 2013 Technical Group meeting in Rome during the week of April 15-19.
- Korea will host the 2014 Technical Group meeting.
- Norway is elected Technical Group Chair.
- Australia, Canada, and South Africa are elected Technical Group Vice Chairs.

Action items from the meeting are as follows:

Item	Lead	Action
1	Technical Group Chair	Provide the Technical Group's recommendation to the Policy Group that the South West Hub Geosequestration Project and the CarbonNet Project be recognized by the CSLF. (*note: this was done at the Joint Meeting of Policy and Technical Groups on October 26*)
2	United Kingdom	Provide a copy of DECC's Cost Reduction Task Force report to the Secretariat as soon as it is available.
3	Secretariat	Send copies of DECC's Cost Reduction Task Force report to Technical Group delegates.
4	European Commission	Provide relevant results from the various CO_2 utilization studies it is sponsoring to the CO_2 Utilization Options Task Force.
5	European Commission	Provide relevant results from the various projects it is sponsoring to the Monitoring Geologic Storage for Commercial Projects Task Force.
6	Secretariat	Inform Technical Group delegates the outcome, once it is known, of the CSLF application for liaison status with the ISO/TC 265.
7	Technical Group Chair	Provide the Technical Group's critique of the Draft Ministerial Concept Paper to the Policy Group. (*note: this was done at the Joint Meeting of Policy and Technical Groups on October 26*)

24. Closing Remarks / Adjourn

Trygve Riis thanked the delegates, observers, and Secretariat for their hard work and active participation in the meeting, and expressed his appreciation to the Australian Government and other meeting sponsors. Mr. Riis stated that there had been an illuminating discussion about the 2013 Ministerial Meeting as well as good progress on the TRM and by the Task Forces.

Mr. Riis reminded attendees of the next day's Joint Meeting of the Policy and Technical Groups and adjourned the meeting.

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THE POTENTIAL FOR REDUCING THE COSTS OF CCS IN THE UK

INTERIM REPORT

PUBLISHED BY THE

UK CARBON CAPTURE AND STORAGE COST REDUCTION TASK FORCE

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LONDON, UK

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EXECUTIVE SUMMARY

Introduction

Electricity generation in the UK is on the brink of a radical transition driven by the Government's ambitious carbon reduction targets, and retirement of ageing coal, nuclear and gas plant. A majority of the current base load generation fleet will require replacement before 2030, and if the UK is to reach its 80% GHG emissions reduction target by 2050, significant decarbonisation of the entire energy sector will be needed at the same time.

The twin requirement to replace ageing plant, and to reduce CO_2 emissions, can be turned into an advantageous infrastructure investment in Carbon Capture and Storage (CCS), to enable long-term use of fossil fuels in a carbon-constrained economy, alongside renewable and nuclear power, and to generate "Green Growth" for the UK economy.

Energy system modelling by the Energy Technologies Institute suggests that successful deployment of CCS would be a major prize for the UK economy, cutting the annual costs of meeting carbon targets by up to 1% of GDP (or around £42 billion per year) by 2050.

The availability and scale of high quality geological storage beneath the UK continental shelf in the North Sea and East Irish Sea, and the UK's well established offshore oil and gas expertise means that CCS represents an opportunity to drive UK economic growth, to retain and grow employment opportunities, to protect and grow the UK's manufacturing base and to gain significant competitive advantage in manufacturing costs over other countries in Europe. This gives the UK a unique position within Europe.

There is also an important and valuable opportunity to exploit the symbiosis between CCS and CO_2 EOR in the UKCS, adding significant revenues to a number of projects and extending the productive life of several UK oilfields. This is a key driver for CCS in the US and Canada, and it may be possible to achieve analogous benefits in the UK.

And in the longer term the UK might choose to sell a storage service to other EU countries to reduce their own emissions, and to export UK CCS-related services across the globe.

The Task Force

The CCS Cost Reduction Task Force was established in March 2012 by DECC to advise Government and Industry on the potential for reducing the costs of CCS, so that CCS power projects are financeable and competitive with other low carbon technologies in the early 2020s.

The Task Force comprises 30 members from the engineering, hydrocarbon, finance, project developer and academic sectors, representing a broad spectrum of UK and international organisations with deep experience in all aspects of CCS.

This Interim Report describes the work undertaken by the CCS Cost Reduction Task Force to date. The report describes the sources of potential cost reduction, along with the key enabling actions required to deliver them.

Key Conclusion

It is the conclusion of the Task Force that:

UK gas and coal power stations equipped with carbon capture, transport and storage have clear potential to be cost competitive with other forms of low-carbon power generation, delivering electricity at a levelised cost approaching £100/MWh by the early 2020s, and at a cost significantly below £100/MWh soon thereafter.

In essence, these costs of electricity can be achieved in the early 2020s through:

1 a. investment in large CO_2 storage clusters, supplying multiple CO_2 sites;

1 b. investment in large, shared pipelines, with high utilisation;

2. investment in large power stations with progressive improvements in CO_2 capture capability which should be available in the early 2020s;

3. a reduction in the cost of project capital through a set of measures to reduce risk and improve investor confidence in UK CCS projects; and

4. exploiting potential synergies with CO_2-based EOR in some Central North Sea oil fields

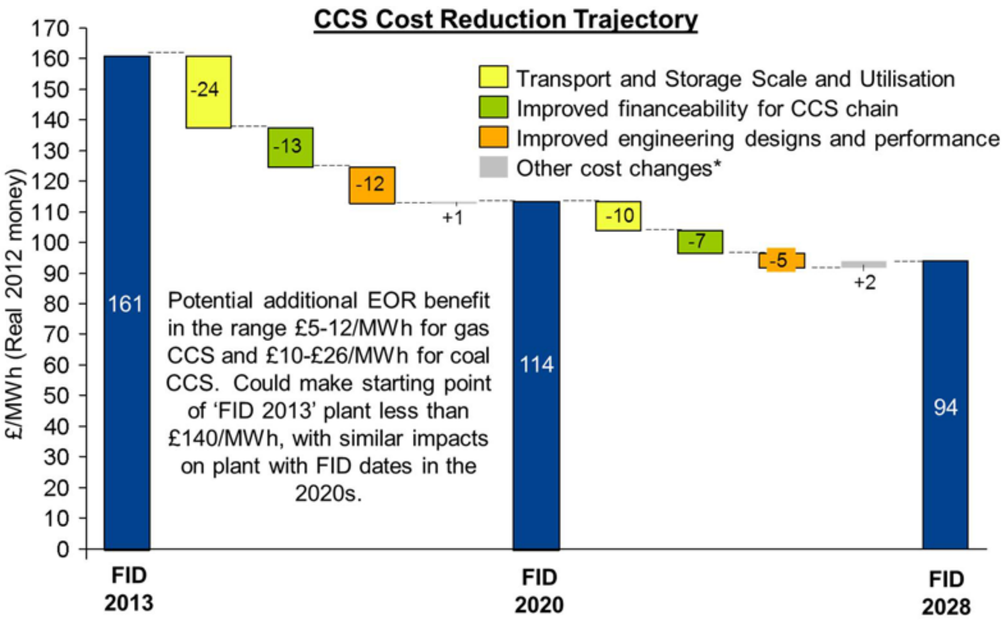
The cost reductions available in the early 2020s will be based on technologies that are already widely used at large scale, and that can be invested in with confidence and manageable risk. Further benefits from 'learning curve' effects, technology innovation, improved construction techniques, supply chain competition and the like will reduce costs further in the later 2020s.

These costs are potentially cheaper than alternative low-carbon generation technologies, without the system costs and drawbacks associated with supply intermittency or inflexibility.

Components of Cost Reduction

Early CCS-equipped power generation projects commissioned before 2020, will have higher costs because of their smaller size; relatively short lifetime if built on existing power plants; single point-to-point (capture-to-storage) full-chain configuration; engineering prudence; and risk averse commercial and financing arrangements. The Task Force anticipates that the first set of projects may have costs in the range of £150-200/MWh.

CCS costs in the 2020s will also depend on the specifics of each particular project. However an indication of the relative significance of the five key factors listed above is given in the graph below. The key conclusion of the Task Force is based on the underlying analysis summarised in this chart. The Task Force is reassured in this conclusion by similarities across capture technologies and the commercial development of analogous technologies such as Flue Gas Desulphurisation and Combined Cycle Gas Power Plant.



Note: Shows average costs across technologies. *E.G. Increasing CO_2 price, falling storage abandonment costs

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The UK "CCS Landscape"

The Task Force is confident that the measures outlined in the five areas above will have the effect of reducing the costs of electricity produced by CCS-equipped power plants by the early 2020s. However, this can only happen if these measures are taken against the background of a landscape in the UK which is favourable to the development of CCS projects.

The following are the key characteristics required of that "CCS landscape":

Credible long-term UK government policy commitment to CCS

i. A continued view within industry that the UK government remains serious about encouraging CCS projects, and will provide the policy and financial support (e.g. through CfDs) to enable their development.

ii. A publically stated aspiration that CCS will be deployed at scale in the early 2020s, provided it can be cost competitive with renewables, would be most helpful.

iii. Equipment suppliers and supply chains have sufficient confidence in the commitment to a steady roll-out of CCS that they can commit to invest their energies in this industry to reduce costs and improve performance.

iv. The planning framework – in all its guises, including national and local planning, seabed usage planning, etc. – should have as its basis the presumption that CCS and associated infrastructure will be needed, rather than the view today that it may or may not be needed.

v. A coordinated plan for transport and storage, which allows for the development of infrastructure incrementally but with vision of the long-term.

vi. A suitable regulatory structure, and fiscal and policy framework to foster development of CCS at scale in the early 2020s.

vii. Clarity on the effective interpretation of the requirement that new gas plants be "CCS Ready".

viii. Continued government support for CCS R&D, to compliment investment from industry.

Multiple operating full-chain CCS projects:

ix. Successful development of the projects coming out of the UK CCS Commercialisation Programme before 2020 (and earlier if possible), with a view to building on the storage and transport infrastructure that they create;

x. On-going offer to future CCS projects, built into the EMR, of a CfD sufficient to make good projects financeable.

xi. Commitment to and frameworks for learning and knowledge sharing from projects and research in the UK and globally.

Continued engagement with the financial sector

xii. It is fundamentally important to maintain the current dialogue with the financial community so that its needs can be fed into policy development – responsibility for this engagement lies both with industry and with policy makers.

Underlying sources of cost reduction

The Task Force has confidence in this conclusion because it has examined in some depth the effect of opportunities for cost savings in five aspects of CCS projects:

Storage

- In order to finance full "economic-scale" CCS power stations, power station investors cannot be exposed to significant CO_2 storage risks. The transport and storage system must be very reliable, and its operating regime well matched to the intended operation of the power station.

  Uncertainty around the geological and operating behaviour of CO_2 storage sites means that reliable storage providers are likely to require access to more than one proven store, and to be capable of switching stores in order to provide back-up. This leads directly to the concept of proven 'storage hubs '.

  Through the correct configuration of the storage facilities in early projects it should be possible to structure a highly reliable storage service using storage hubs and multiple storage sites for follow on projects. This will make larger-scale generation and capture projects deliverable and financeable at costs in line with industry norms.

- A large part of the cost of CO_2 storage is set by the development costs of the surface facilities for the storage reservoir, which do not vary hugely with the rate of storage. Early projects with low CO_2 injection rates for storage will therefore incur high unit storage costs (unless they can share their storage).

  Storage will benefit significantly from scale. Multiple large generation plant supplying CO_2 to a hub will allow the storage development costs to be shared across large volumes of CO_2 stored.

The Task Force estimates that storage costs can be reduced from around £25/MWh in early projects to £5-10/MWh through investing in a CO_2 storage cluster supplying multiple CO_2 sites, which store volumes of around 5 million tonnes of CO_2 per annum. Lower costs per MWh could be seen in the longer-run, particular for gas based CCS, if higher volumes of CO_2 from multiple large capture plants feed into larger storage clusters.

Transport

- A well designed pipeline network is a key enabler of the storage hub. It allows new storage sites to join the network over time; it allows multiple storage sites to operate together; and it allows operational switching between storage sites when necessary. The configuration of the transport system for early projects should take into account the likely future development of the CO_2 pipeline network, in order to reduce future costs.
- The unit costs of transporting CO_2 by pipeline decreases as scale increases. Both utilisation and scale are important. This is supported by a key conclusion of the recent Mott MacDonald report, and endorsed by the Task Force, that leveraging early CO_2 infrastructure, if it designed correctly, can reduce the incremental cost of transport and storage substantially for later projects.
- CO_2 pipeline transport is a well-established technology and can be expected to have very high reliability, provided pumping reliability is given suitable attention.

The Task Force anticipates that transport costs could drop from around £21/MWh for early projects carrying 1-2 million tonnes of CO_2 p.a., to £5-10/MWh for large, well-used pipelines carrying 5-10 million tonnes of CO_2 p.a. Even lower costs per MWh could be seen in the longer-run, particular for gas based CCS, if still higher volumes of CO_2 from multiple large capture plants were feeding into an interconnected right-sized network.

Generation and Capture

- Early CCS projects developed in this decade are likely to be of modest size, in order to minimise risk across the full chain. Their levelised cost of electricity is therefore expected to be fairly high.

  Once CCS is established, significant reductions in electricity cost will be available through scaling up to plants sizes of around 1 GW, equivalent to unabated plants being installed elsewhere in the world.

  The Task Force has confidence that full scale plants with CO_2 capture will be available, operable and financeable in the early 2020s, and therefore that these economies of scale will be realised.
- CCS power generation and capture technology, although not new, is not yet fully mature. Significant, progressive improvements, particularly in CO_2 capture capability, and reductions in the energy penalty of capture can be foreseen for the early 2020s.

  In addition costs can confidently be predicted to fall further thereafter, once learning from early plants installed across the world becomes available.
- Suppliers of CCS power generation and capture plant technology continue to be aggressive in developing their technology, and competition is substantial. If they continue to be confident that this market will grow, increasing supply chain scale and price competition will drive prices downwards.

  Cost reductions will also come from reduced redundancy, appropriate process integration and use of improved materials.

The Task Force estimates that generation and capture costs could drop from an average of around £116/MWh for early projects to £96/MWh for projects in the early 2020s. Significant further reductions in generation and capture costs are possible by the late 2020s and beyond through continued improvements in capture technology.

Reduction in Cost of Capital / Achieving Affordable Finance

Early UK CCS projects' cost of capital will reflect their novel nature, their limited size, a lack of industry track record, Government's requirement to limit its exposure and the commercial risks inherent in the CfD FiT structure.

For example:

- No commercial scale projects yet exist from which financiers can gain confidence in the model and the business;
- Storage risks and uncertainties can be perceived as significant until the store is operational and well proven;
- The CfD mechanism does not take account of the project-on-project risk along the CCS chain, with each part of the chain exposed to on-going cost but no income if another part of the chain fails.

However, as the industry matures several developments are likely to reduce the cost of financing projects. In particular:

- De-risking the CCS chain, in particular through:
  - roviding a regulatory and policy structure that leads to financial security and insurance structures which allocate risk to those parties best able to manage them;
  - ting an optimal contracting structure which balances contract standardisation to encourage financing with flexibility to adapt to project specific requirements;
  - elopment of a storage solution which is ‘proven’ and demonstrably fit for purpose and robust to problems in any one store or well;
  - uilding on the success of early projects to provide confidence in the operational performance of CO_2 capture equipment and the interaction with rest of the chain;
- Development of a suitable funding structure which caters for the full chain required by CCS projects, and incentivises them to provide flexible back-up to intermittent renewables in the future;
- Continued education and development of a critical mass of financial sector interest and involvement in CCS projects.

Estimating the individual contributions of each of these components is not straightforward, but informed members of the Task Force have suggested that the cost of capital (however raised) could fall from the “high teens” for early projects to around 10% or below by the early 2020s.

CO_2-based Enhanced Oil Recovery (EOR)

- CO_2 injection into oil fields is one method of recovering otherwise unrecoverable oil from mature oil fields, creating additional income to offset CCS costs, and deferring substantial decommissioning costs. The Central North Sea (CNS) oil province is mature with many fields set to close in the next decade.

  CCS and CO_2-based EOR fit together extremely well. Storage can be undertaken alongside EOR, and the revenue from additional oil production is a key reason for the development of many CCS projects in the US and Canada.

  A word of caution is needed when considering EOR, as not all Central North Sea fields are suitable for CO_2 EOR projects, technical and cost risk profiles are different from North America and there is no direct experience of offshore CO_2 EOR in the Central North Sea (CNS) or elsewhere. However, several oil companies are actively exploring the option of pursuing CO_2-based EOR on a number of fields in the CNS.
- Only a rough estimate can be made currently as to the value CO_2 may attract, if it were delivered, at pressure, to CNS oil field operators. Based on US experience this could well cover the cost of conventional CO_2 storage, and perhaps some of the transport costs as well. As a result this might decrease electricity costs by £5-12/MWh for gas CCS and £10-£26/MWh for coal CCS.
- It is the view of a number of informed Task Force members, and others who have been consulted, that EOR investments will be actively pursued, and probably sanctioned on some fields, as soon as there is confidence that CO_2 is being delivered to the Central North Sea (CNS); and that this will reduce the costs of electricity from some of the power project investments which are expected to be built in the early 2020s.

- In addition to reducing the cost of CO_2 transport and storage, CO_2 Enhanced Oil Recovery (EOR) in the UKCS, could extend the productive life of some UK oilfields significantly. The resulting benefits could include tax revenues, employment, delayed decommissioning, and enhanced UK balance of payments.

Other Applications of CCS

Development of CCS in the power sector could unlock the opportunity for a wide range of applications of CCS with broader benefits for the UK economy and its low carbon transition. These are not taken into account in simple comparisons of Levelised Cost of Electricity (LCOE) figures during the 2020s and include:

- Industrial applications, enabling emissions reductions at low incremental costs, helping to safeguard key UK industries against decarbonisation requirements;
- Future CCS applications (including those with bio energy and gasification technologies) which can potentially enable the use of a wider portfolio of low carbon energy technologies encouraging greater efficiency and flexibility in meeting 2050 targets.

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1. INTRODUCTION

In recent years, sustainability and security of supply objectives have become increasingly important for the energy sector. Energy policy and regulation objectives at European and UK levels have had to evolve in line with this change in direction. In its 2011 Electricity Market Reform white paper, the Department of Energy and Climate Change (DECC) summarised its policy objectives as:

- to ensure the future security of electricity supplies;
- to drive the decarbonisation of our electricity generation; and
- to minimise costs to the consumer.

The UK electricity generation sector is now on the brink of a radical transition to replace aging power plant capacity and to move to low carbon alternatives. Over the coming years, closure of existing coal, nuclear and gas plant will be driven by both the age of the existing generation fleet and by European environmental Directives. The requirement to replace this capacity could be turned into an advantageous infrastructure investment to enable continued use of fossil fuels in power and industry in a carbon-constrained economy. Gas and coal-fuelled generation fitted with Carbon Capture and Storage (CCS) is, alongside renewables and nuclear, a core option for this replacement plant. The ultimate size of the CCS generation tranche will be determined by its cost competitiveness compared to alternatives and the timescale of which cost competitive plant is available.

The CCS Cost Reduction Task Force was set up by DECC to advise Government and industry on the potential for reducing costs so that CCS generation projects are financeable and competitive with other low carbon technologies in the early 2020s. This interim report provides a summary of the initial findings of the Task Force. A final report will follow by April 2013.

1.1 Role of CCS in UK electricity generation mix

Several potential generation technologies are available to help achieve the decarbonisation goals. Some have negligible carbon emissions and some have much lower emissions than available from current technology. The approximate carbon intensity of generation from selected technologies is shown in Table 1 below.

Table 1 – Approximate emissions intensity of generation: Example technologies

Technology	Carbon intensity (gCO_2/kWh)
Conventional coal (unabated)	750-900
Conventional gas (CCGT) (unabated)	350-380
CCS coal	80-150
CCS gas	30-70
Dedicated biomass	Negligible net contribution
Nuclear, Wind, Marine	Negligible emissions
CCS biomass	Negative emissions

Note: The numbers above reflect emissions at the point of generation. Lifecycle emission analysis, including any requirement for additional 'back-up' generation for intermittent generation, would show a higher emissions intensity.

The prospects and timescales for deployment of low carbon generation vary for different types of technology. However, given the rates at which new low-carbon plant can be commissioned, and the attendant risks associated with all technologies, it is essential that a complementary mixture of technologies is deployed. Early deployment of coal- and/or gas-fuelled CCS will help to mitigate technical and economic uncertainty and will increase the likely contribution from these technologies in the future – this will be particularly helpful in progressing towards the additional decarbonisation required after 2020.

One peculiar aspect of wind power generation is that, being at the mercy of the weather systems passing through the UK, output will be highly variable over time. Over the next decade, the main new technology built to meet renewables and decarbonisation targets in the UK is likely to be wind generation, both onshore and offshore.

Inevitably the intermittency of this new wind generation capacity will create additional challenges for the electricity market and system operation, as conventional generation has to be available to take over when there is little wind generation, and switched off when there is a lot of wind generation. There are therefore significant network management benefits in the longer-term to introducing alternative, potentially flexible, sources of low-carbon electricity such as abated coal and gas alongside intermittent renewable generation. By ‘flexible’ generation, we mean power stations whose output can be ramped up or ramped down in order to compensate for fluctuations in the power output from wind generators. Such plant flexibility is likely to be valuable even if it is only required in a relatively small number of time periods.

Fossil fuel generation with CCS is potentially able to operate in a flexible mode, increasing generation at times of high demand/low wind output and decreasing generation, even switching off, at times when it is not required. It therefore has the potential to provide much needed flexibility to the system and help avoid curtailment of wind generation.

1.2 Other opportunities and benefits associated with CCS

The benefits of the CCS Commercialisation Programme can extend well beyond the narrow confines of electricity generation. For example, CCS is an essential route to reducing carbon emissions for a number of UK industries; and the availability of transport and storage infrastructure will be critical to underpinning their economic health, and even their continued presence in the UK, beyond the early 2020s.

Furthermore, some CCS technologies under consideration for power applications involve the production of hydrogen in bulk, providing the opportunity to also decarbonise smaller CHP installations, provide feedstock for industry and, in the longer term, the opportunity to provide low carbon transport with reduced dependence on oil and also to enable partial decarbonisation of space heating. Availability of low carbon electricity production using CCS, can also promote fuel switching to electricity from gas, coal or oil for transport and heating.

There are also wider economic benefits to CCS which have been previously discussed by both DECC[1] and the Scottish Executive[2]. The Technology Innovation Needs Assessment (TINA)[3] stated that *“[CCS] Innovation could also help create a UK industry with the potential to contribute further economic value of £3-16bn to 2050.”* Additionally

1 http://tinyurl.com/bsf4g9q

2 http://tinyurl.com/5sgbgsu

3 http://tinyurl.com/bsg65wb

much valuable work has been undertaken by proponents of regional 'CCS clusters' in numerous locations around the UK. These benefits include:

- supporting regional development in:
  - egions where carbon capture can be deployed to large emitting power and industrial sources, helping to support the continued operation of those industries; and
  - ions where traditional offshore expertise can be utilised to develop CO_2 storage
- tens of thousands of new jobs in the CCS industry by 2030 as well as the protection of existing jobs in vulnerable industries;
- value creation from exporting CCS expertise to other geographical regions;
- long-term infrastructure development creating construction jobs as well as laying down valuable long-term strategic assets for the UK economy; and
- additional treasury revenue from increased taxation income where EOR allows further oil reserves to be exploited.

1.3 Composition of the Task Force

The CCS Cost Reduction Task Force was set up by DECC to advise government and industry. The Task Force comprises around 25 members, selected from the engineering, hydrocarbon, finance, project developer and academic sectors. A full list of Task Force members and the Terms of Reference of the Task Force can be found in Annex C.2.

1.4 Approach

Task Force methodology

The CCS Cost Reduction Task Force was established by DECC as part of the actions arising from the CCS Roadmap and is chaired by Dr Jeff Chapman, CEO of the CCSA and project managed by The Crown Estate. Three workstreams were established covering key potential areas of cost reduction with 'workstream champions' nominated as experts in the field to lead those discussions:

- Planning and Infrastructure: Mike Saunders (represented by Alastair Rennie), AMEC
- Commercial and Financial: Allan Baker, Societe Generale
- Generation and Capture: Leigh Hackett (represented by Thomas Stringer), Alstom

Task Force members were given the opportunity to:

- take part in a series of workshops in each workstream;
- provide written response to a questionnaire seeking detailed cost reduction opportunities and the impact each would have on a levelised cost of energy (LCOE) for CCS equipped CO_2 emitters; and
- provide detailed input via a one-to-one discussion / interview session.

The overall process was facilitated by Pöyry with additional key experts not included in the original task force also consulted where it was felt they could provide significant expert knowledge in particular areas.

The key conclusions from this process were then discussed by the entire Task Force with individual chapters of the report reviewed by workstream champions. Finally, the overall document was assessed by a core team of Task Force members and agreed to broadly reflect Task Force opinion (recognising the range of views on many subjects).

Modelling approach

Pöyry reviewed the model used in the DECC sponsored report by Mott Macdonald on potential cost reductions in CCS in the power sector[4]. Pöyry used the same general methodology and have taken Mott Macdonald data as a base for assumptions wherever possible. The model inputs were reviewed by the Task Force to establish a baseline from which to measure cost saving potential. This baseline is taken as a starting point when discussing cost reduction opportunities, and their impacts, within this report.

Cost savings for all four technology configurations covered in the Mott Macdonald report were examined:

- Post-combustion coal CCS;
- Post-combustion gas CCS;
- Oxy-combustion coal CCS; and
- Pre-combustion coal also known as Integrated Gasification Combined Cycle (IGCC) with CCS.

In places we refer to the technologies individually but we often show the average cost level across all technologies to simplify the message. Despite the differences in cost profile, the process has shown that the importance and magnitude of cost saving opportunities is broadly similar between the different technologies.

It should be recognised that:

- quantification of cost savings is difficult but the findings of this report appear broadly consistent with Mott Macdonald's analysis and findings in other similar studies once study-specific assumption have been accounted for; and
- forward-looking cost analysis is subject to uncertainty and there is potentially more work that can be done to provide further clarity on the modelled outputs and overall cost levels.

What this report IS

This report is a representation of the opinion of the Task Force members on the opportunities for reducing the costs of CCS in power generation and what impact the delivery of those options may have on the agreed baseline referred to above. The report broadly references a single LCOE path, however this path is for discussion purposes only and is used to highlight the degree of impact potential cost reduction opportunities may have on the overall LCOE of CCS equipped CO_2 emitters.

What this report IS NOT

This report is not a detailed model or representation of CCS project costs. It is also not a list of actions which have been assigned to industry, government or any other stakeholder. The report presents cost reduction opportunities. Further analysis is required to determine exact impacts and costs and agreement is required as to who may undertake identified candidate actions if and when they are adopted.

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[4] Potential cost reductions in CCS in the power sector, Discussion Paper, May 2012 http://tinyurl.com/c3cj9e8

2. CREATING A FAVOURABLE LANDSCAPE FOR CCS IN THE UK BY THE EARLY 2020s

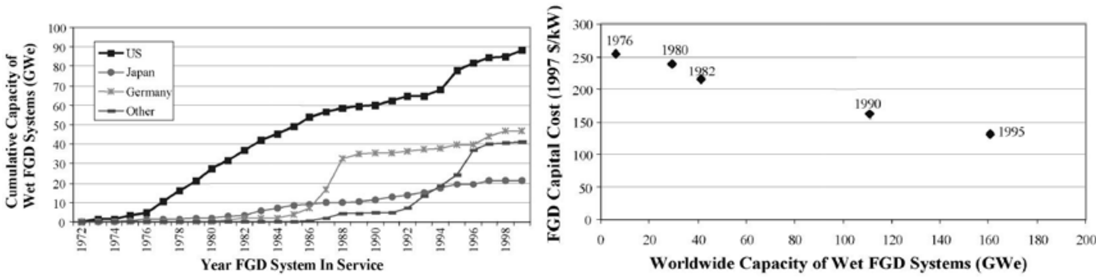
Like other technologies at an early stage of deployment CCS equipped power stations will have many opportunities for cost reductions as the deployment of the technology gathers pace.

Experience curves in a parallel technology: Flue Gas Desulphurisation (FGD)

Parallels can be drawn between the development of carbon capture and other emissions control technologies. This example is taken from a 2004 paper 'Experience curves for power plant emission control technologies' by E.S. Rubin et al.

From the 1970's onwards progressively more stringent controls have been introduced in the US, Japan and Europe over sulphur emissions from power generation. Historically this has been most relevant to coal-fired power plants. The increasingly strict emissions limits have led to the widespread adoption of post-combustion control systems of sulphur emissions, otherwise known as FGD. The most prevalent of these is a 'wet' FGD system employing limestone or lime as a chemical reagent.

If we can compare the capital cost of contemporaneous FGD systems (in this case fitted to a 500MWe coal plant, 3.5% sulphur coal with 90% SO_2 removal) to the worldwide installed base of FGD we can extract the 'experience curve' for FGD, showing the relationship between technology cost and installed capacity.

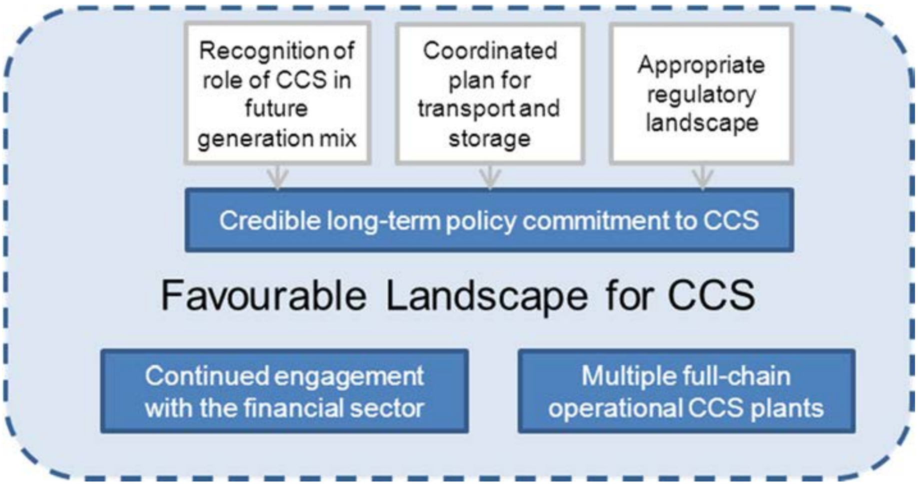


We can see that FGD costs exhibit significant declines over time. The view is that the costs reductions were largely the result of continued R&D activity although it is noted that competition between FGD vendors may also have contributed.

These experience curves are consistent with a large body of literature which examines a range of technologies.

However, cost reduction will only take place if a conducive 'landscape' engenders the transition from the early projects to a situation in which the application of CCS is viewed as 'conventional' in the same way CCGTs (or FGD systems – see box) are now. If such a landscape were to evolve then many of the cost saving measures will manifest themselves as a function of installed capacity, as commercial market drivers drive industry toward cost saving measures.

The key elements of such a landscape are described below.



2.1 A credible long-term policy commitment

Although the CCS industry is committed to continuing to play an active role in policy development, many of the most critical decisions to put in place the correct fundamental drivers are in the hands of policymakers. If the right conditions are created, then the Task Force firmly believes that CCS will be able to compete with other sources of low carbon generation. These key conditions include:

- recognition of the role of CCS in the future generation mix;
- working with industry to facilitate coordinated deployment of transport and storage infrastructure; and
- ensuring the regulatory landscape is fit-for-purpose and does not unintentionally block CCS projects.

We now discuss each of these in more detail.

2.1.1 Recognition of the role of CCS in the future generation mix

The Task Force recognises recent positive statements made by the government regarding the future role of CCS, as well as the funds made available through the CCS Commercialisation Programme. Nevertheless, some ambiguity remains in terms of the long-term pathways for decarbonising the UK economy, and for roll-out of CCS in particular. Making large-scale CCS power generation explicitly part of energy mix plans, provided it can be competitive with renewables, would help to resolve this uncertainty. It would also be helpful if the government were to recognise explicitly the potential cost effectiveness of CCS as part of emissions reduction and need for fossil fuels to back-up intermittent wind and loss of current nuclear fleet.

In order that equipment suppliers, project developers, financiers and other industry participants can make firm commitments to developing CCS in the UK, confidence in the long-term future of the industry is needed. In particular the development of the CCS supply chain, will require a perception that the UK will be undertaking a ‘steady-roll out of CCS’. This will create an on-going market for related products and services, without large boom and bust cycles of investment.

This recognition of the need for CCS, and the continuing need for CCS must also be present in the planning framework in all its guises, including national and local planning, and seabed usage planning. The planning and policy statements that influence those planning decisions, should have as their basis the presumption that CCS and associated infrastructure will be needed, rather than the view today that it may or may not be needed.

Candidate Action: Development of CCS could benefit from a planning framework that has an assumption that CCS will be needed, rather than that CCS might be needed.

2.1.2 Coordinated plan for transport and storage

The high-upfront costs of pipeline and storage infrastructure and the known large potential benefits from developing an optimal network of transport and storage suggest that potential cost savings could be realised if infrastructure is developed incrementally but with vision of the long-term.

Transport and storage developments are also linked as a well-designed pipeline network will also be a key enabler of storage hubs. So new storage sites will be able to join the network over time; multiple storage sites will operate together; and operational switching between storage sites will be simpler to execute when operational factors at any individual store require it to reduce capacity.

The Task Force believes that:

- Some form of long-term visibility of infrastructure plans would help project developers to plan suitably sized and located capture/storage sites. It is not yet clear whether this should extend as far as a centrally coordinated approach, or just an open and collaborative approach amongst project developers; and
- It would be advantageous if national planning framework/guidelines can be used to fast track consenting for storage and pipeline infrastructure.

It is currently unclear how much central planning is required to create a low-cost robust pipeline and storage network in the early 2020s and how much it is really a later stage issue.

Candidate Action: Consider work on an optimal strategy for locating CCS, to optimise fuel transport, electricity transport and CO_2 transport across the UK.

2.1.3 Appropriate regulatory landscape

The complex nature of CCS projects, with the likelihood of most of them having different companies involved in each of the capture, transport and storage elements, will require a unique approach to regulation in general and funding mechanisms in particular. Some projects are likely to develop as end-to-end CCS chains, whilst others are more likely to form or join clusters. Different elements of the chain may require different regulatory treatments. Some projects may include using the CO_2 for Enhanced Oil Recovery (EOR), whilst others will be simple storage. Regulations will have to be designed in a way that they retain their underlying drivers while also offering sufficient flexibility for a wide variety of project schemes.

More specifically, it is important that CCS is not artificially disadvantaged by the structure of funding mechanisms. There is some doubt within the Task Force as to whether the current EMR proposals will be fit for purpose for commercial scale CCS projects, and many members believe that unnecessary risks could unintentionally be introduced. The Task Force's views on funding mechanisms for projects reaching final investment decision in the early 2020s are discussed in detail in Section 5.2; it is also important that there is recognition that the unique features of CCS may necessitate a different treatment to other low-carbon generation in the next few years (i.e. at early stages of deployment).

Aside from the form of any support arrangements, it will also be important that Government can confirm that sufficient funds will be available to meet CCS and other low-carbon commitments, providing clarity around any funding limits applicable under the Levy Control Framework.

Industry and Government are already collaborating successfully on many areas of R&D in relation to CCS. The R&D requirement from both industry and Government is on-going to deliver low-cost CCS in the early 2020s and to keep costs on a continued downward trajectory.

There has also been discussion in the Task Force that additional clarity on the effective interpretation of the requirement that new gas plants be "CCS Ready" would be beneficial. As much of the infrastructure required for CO_2 transport and storage will need to be built with vision of the long-term, the potential future retrofit of gas plants with CCS could have a significant influence over shorter-term decisions for CCS infrastructure development.

Finally, the Task Force notes that excessively burdensome or overly prescriptive regulation is likely to stifle innovative solutions, and should be avoided.

2.2 Operational CCS plants

Demonstration of a variety of technologies and storage types/locations will be required to enable a full range of cost reductions to be realised in the 2020s and beyond. The Task Force considers that, for any given project, approximately three years' of successful operation is required for equipment suppliers and operators to 'learn' for the next wave of projects. This implies that in order for cost reductions to be achieved by the early 2020s a small number of projects must be deployed within the next five years.

The Task Force strongly supports the aims of the Government's Commercialisation Programme, and believes that this action will have the potential to kick-start a first wave of CCS projects in the UK. Delivery of this programme will be essential if the cost reduction opportunities outlined in this report are to be realised, as it can demonstrate that both the technical and commercial aspects of CCS are realisable (within each component in combination across the full chain). It will also raise public and investor confidence in what is still seen as a novel technology by those outside the industry.

A key aspect of the CCS Commercialisation Programme is to develop practical experience of the consenting and development process, which should in turn lower certain regulatory risks – not least, clarification around the long-term liabilities for CO_2 held in storage sites.

The Task Force also notes that CCS projects outside the UK have potential to provide useful information and experience that could be leveraged within the UK. Learning from other projects in Europe and beyond will be valuable and should be pursued wherever possible. Nevertheless, to stimulate development of supply chains and establish consenting processes a small number of projects will be required within the UK. These should have a track record of successful stakeholder engagement programmes which will help to avoid public acceptance concerns that would make planning more difficult.

2.3 Continued engagement with financial sector

Financing early commercial CCS projects is likely to be far more complicated than conventional power projects, because new financial structures need to be developed, and appropriate sources of funds brought in. Subject to suitable revenue streams being in place, some parts of the CCS chain may be financeable through conventional project financing, whilst others will require a more tailored approach. In particular, project finance for the storage sector is unlikely to be forthcoming without proven revenue certainty, which in turn will be extremely difficult for early projects.

These challenges dictate that the financial sector is able to adequately understand and assess the value drivers and risks associated with CCS projects. Conversely, policy must account for the real-world imperatives faced by banks and others involved in financing CCS projects.

The Task Force notes that realistically, there is likely to be limited active interest from commercial banks and other finance providers now, due to the lead times in developing commercial scale CCS projects. Nevertheless, it is fundamentally important to maintain the current dialogue with the financial community so that its needs can be fed into policy development. Failure to take account of these needs would be to risk the potential for 'bankable projects' in the 2020s.

The nature of this engagement is likely to require that a core number of 'experts' from the financial community remain involved in the debate – and that these individuals are drawn not only from the banking sector, but also the insurance industry and other related areas. The responsibility for this engagement lies both with industry and with policy makers.

2.4 Key conclusions

The landscape described above will not, by itself, guarantee that costs of CCS projects in the early 2020s can be reduced to a satisfactory level. However, it will enable a wide range of cost-reducing actions to be pursued. The most tangible ones can be grouped into three areas corresponding to the Task Force workstreams:

- **Planning and infrastructure developments** – focused on maximising transport and storage economies of scale.
- **Generation and capture technology development** through improved engineering designs and performance; and
- **Commercial and financial arrangement evolution** to achieve affordable finance for the CCS chain.

These three broad areas are discussed in the following sections of this report.

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3. MAXIMISING TRANSPORT AND STORAGE ECONOMIES OF SCALE AND SYSTEM EFFICIENCIES

Virtually all of the CCS projects proposed in the UK to date are based on isolated full chain schemes in which a single power station is connected via a single dedicated CO_2 pipeline to a storage site in the UK Continental Shelf (UKCS), generally a depleted oil and gas field (DOGF) or else a saline aquifer. Pipeline and storage costs in these early projects will be significant contributors to the LCOE with costs in the region of £30-50/MWh.

In the context of the landscape actions discussed in Section 2, a variety of cost saving routes were identified by the CRTF. This section will present the main findings for costs reductions from the Transport and Infrastructure Workstream.

3.1 Achieving optimal scale in transport and storage

Storage

A large part of the cost of CO_2 storage is associated with the development costs of the storage reservoir, which are incurred even for quite low volumes of CO_2 injection. As higher volumes of CO_2 are injected in a particular site, additional costs will be incurred (primarily more wells and additional monitoring) but the percentage cost increase will be small in comparison to the overall increase in volumes. Early projects with lower CO_2 volumes for storage will therefore incur higher unit storage costs (unless they can share their storage) but as with transport, storage will benefit significantly from scale.

The Task Force estimates that storage costs can be reduced from around £25/MWh in early projects to £5-10/MWh by investing in a CO_2 hub (or cluster), supplying multiple CO_2 sites, storing CO_2 volumes of around 5 million tonnes of CO_2 per annum. Lower per MWh costs could be seen in the longer-run, particular for gas based CCS, if higher volumes of CO_2 from multiple large capture plants were feeding into larger storage clusters.

In addition, if a storage cluster is developed so that there are multiple storage types and geologies, the reliability of the storage would be increased so lowering risks for developers in each element of the chain. This will be a key step in making full economic-scale generation and capture projects deliverable and financeable at costs in line with industry norms (see Section 3.2 and 5.1.3)[5].

For such storage hubs to be in development by the early 2020s, the Task Force believe that the current CCS Commercialisation Programme would need to deliver a number of projects which are structured to deliver a high reliability storage service to follow on projects which aim to operate in the early 2020s.

Candidate Action: Future projects need to build on opportunities created by early projects to achieve cost savings through storage hubs.

Candidate Action: Consider how to ensure contracts and licences can be structured flexibly enough to allow CO_2 to be injected into alternative stores by agreement between storage owners.

5 Development of storage clusters has been discussed in some depth by Task Force members in the past in previous reports such as the Central North Sea – CO_2 Storage Hub report released in September 2012.

Transport

The unit cost of transporting CO_2 has the potential to decrease significantly at higher volumes because the costs of constructing and installing pipelines grow at a much slower rate than volumes they can transport. In an ideal world a single, very high capacity (over 10mt/year) source committing to fully use a pipeline for 25 to 40 years would give a low transport cost. However, the utilisation factor is also important because a large pipeline which has spare capacity for much of its lifespan would have higher unit transport costs than a smaller one which is full year on year.

Additional fundamental drivers of transport costs are pipeline distance, the crossing terrain (particularly onshore) and planning costs. It is therefore apparent that the lowest cost transport network will be one which:

- transports large amounts of CO_2 in appropriately sized pipelines;
- is cognisant of sizing of trunk line sections and feeder line sections to ensure high utilisation for the maximum period of the asset lifetime (average flow compared to maximum flow);
- minimises the distance CO_2 is transported (factored for terrain, shoreline crossings and planning constraints) restricted by decisions on the capture and storage sites; and
- minimises the need for building additional pipelines that would incur significant planning costs.

The Task Force anticipates that transport costs could drop from £18-23/MWh for early projects carrying 1-2 million tonnes of CO_2 p.a., to £5-10/MWh for large, full pipelines carrying 5-10 million tonnes of CO_2 p.a. Even lower per MWh costs could be seen in the longer-run, particular for gas based CCS, if even still higher volumes of CO_2 from multiple large capture plants were feeding into an interconnected right-sized network.

This is supported by a key conclusion of the recent Mott MacDonald report, and endorsed by the Task Force, that leveraging early CO_2 infrastructure, if it is designed correctly, can reduce the incremental cost of transport and storage substantially for later projects.

Candidate Action: Consider how to ensure that the configuration of the transport system for early projects takes into account likely future developments of the CO_2 pipeline network, in order to minimise long-run average costs.

3.2 Characterisation of storage

Site selection for storage is important to access low cost, low risk storage. Assessment of each particular storage site will depend on a number of factors:

- Geographical location of storage site;
- Timing of storage site availability (generally due to other activities at the site);
- Data availability, particularly for existing wells and seismic data, allowing development of a geological model and parameters for the rock and fluid properties; and
- Being able to build a sufficiently good storage reservoir model.

This then enables key features such as injectivity, well design, and capacity to be used with some confidence level in the business case for investment.

To some extent necessary data on potential storage sites is contained in public and private databases; this is particularly the case for depleted oil and gas fields. For other reservoir types, generally saline aquifers, significantly more characterisation work will be required (although it should be recognised that within these broad categories of storage type the level of data for individual sites can vary greatly).

Collecting and having access to reliable data on storage opportunities will:

- create additional confidence in general storage solutions, minimising the risk perception for CO_2 storage:
  - able the development of diverse storage options, so that (collectively) their storage capacity is "bankable" which ultimately requires several 'proven' stores that are equally accessible. This is referred to as a storage hub.
  - inancial institutions currently regard storage as the least well known element of the chain and public perception of storage is mixed – this is part of a general de-risking of the CCS chain as described in 3.1.3.
- maximise the ability of firms to select the most advantageous storage sites, reducing capital and operational costs, and the probability of selecting inappropriate sites.
  - hilst the geo-science and CCS communities are both confident of overall storage potential in the North Sea, the suitability (with regard to 'average' injectivity and storable CO_2 volume) of individual sites is necessarily uncertain.
  - o some extent a site will be more favourable if there are other good potential injection sites nearby.
- attract a wider range of players into the storage business in the long-run, bringing competition and lowering costs.

However, there are significant costs involved in characterising storage. Key steps are typically: a desktop study of seismic and well data; the collection of new seismic data; drilling new data collection wells; drilling test injection wells and injecting water/CO_2.

The step-up in cost at each sequential stage of characterisation at an individual store is significant (up to 10's of £m at the top end). Whilst not as speculative as drilling for hydrocarbons it must be assumed that some test wells will prove that a storage formation is not suitable. Once a formation is selected for investment and is proven, it will be natural that additional capacity will be sought in the same formation and/or nearby because of better local knowledge, to minimise the risk of new negative information. Such new sites will then benefit from lower incremental transport and CO_2 test injection costs.

Given the likely high costs, one potential development model to manage the costs and risks for an individual hub would be as follows:

- Target the nearest potential hub location that has diverse storage options.
- Without new drilling, characterise options in the area, (using existing cores, seismic and regional data) select the lowest risk option for storage in the context of the business case for the hub.
- In the case where there is an available depleted oil & gas (DOGF) storage as an early, already highly characterised store it may be possible to avoid new drilling as at worse it may take the full CO_2 output of a single CCS project for only a limited number of years;
- Provide transport; use what capacity is available with existing pipelines or build a right sized hub trunk line connection.

- After a period of first injection characterise and test nearby opportunities in additional DOGF storage and/or saline aquifer storage to increase the storage capacity and flexibility of the hub. This is important as it de-risks there being unexpected problems with the first store. Hub spoke pipes are sized to suit the incremental capacity.
- Develop spoke pipelines to EOR opportunities as fields become available to create additional value for the CO_2 hub and lower the cost of CO_2 storage (see Section 6.1).

The commercial arrangements could become complex as store operators offset their service obligations by options to store with other operators, but being able to do that will benefit emitters, otherwise emitters will require multiple storage off take contracts to ensure their CCS asset utilisation.

The natural advantages from developing additional storage sites at a hub or next to an existing CO_2 pipeline mean that there are natural economic drivers to further expand it (as pipeline savings from shorter distances are likely to be outweighed by confidence of a proven storage reservoir). However, there may be significant value to establishing a new hub if there is very large storage capacity and it lowers storage and transport costs in the long-run.

Entirely new hubs will only be developed if there is a decent prospect of a step change in cost reduction because of the risks involved. Gaining access to the lower potential costs are one of the reasons that a strategic plan for transport and storage would make sense.

It should be noted that the UK is endowed with an enormous strategic asset in relation to the storage capacity in the UKCS and that the rights for carbon dioxide storage are vested within The Crown Estate[6].

Candidate Action: Consider further work to be undertaken to examine the options for a more or less coordinated approach to developing transport and storage of CO_2 in the Central and Southern North Sea, and to recommend a way forward

3.3 Regulatory framework and funding mechanism

Both the Task Force and the UK CCS Roadmap recognise that creating the right regulatory framework for CCS is crucial for the deployment of CCS. However, the lack of CCS projects in the UK means there is also a lack of experience in regulatory agencies and commercial entities of how regulatory systems would apply to CCS infrastructure. This increases the risk for the establishment of early CCS projects, driving up the costs of development.

A key aspect of the CCS Commercialisation Programme is to develop practical experience of the consenting and development process, which should in turn remove certain regulatory risks. Not least, clarification around the long-term liabilities for CO_2 held in storage sites.

Long-term liabilities associated with storage of CO_2 for very long timescales will need to be addressed in order for projects to be financeable. Commercial entities will find it extremely difficult to carry large and open-ended liabilities on their balance sheets, and will look to Government to take over responsibility at some point. The Task Force welcomes the progress on these issues that has been made as part of the Commercialisation Programme, but believes a robust and enduring solution will need to be put in place that is suitable for all projects, through the 2020s and beyond. This learning from operational projects forms part of our landscape as described in Section 2.

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6 http://www.thecrownestate.co.uk/energy/carbon-capture-and-storage/

In the longer-term, several concerns were raised by the Task Force regarding how the regulation and funding mechanisms for CO_2 transport and storage may change over time as the industry matures.

There are a wide range of options available for the future of the industry, in particular the level and extent of regulation that will be used in transport and storage sectors:

- Light-touch regulation whereby development of the transport and storage industry is market led with standard third-party access requirements in-line with current pipeline infrastructure; or
- Heavier regulation, such as defining a monopoly provider of transport and storage infrastructure in a region then applying regulation on the allowable rate of return.

Whilst developing a highly regulated sector would require significant regulatory changes before 2020, a stable regulatory framework in the 2020s will be critical for the deployment of low cost CCS. Wherever possible, the key principles governing the future regulation should be established as early as possible to reduce regulatory risks for participants.

Whilst the regulations are in place for third party access the guidance for this, particularly for storage access, has not yet been issued. Whilst third party access for storage is quite difficult to describe, some guiding principles can be defined. For example allowing cost recovery and enabling storage owners to agree options with other storage in hubs will help ensure that long-term emitters (who can access transport and agree a storage contract with a store owner) will be able to store their CO_2.

The funding mechanism that is applied to the transport and storage of CO_2 could also have a large impact on the costs of deployment. These options were discussed as part of the Planning and Infrastructure Workstream as well as in the Commercial and Finance Workstream. These funding options and the impact they have on costs is discussed further in Section 5.2.

Candidate Action: Assess what future development of the regulatory regime is required to deliver CCS projects, including guidance on whether access by third parties to storage is required.

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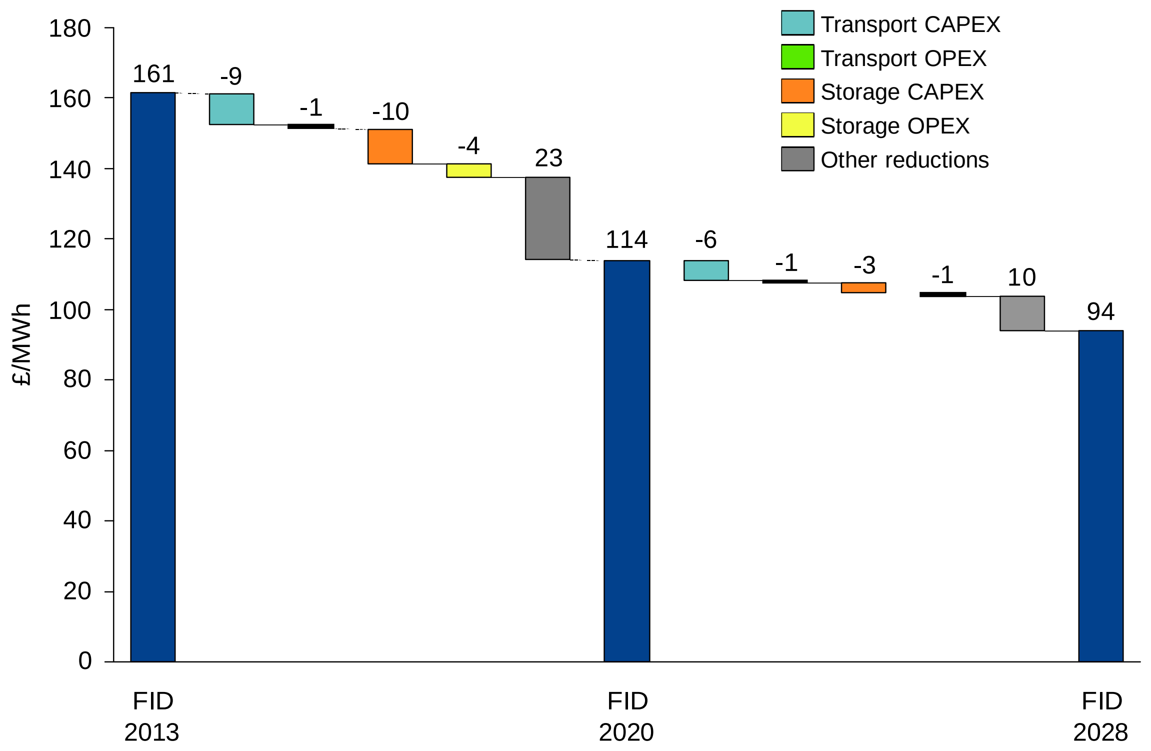
3.4 Conclusions: storage and transport cost reduction opportunities

All the routes described above effectively facilitate access to two general cost reduction mechanisms: reduced capex and reduced opex in both storage and transport sectors.

In summary, the potential for cost reduction that falls within these mechanisms is summarised in Figure 1. The 'Other reductions' category includes the cost reduction measures achievable by the other cost reduction pathways in this report. These are discussed in Chapters 4 and 5 below but it should be noted that the Commercial and Financial Workstream also included measures that impacted transport and storage costs.

Figure 1 – Potential cost reductions from maximising economies of scale and system efficiencies of transport and storage (real 2012 £/MWh)



Notes:
Diagram show technology average costs (i.e. average costs across all four technologies examined).
Results are presented on a £/MWh basis, the general pattern would be similar if presented in a £/tonne basis, however, future benefits would appear less favourable due to increased plant efficiencies (and consequently a declining CO_2 capture rate)

The Task Force anticipates that there is the potential for transport costs to drop from £18-23/MWh for early projects to £5-10/MWh for FID 2020 plants and £1-3MWh for plant reaching FID in the late 2020s. Additionally there is the potential for storage costs to drop from £22-26/MWh for early projects to £5-10/MWh for FID 2020 plants and £2-5/MWh for plant reaching FID in the late 2020s. A breakdown of modelling assumptions and costs is provided in Annex A.

The underlying driver of cost reductions in both transport and storage is the ability to facilitate increased throughput of CO_2 into the system (ultimately manifested by applying routes discussed in Section 3.1). Increasing the CO_2 throughput of the system incurs costs associated with the deployment of larger diameter pipes and longer pipe lengths (representing the facilitation of clusters); however, the increase in the equipment costs is significantly outweighed by cost savings associated with increased CO_2 throughput.

In the model, increased throughput is effected via an increase in pipe diameters. By FID 2020 pipe diameters have increased from 15" to 18" (coal plants) or from 10" to 15" (in the case of gas plants); this facilitates an increase in throughout from 2 to 4 mt/year and from 1 to 2 mt/year respectively.

By FID 2020, average onshore pipe length has also increased from 30 to 40 kilometres (we assume, in line with Mott MacDonald, that average offshore pipe length remains at 300km throughout the modelled period). These increases in throughput (and the pipeline diameters assumed) are in-line with capture volumes from larger single CCS projects on power stations – it may be that larger pipelines are being developed (for future CO_2 flows to feed into at a later date) but the potential positive impact of such a system is not included.

By FID 2028 the model assumes further increases in pipe diameter, reaching 36" (and assuming 15mt/year throughput) in all cases, representing increased economies of scale from clustering projects. However a 36" pipe has the potential to transport more than 15mt/year at higher pressures meaning that there is the potential for even greater economies of scale (above those assumed in the modelling to 2028) to be realised.

The capex reduction mechanisms discussed above are also expected to bring down the opex of projects (as annual opex is assumed to be 2% of capex throughout the modelled period, as per Mott MacDonald assumptions), opex therefore declines in proportion with capex.

3.4.1.1 Additional cost reductions in transport and storage

It should be noted that additional reductions in transport and storage costs can be accessed through financial mechanisms (in particular, by improving the financing terms available, see Section 5); these mechanisms should thus ultimately be considered together. Such financial benefits can only be exploited by reducing risks, particularly those associated with storage and regulation. This is in part facilitated by the measures discussed in Sections 3.1, 3.2 and 3.3.

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4. IMPROVING GENERATION AND CAPTURE ENGINEERING DESIGNS AND PERFORMANCE

CCS plant in general will have higher cost metrics than conventional thermal power stations because the process needs additional capital equipment to capture and compress the CO_2; additional energy is needed to run the separation and compression plant (thus affecting the net energy output of the plant[7]); and additional operating expenses are incurred due to consumption of solvents, chemical reagents, catalysts and formation of waste products.

Additional generation and capture costs for the first commercialisation phase projects suggests a range of costs from £35-46/MWh (after removing carbon cost impacts). However, there is clear scope to minimise the difference through lower:

- capital equipment costs;
- capture operating costs; and
- energy penalty (i.e. the difference between the net energy delivered to the grid in a CCS case and the net energy delivered to the grid in a non-CCS case[7]).

The main routes are described below.

4.1 Optimal scale of generation and capture unit size

Early CCS power projects developed in this decade are likely to be of modest size, in order to minimise risk capital across the full chain in the first developments. The levelised cost of electricity from these plants is therefore expected to be fairly high.

Once CCS is established, significant reductions in electricity cost will be made by scaling up to plants sizes to around 1 GW or more, equivalent to unabated plants being installed elsewhere in the world today. This will:

- improve efficiency in the base plant;
- lower capital costs and some operational costs at the base plant;
- allow additional economy of scale benefits in components of the capture units;
- allow additional economy of scale benefits in the transport and storage sectors (see Section 3.1).

To some extent “the bigger the better” with regard to the unit costs of capture components as potential economies of scale are regarded as significant. However, it should be noted that for several of the key equipment and systems required in a CCS plant, larger sizes are often not yet commercially available and therefore, the currently available size “breakpoints” will limit scale-ability. With the widespread introduction of CCS projects, industry will have the incentive to push the limits on such equipment and develop larger and more cost effective components. Examples of such equipment where economies of scale are expected to be significant include: ASU cold boxes, air compressors (for ASU’s), CO_2 compressors, pumps, heat exchangers, columns (distillation, absorbers, regenerators) and gasifiers. There are likely to be different

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[7] Many observers use the term “energy penalty” to describe the extra energy costs of the CCS process compared to conventional plant. For convenience we use this terminology in this report, although it should be recognised that many aspects of this are identical to the thermal efficiency of any plant i.e. that there are energy losses.

optimal scales for different technologies but scale benefits on individual components could be of the order of 25% of capital costs for that particular component.

Although these larger sized components, once commercially available, ought to drive a lower capex for the CCS plant, there is likely to be a corresponding increase in single point failure risk. In this case, there will be a tendency toward potentially increasing contingency requirements and introducing limits to reasonable gains.

Even where there are limits to the scale of the component parts, there will be potential additional benefits from ordering more than one component from a single manufacturer. Benefits in the order of a 15% reduction in cost for a second component (compared to the first) are regarded as reasonable.

Over-capacity of critical components is often designed into a power train to ensure continuity of generation during outage, for example additional solvent feed pumps or ASU modules. Larger plants with more critical units may still require only one back-up unit. These kinds of impacts are discussed in more detail in Section 4.2 below.

The Task Force believe that full scale plants with CO_2 capture can be available, operable and financeable in the early 2020s if the landscape described in Section 2 is in place. There is therefore strong confidence that economies of scale associated with power plant scale-up will be available in the early 2020s.

A suite of early phase pre-commercial CCS projects in the size range 200-400 MW will provide industry with the incentive to push the existing envelopes and develop these offerings. Such projects, once operational will enable suitable testing opportunities and provide data on performance and availability that can be used to provide the guarantees likely to be required to make CCS financeable.

Candidate Action: Projects developed in the UK following those arising from the Commercialisation Programme should be of a size much closer to the full size unabated plants available in order to capture the economies of scale that should then be available.

4.2 Optimisation of early designs and reduction of engineering redundancies

In addition to the benefits of increased plant scale, some other costs associated with the first commercialisation phase projects are likely to fall during the second and third waves of projects without the need to assume technological advancements. Optimisation of processes, designs and a reduction in engineering redundancies has the potential to significantly reduce capture costs.

Reduced developer/design contingency

As the first wave of CCS plants deliver operational experience (described in the landscape) and larger plants are developed, plant designs should remove certain types of redundancy and design margin. Alongside optimised construction strategy, this reduced contingency should reduce ‘superfluous’ costs.

Balanced against the cost advantages of lower margins/redundancy, will be a reduced level of availability as the system will no longer contain such a high level of back-up. Designs can therefore be expected to optimise the ‘availability versus redundancy’ equation such that costs decrease and/or availability improves over time.

However, experience in other industries indicates that costs can actually increase from the first wave of projects to the second wave before then decreasing again with further deployment. It is often the case that this cost increase is driven by overly strict performance standards on the technology in the early stages of commercial deployment. CCS can avoid this pitfall (and must if it is to deliver low cost in the early 2020s) by ensuring that:

- market support allows plant to operate at less than baseload without CCS without having a distorting impact on plant returns;
  - . If you impose an 80% availability requirement on a plant which, in its first year, only manages 79% then it could lose all revenue whereas in a market situation it would only be marginally affected.
- policy allows plant to operate at least some of the time partially without CCS without unduly affecting the plant returns; and
  - ring required capture rate for early years of operation.
- making sure that plant design margins and CO_2 quality standards are fit for purpose given the H&S implications.

It remains to be seen just how significant this process of reduced contingency can be as it will depend on the performance of the first commercial scale CCS projects, and future licensing and permitting requirements.

Candidate Action: Ensure that any constraints (e.g. CO_2 specifications), design requirements (e.g. capture percentage limits) or performance objectives (e.g. minimisation of cost of electricity generation) are set with the intended and unintended consequences of these limits clearly understood and agreed.

Candidate Action: A proper dialogue needs to occur between the project developer, plant designer and supplier of critical equipment to ensure that the optimal balance between scale risk, equipment redundancy, design margins and required availability is achieved.

Better integration of capture unit into generation plant

We could expect to see engineering designs improve the level of heat integration between the capture unit and the generation plant. By utilising steam/heat at the optimum temperature level (i.e. using the lowest grade heat possible from the power plant) you can minimise the energy penalty associated with the capture system. However this must be balanced against:

- the principal disadvantage of reduced flexibility/availability, for this reason, over-integration may prevent effective operation in future market; and,
- the need for reliability as a fundamental prerequisite for effective integration reduces the speed with which integration can be progressed.

To some extent early projects will already be aiming to maximise integration whilst still maintaining flexibility and reliability but the ‘optimal’ setup is uncertain and will depend on the evolution of the rest of the electricity market and other sources of value (see Section 6.4). Indeed some Task Force members questioned whether or not early plant designs may already be too integrated. For this reason, although there is perceived potential for increased integration into the plant, the scope is regarded as limited by the early 2020s.

Benefits in capital cost optimisation can be achieved through smart “physical” integration between the CCS plant and the power plant. This will be the case for a greenfield power plant with CCS which has considered the optimum layout of all physical components and minimizing interfaces such as duct work, utility piping, electrical tie-ins, etc.

Candidate Action: The benefits and downsides of integration should be examined from the experience of all early projects, worldwide, in order to incorporate this experience into future designs.

4.3 Evolution of current capture technologies

In general technological improvements will be a function of how many plants are deployed globally. Thus, the more plants in operation the faster the evolution. On the other hand, if only a few plants are developed before 2020 the rate of technological advancement would be slow.

In general significant improvements are expected in existing capture technologies between now and the early 2020s. All technologies should continue to improve during the 2020s as roll-out continues but over time we can expect the costs of these 'current generation' technologies to tend towards natural limits.

Capture process

There is a potential for current capture technologies to improve incrementally as experience grows between today and projects reaching FID in the early 2020s. These current capture technologies can be largely defined as:

- **Post-combustion**: Capturing CO_2 from the flue gas of a conventional gas or coal fired power plant using an absorption based process (utilising absorbents such as amines or ammonia);
- **Oxyfuel:** Coal is burned with oxygen (generated from an Air Separation Unit) rather than air resulting in a flue gas containing CO_2 and water (no nitrogen). CO_2 is then captured from the resulting flue gas.
- **Pre-combustion:** Gas or coal is converted in a gasifier into a mixture of hydrogen, CO and CO_2 . In the case of power generation, the CO is further converted to CO_2 which is then captured from the resulting gas, generally using an absorption based technology. The remaining H_2 rich gas is then burned in a gas turbine to generate power.

There are a number of specific technology improvements that are at pilot-stage or very close to pilot, and as such these represent opportunities for cost saving by the early 2020s timespan. These include:

- solvent (e.g. amine) improvements;
  - re have already been considerable improvements made in the last 5 years as technology providers have shifted from using standard solvents such as monoethanolamine (MEA) to more advanced solvents tailored for post-combustion capture. As much as a 25% improvement has been realized to date by many technology providers. Further improvements can be expected, however, as these will likely mean tailored chemical solvents, the cost and supply chain considerations need to be traded off against the potential energy benefits.
- alternative solvents (i.e. alternatives to amine) that fit within similar overall flowsheet;
- absorption process improvements such as improved internal heat integration, external heat integration and overall process optimisation;
- improvements in physical absorption processes used in Pre-Combustion based systems;
  - vances currently underway through the ETI technology programme;

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- further improvements to IGCC as learning develops from the operational experience of IGCC projects worldwide;
- improvements in critical equipment performances such as column packing, heat exchangers and CO_2 compressors; and
- improvements in Air Separation technologies (process cycles optimised for oxy-combustion processes) resulting in low specific energy consumption.

It should be remembered that there is a theoretical lower threshold to the level of energy consumption required to extract CO_2 using any of the above technologies. Some technologies will 'plateau' earlier than others and it is currently unclear which technologies can 'go further' than others in the necessary time-frame.

The Task Force believes that there is no current obvious technology or fuel winner for CCS and developing a market for CCS in the long-run is the optimal way to drive improvements and lower costs.

The key question for each of these technologies is:

What can we do to make improvement in this area happen? What will drive technological improvement?

Improvements in materials of construction

Optimisation of materials of construction utilised within the capture plants has the potential to lower capital costs. Potential cost saving measures by the early 2020s include:

- using cheaper material (including a reduced dependence on steel) as a better understanding of material robustness and corrosion resistance is gained through operational experience. Examples include:
  - ing more concrete (in absorbers in particular) could save up to 30+% of cost can be saved on the absorber; and
  - ing lower cost steel or polymers;
- the use of off-site fabrication for certain components which may be more cost effective when large plants with multiple units are being constructed.

Improvements in flexibility of Power Generation with CCS

During the period between today and 2030, the UK's power grid is expected to evolve toward a greater percentage of renewable power generation (e.g. wind power). This evolution means that fossil power generation with CCS will need to be flexible in order to efficiently match the demands of the grid (see Section 1.1 and Section 2.1.1.)

It is expected that the current capture technologies will be capable of enabling a sufficiently flexible CCS installation. However, the exact capabilities of CCS power will vary based on the actual technology employed and will need to be further proven through the early phase projects. The current views on system capabilities can be summarized as follows:

- Post-combustion: Absorption based processes can be made to follow the load of the host power plant through the use of advanced control systems. A key factor will be the specifications imposed on the capture plant performance. If the CO_2 recovery rate can drop below 90% (for example) for a short period of time during the ramping period, then it should be quite straightforward to achieve rapid ramping rates.

- OxyFuel: Ramping an oxyfuel CCS process will require load following of the ASU as well as the back-end CO_2 purification system. While dynamic ramping can be achieved through advanced controls, an oxyfuel system offers a unique approach to reacting to load. During periods of low load from the grid, the power plant can remain at a constant load and the extra electricity used to generate liquid oxygen from the ASU which is then stored. Then during periods of high electricity demand, the ASU can be turned down and the liquid oxygen used to supply O_2 to the process. In this way, the liquid oxygen serves as a form of energy storage.
- IGCC: Compared to a PC-Coal or NGCC plant, IGCC has a lower operational flexibility. While PC-Coal or NGCC plants have proven to reliably cycle down to low loads, the gasifiers associated with IGCC plants are best operated at a constant or near constant rate. However, flexibility can be achieved with an IGCC solution if there's an outlet for the syngas from the gasifier (or the H_2 rich gas normally sent to the turbine). In the case where the gasifier produces syngas for downstream chemicals production in addition to power production, then a balance between power generation and chemicals synthesis could provide the necessary flexibility.

Industry will continue to further drive improvements in all areas above providing a favourable landscape for CCS is in place, with a first wave of projects being developed and a clear vision of an on-going market developing closely behind the first wave.

4.4 Developing the CCS supply chain

Developing the supply chain for components of CCS has the potential to bring down the costs of components. The supply chain for CCS will develop as a favourable landscape for a CCS market is created and suppliers can foresee a smooth pipeline of projects. On the other hand if roll-out of CCS happens too quickly, it could mean that existing supply chains cannot cope with demand which perversely would increase costs for CCS project developers for bottle-neck components.

A developed supply chain will be one where:

- supply of all equipment (e.g. packings, heat exchangers, compressors, etc.) and related raw materials (e.g. steel) is possible within reasonable timescales to meet demand;
- a suitable level of competition between equipment suppliers drives efficiency, innovation and ultimately lower costs; and
- standardisation and significant volume of orders allows expansion by manufacturers towards a minimum efficient scale of production.

However there is a tension between providing incentives for equipment manufacturers to remain engaged in early projects, while bringing in competition in the longer term to lower costs. Standardisation too can be a double edged sword in that standardisation to the 'wrong' standard could limit the ability of a firm to export technology to wider global developers.

The extent to which supply chain effects will lower costs in the 2020s will depend on how rapidly the CCS supply chain can develop and how large a supply chain is required to significantly bring down component costs.

4.5 Next generation capture technologies

Beyond the current suite of capture technologies currently being deployed at pilot-scale around the world are the next generation of capture technologies, loosely classed as technologies at the laboratory- or bench-scale. These technologies have the potential to enable step changes in capture costs but are often based on very different processes to current capture technologies.

While opinions in the Task Force differ as to the timescales for development of these newer technologies it is generally viewed that they must go through at least two levels of scale-up before they would be ready for commercial deployment. For this reason they are really only suitable for inclusion on a wide scale from the late 2020s onwards.

There are many different technologies at this scale of development and it is not possible to say which of these will offer the greatest commercial attraction in the long-run.

Four example technologies discussed were:

- Alternative technologies suited for gas/CCGT post-combustion such as Flue Gas Recirculation.
- Advanced oxygen generation technologies (e.g. non-cryogenic, membrane) which have the potential to drive a step change reduction in the cost of oxygen and a corresponding reduction in oxyfuel CCS costs.
- Chemical looping which can be viewed as an advanced oxyfuel process whereby the ASU is eliminated.
- Advanced post-combustion capture such as the Regenerative Calcium Cycle (RCC) process which offers the possibility for a step change reduction in energy consumption – see box below.

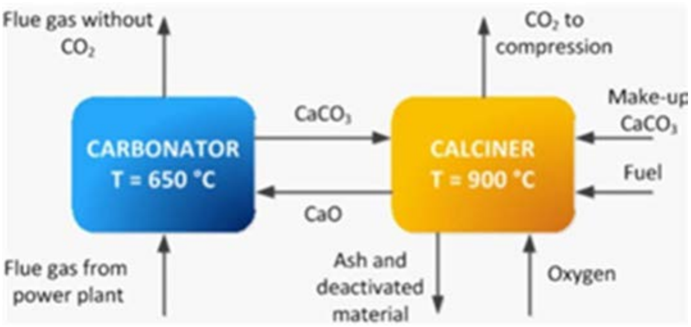
Candidate Action: R&D funding for future technologies should continue from all sides to create cost reductions beyond the incremental reductions available from existing technology.

Example Next Generation Technology: Regenerative Calcium Cycle (RCC)

The Regenerative Calcium cycle (RCC) is a post-combustion process that operates at high temperatures (600-750Deg C in the absorber) and (900 Deb C in the regenerator) and utilizes a solid absorbent, lime (CaO). In the RCC process, CaO absorbs the CO_2 from the flue gas, in a carbonator. The $CaCO_3$ formed is transferred to a calciner, where the CO_2 is released by increasing the temperature to approximately 900C. The stream of highly concentrated CO_2 is ready for compression and storage, whereas the regenerated CaO is transferred back to the carbonator closing the Ca-loop. The following chemical reaction describes the capture and release cycle for CO_2:

$$CaO\ (s) + CO_2\ (g)\ o\ CaCO_3\ (s),\ LiH = -178\ kJ/mol.$$

Because the reactions take place at elevated temperatures, there is a great potential for optimization through efficient integration into a power plant or industrial plant (e.g. cement). A further evolution of the technology envisions the use of heat above the level of the power plant steam cycle through the integration of the calciner into the boiler thereby making use of “indirect calcination”. Such a solution has the potential for a high rate of CO_2 capture with minimal energy penalty on the host power plant.



Development of new technologies such as RCC require continued R&D but have the potential to lead to significant longer term improvements in CCS technology beyond 2020.

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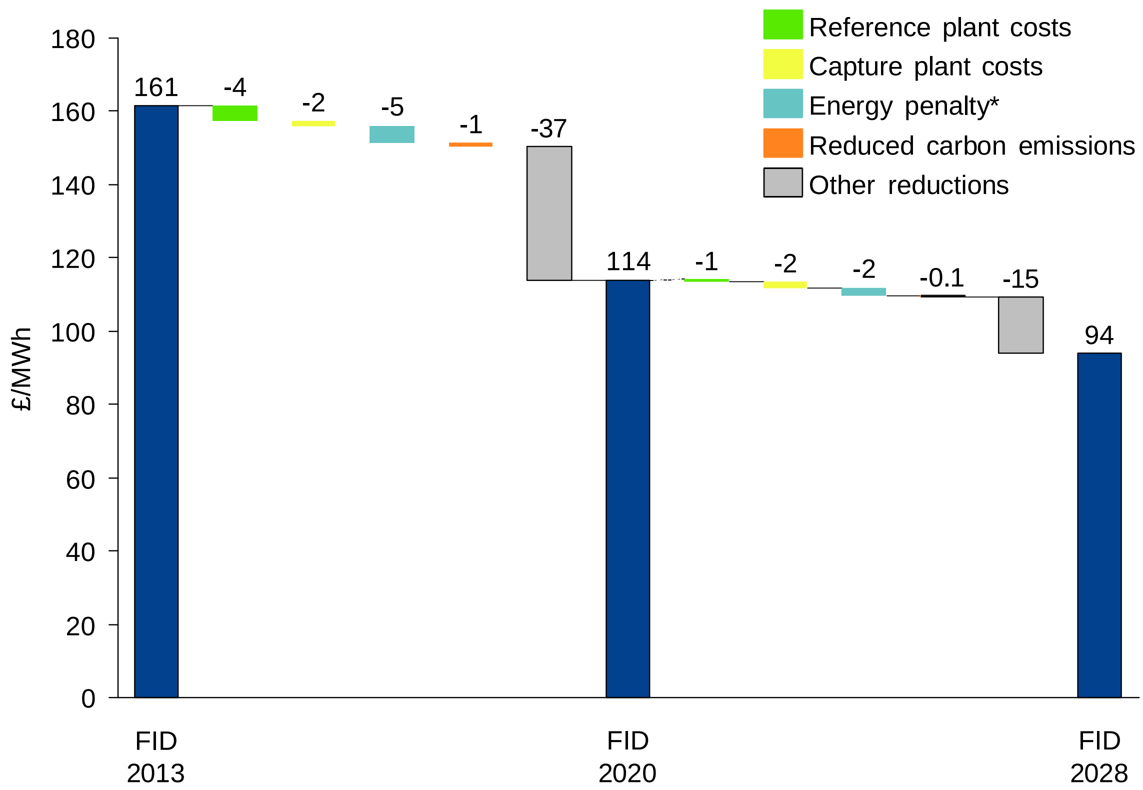
4.6 Conclusions on generation and capture cost reduction opportunities

Figure 2 summarises the cost reductions that can be accessed through improved performance of capture technologies. The 'Other reductions' category includes the cost reduction measures achievable by the other cost reduction pathways in this report. These are discussed in Chapters 3 above and 5 below.

Figure 2 – Potential cost reduction mechanisms relating to improvements in capture technologies (real 2012 £/MWh)



* Includes host plant costs and additional fuel costs

The Task Force estimates that generation and capture costs could drop from £116/MWh (with a range of £104-125/MWh across technologies) for early projects reaching FID in 2013 to £96/MWh (£88-106/MWh) for plants reaching FID in 2020. In the late 2020s generation and capture costs could drop further to £87/MWh (£82-93/MWh). A breakdown of modelling assumptions and costs is provided in Annex A.

In line with Mott MacDonald low cost path assumptions, the model assumes continuing technological progress in the underlying Reference Plant, manifested through capex reductions:

- Post-combustion coal and oxy-combustion coal: £1,500/kW, £1,400/kW and £1,400/kW (in 2013, 2020 and 2028 respectively).
- Post-combustion gas: £550/kW, £500/kW and £500/kW (in 2013, 2020 and 2028 respectively).

- IGCC[8]: £2,200/kW, £2,000/kW and £1,900/kW (in 2013, 2020 and 2028 respectively).

In addition to Mott MacDonald assumptions, the model also assumes that reference power plant efficiencies also improve through time[9]:

- Coal Fired Power Plant: 43%, 45% and 45% (in 2013, 2020 and 2028 respectively).
- Combined Cycle Gas Plant: 54%, 56% and 56% (in 2013, 2020 and 2028 respectively).
- IGCC: 43%, 45% and 45% (in 2013, 2020 and 2028 respectively).

Mott MacDonald low cost path cost-reduction rates have been considered by the Task Force and whilst there is uncertainty and a range of opinions over such numbers, they are considered as a valid assumption basis.

Whereas cost savings arising from improvements in reference plant technology are largely focused in the nearer term (before 2020), capture plant improvements are seen to have similar cost saving effects both pre- and post-2020. The costs assumptions assume that reduction occurs at different rates for different elements of the capture process, with average reductions in capture plant capex as follows:

- Post-combustion coal/gas: 10% before 2020 and a further 13% by 2028.
- Oxy-combustion coal: 10% before 2020 and a further 14% by 2028.
- IGCC: 2% before 2020 and a further 7% by 2028.

Concomitant with these capex improvements, we also assume a steady reduction in energy penalty (representing overall improvements in the capture process)[10]:

- Post-combustion coal and oxy-combustion coal: 25%, 18% and 15% (in 2013, 2020 and 2028 respectively); original Mott MacDonald low cost path efficiencies were 25%, 23% and 18%.
- Post-combustion gas: 19%, 14% and 11% (in 2013, 2020 and 2028 respectively); original Mott MacDonald low cost path efficiencies were 15%, 14% and 11%.
- IGCC: 17%, 16% and 12% (in 2013, 2020 and 2028 respectively).

Additionally, in line with Task Force recommendations, we assume an increase in CO_2 capture rates of the plants (increasing from 85% to 90% between 2013 and 2020).

The reduction in cost of capture technology is particularly difficult to predict because technological development, by definition, is not a known quantity. Also, the response of the supply chain to a substantial, competitive CCS market alongside other demand sectors is difficult to predict. Whilst this generates uncertainty in costs savings, many Task Force members think there is the potential for considerably greater savings than those above based on previous experience with other technologies.

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8 Estimates of IGCC capital costs vary greatly, and as such are they are regarded by the Task Force as subject to a greater range of uncertainty than the other technologies.

9 Mott MacDonald assumptions assumed constant efficiencies throughout the modelled period of 40% in coal plants and 53% in gas plants.

10 The energy penalty figures are dependent on the reference plant efficiency, therefore care must be taken when comparing such numbers from project to project.

5. ACHIEVING AFFORDABLE FINANCE FOR CCS CHAIN

This section presents the main findings for cost reductions from the Commercial and Finance Workstream.

All elements of the Carbon Capture and Storage chain are by nature capital intensive so the efficiency of the financing structure has a large influence on the overall LCOE.

In general there is significant interest in CCS from certain financial institutions but the overall perception is that risk is high which in turn constrains financing options and increases costs above those for conventional power projects.

Current large-scale CCS projects worldwide are generally funded via a mix of capital grants, equity, subsidised loans (from multinational development banks, export credit agencies etc.) and limited scope commercial loans. However, the nascent nature of the industry means that there are no standardised finance structures in place for CCS projects and the terms of future commercial loans are highly uncertain.

5.1 De-risking the CCS chain

One of the key mechanisms by which increased learning and experience will lower costs is through lower cost of capital, including financing for all elements of the CCS chain. The mechanism by which these costs reductions are realised is through:

- A reduction in the equity hurdle rate required by firms to invest in CCS as they better understand and price the particular risks of the industry;
- An increase in the equity value attributed to later years of an asset life (through greater perceived certainty in longer-term revenue streams and costs);
- An increase in the gearing available to projects as well as increasing debt liquidity available to CCS overall, leading to an improvement in the available terms of debt (margins, ratios, covenants etc.) as the perceived risks of the industry are better defined and understood through experience.

There is considerable overlap with the other workstreams for de-risking the CCS chain. However there are some specific routes by which cost saving can be achieved which were discussed by the Commercial and Finance Workstream.

5.1.1 Optimal industry structure for risk management

As the CCS landscape develops, the risks in the chain should be more efficiently allocated to those parties that are best able to manage them, thus reducing the overall cost of risk associated with CCS.

The ability of the industry to allocate the different risks will depend on many things, not least the regulatory and policy environment for CCS which will have a material bearing on the industry structures established. Different interventions can lead to a variety of industry structures, in particular in the CO_2 transport and CO_2 storage sectors of the chain, which could make risks more or less acceptable to different stakeholders.

Below we outline some potential industry model structures that were discussed as part of the workstream workshops. Appropriate industry structures for CCS equipped power stations are likely to change over time as the risk structure of the industry evolves.

Fully integrated (JV) model

This is a fully integrated (or Joint Venture (JV)) project structure where each 'full-chain' capture, transport and storage project is owned by a Special Purpose Vehicle (SPV). The SPV is set up and managed by JV partners who may be specialists in one particular aspect of the chain with SPV integrating the full chain.

This will be optimum in terms of risk sharing as many of the interface risks are internalised and profits and costs can be shared However, JV partners operating in different sectors can have very different approaches to business and more importantly risk/return expectations making this approach challenging to set up. From a financing perspective though, this could be an attractive structure if the JV partners were reputable and credit worthy entities and if the JV/shareholder agreement adequately addressed these differences to ensure risks were well managed.

A JV model is likely to be most applicable to single or related projects but could also be applicable to provision of transport and storage infrastructure to serve hubs of multiple capture projects.

Market led, disaggregated industry model

In this model, each component of the CCS chain is owned and operated by a different entity with the relationships governed by commercial contracts. These contracts could have a variety of forms including availability based, Take-or-Pay, Ship-or-Pay and variable charge payment mechanisms and would be regulated by standard Third Party Access (TPA) requirements.

This model would potentially provide the developers and operators of each chain element with the strongest incentives to manage their own construction and operational risks. However it also increases the potential for, and impact of, project-on-project type risks where individual elements of the chain may be unduly exposed to operational risk in other components of the chain. Whilst this can be mitigated with the contractual arrangements between the individual links, the negotiation of these contracts and the ability of the individual companies involved to honour their obligations is crucial to making the disaggregated model work.

It is not currently clear what the optimal approach would need to be to fund such a disaggregated model as a 'trickle-down' of revenue from capture to transport to storage combined with the other issues described above may make it difficult to finance some elements of the chain.

Regulated returns/revenues for transport & storage sector

Establishing a central or regional transport & storage entity could help to significantly lower the cost of capital and financing if based on a Regulated Asset Base or similar structure; examples being the gas and electricity grid and to a certain extent, the Offshore Transmission Owners (OFTOs) for offshore wind. Such a structure would enable socialisation of the costs of transporting and potentially storing the CO_2, leading to lower financing costs than the same transport sector which was funded on a purely commercial basis. However, the structure put in place would need to also encourage costs minimisation and ensure that the scale of the network was suitable to meet the expected development of the industry.

Additionally it is widely recognised that the UK government would not accept such an industry on its balance sheet so a private sector 'monopoly' provider would be required but examples do exist. The appropriateness of this type of model depend largely on the expectations for the wider development of the industry as this type of model will clearly be more appropriate for a more mature industry with hubs and multiple capture plants than single point to point projects that may emerge from the Commercialisation Programme.

Candidate Action: Consider how the business model for CCS in the UK should migrate away from early end-to-end full chain projects to projects more suited to cluster development.

5.1.2 Contracting structure

As the first CCS projects are developed as part of the CCS Commercialisation Programme, a commercial structure will be established governing parties' responsibilities. There is a clear opportunity for these early commercial agreements to form the template for subsequent projects, as was the case for the early CCGT power projects in the UK and Independent Water and Power Plant (IWPP) projects in the Middle East. The ability for CCS projects to look to these contracting structures as guidelines for new projects will improve the efficiency of executing subsequent projects and the Task Force believe that there are potentially significant financing benefits from defining an early robust 'copy-cat' model for commercial contracting and risk sharing which will contribute to the cost reductions in the industry on both development and financing.

Competing forces influence the desirability, in contracting terms, of separation of the chain into smaller individual components:

- Different elements of the chain (generation, capture, transport, use, storage) may require very different financing and contracting structures to make the business commercially viable. However;
- 'Project-on-project risk' (or the risk arising from interactions between sequential parties in an interdependent group – sometimes known as 'chain-risk') will increase as the number of links in the chain is increased. In other words, contingency is, in part, a function of the contractual interface and the more interfaces, the more the potential for layering of contingencies – other things being equal, reducing the number of contracts reduces this inefficiency in contingency costs.

To the extent possible, establishing a standardised commercial and financing model for CCS will be beneficial if it is appropriate for future CCS projects. However the model will need to be flexible enough to cope with unique features of individual projects, not least differing capture technologies and pipe-storage configurations.

5.1.3 Characterisation or 'proving' of storage

For financial institutions, generation is understood and CO_2 transport has been widely demonstrated in the US and elsewhere. In particular, CO_2 use and storage in the UK are much less familiar to financial institutions even if there is some precedent in other industries that use project finance services.

The Task Force believes that these storage risks are regarded by the finance community as being a major current issue for financing CCS. Without a low risk profile for the storage element of the chain, CCS projects will find it difficult to get low cost (or possibly any) external finance, thereby increasing costs and limiting the scale of any individual CCS power plant (further reducing potential costs savings from power plant scale – see Section 4.4).

Financeable CCS in the early 2020s therefore requires a storage solution that is generally regarded as 'proven' and demonstrably fit for purpose in order for financing to be raised, the focus of which will be:

- characterisation of storage sites and a track record of storage injectability and CO_2 dispersion behaviour as expected in key localised areas; and
- diverse storage options to provide contingency, so that (collectively) the probability is "bankable" which ultimately requires several 'proven' storage options.

Alternatively, storage will have less impact on overall financing if the financial performance of the rest of the chain is somehow insulated from the storage risk. This could be achieved by a separate storage entity assuming the storage risks although it is not clear which entity could perform that function at present.

The need to address storage risks has been highlighted by the Planning and Infrastructure Workstream as well as the Commercial and Financial Workstream. It is discussed in more detail in Section 3.2.

5.1.4 Demonstration of Capture technologies

The Task Force believes, in addition to the storage risks outlined in 5.1.3 above, Capture technologies at a scale required for application to power stations are still regarded as novel by the finance community and as such are regarded as a high risk element of the CCS chain for power stations. This risk perception for current capture processes currently creates an issue for financing CCS.

The Commercialisation Programme in the UK and capture projects elsewhere in the world have the opportunity to help mitigate these risks by the early 2020s through the successful deployment of operational CCS plants (as discussed in 2.2). Financeable CCS requires a capture process that is technically proven in order for financing to be raised, the focus of which will be:

- construction risk for the capture units; and
- technical performance of the capture process post commissioning (rate, costs etc.).

As technologies are tested at scale we would expect the risk perception on those technologies to decrease although the variety of options for each CCS project (such as geography, generation technology, fuel-type, other heat loads etc.) will mean that this de-risking process will take time.

As newer, 'next generation' capture technologies are developed over time these will also need to undergo a similar process of testing both at scale and in a variety of conditions to lower their technical risk and make them financeable.

5.2 Ensuring funding mechanisms are fit-for-purpose

A fit-for-purpose funding mechanism which matches the cost structure of the project and provides revenue certainty (subject to performance) will lower the perceived risk of the CCS project, lowering the hurdle rates for CCS projects and giving access to low cost finance (as described in the wider de-risking description – see Section 5.1).

Electricity Market Reform

The UK currently presents one of the most attractive potential investment environments in the world for CCS due to its geography, skills base and suite of potential support mechanisms for CCS. The EMR process has put in place potential long-term remuneration for CCS in line with other low carbon generation options through the CfD mechanism.

After the commercialisation programme the strike price, as provided by the CfD mechanism, is intended as the primary method of support for CCS. However the technical details of the CFD mechanism are still being decided and, the initial strike prices will be set by negotiation before becoming technology neutral in the 2020s.

The following key CfD features, some of which have already been discussed as part of the EMR process, have been highlighted by the Task Force as having the potential to offer value for consumers by making CCS more financeable without increasing the absolute costs to consumers:

- A mechanism to ensure the value of flexibility and firm-availability is rewarded (see Section 6.4);
- Allow renegotiation of CfD strike price after construction to remove construction risks from the project;
- Index the CfD strike price to fuel prices to remove fuel price risks; and
- Present a viable CfD counterparty so that counterparty risk is minimised.

Whatever funding mechanism is used for the CCS chain it will need to be simple enough for financial institutions to understand, model and be confident that the revenues flowing from it are stable, reliable and deliverable in the long-term. Whilst the outline of the EMR proposals are encouraging in this respect the detail will be crucial for the bankability or otherwise of CCS projects.

Candidate Action: Continue work to develop the CfD structure, and other relevant EMR instruments, with a view to their widespread use in CCS projects.

Separate funding mechanisms for T&S sectors

The current CfD funding proposals for CCS are focused on the power generation sector with the key metric being the delivery of low CO_2 power to the grid at the power station fence. Payment for the transport and storage of the CO_2 is expected to be covered by the CfD payment.

Where the entities that are transporting and storing the CO_2 are separate from the power generator, the current model is for payment for CO_2 transport and storage to be via a negotiated contractual relationship. The nature of these contracts will govern the risk profile of the individual elements of the CCS chain.

The CfD mechanism has good potential and, notwithstanding the above points, is regarded as a relatively good mechanism for addressing the risks and creating financeable generation and capture of CO_2. However, transport and storage have very different risk profiles:

- As the transport networks have a very high proportion of capital costs they will favour fixed annual payments – they will be particularly exposed to contracts which are based on a per unit fee for delivery of CO_2. The power station on the other hand would prefer all payments to be based on a per-unit delivery of CO_2;
- Storage operators may need to take speculative approaches to storage characterisation, investing significant sums of money in uncertain sites before a CO_2 flow is ensured. They will therefore require higher levels of compensation to account for the risk.
- Use of CO_2 for EOR raises another set of issues as the CO_2 user will require reliability of volumes when required but also technical flexibility related to the independent operation of the field utilising EOR.

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5.3 Continued involvement from financial and insurance sectors

If, as expected, the perceived risks associated with CCS change positively in the medium term to improve the financeability of the industry, there will be increased competition, all else being equal, for the provision of project finance and other services to the CCS sector. This will clearly help to ensure that financing costs of CCS projects are reduced as the industry matures.

The role of the insurance sector should not be underestimated in improving the financing conditions for CCS as they will be best placed to deal with and mitigate certain risks which will still exist within the CCS chain.

On-going work within the CCSA and ClimateWise, the global insurance industry's leadership group to drive action on climate change risk, considers the role that insurance might be able to play in helping to manage the regulatory and commercial risks faced by CCS project developers[11].

Candidate Action: Keep a variety of financial institutions, analysts and insurance companies engaged in CCS such that they:

- **understand and gain comfort with the full chain of CCS, its technical characteristics and the financing mechanisms in place;**
- **can correctly analyse risks and risk mitigation options; and**
- **can work with the industry to provide the financial structuring expertise required to fund the anticipated growth of the industry in an efficient manner.**

5.4 Conclusions on commercial and financial cost reduction opportunities

From a modelling perspective, cost reduction mechanisms in this area are simulated by:

- Incorporating longer economic asset lives in later projects allowing longer term financing (increasing the assumed economic life from 15 years to 25 years between 2013 and 2020 in all sectors). By doing so we move to a figure more representative of (what in later years is expected to be) a more mature industry. Longer economic lives represent the impact of improved financing terms and the potential for progressive refinancing of debt, and serve to drive down costs by, in effect, allowing projects to recoup capital expenditure over an extended period of time.
- Reducing the cost of capital:
  - n capture and transport sectors, the cost of capital remains at 10%[12] until 2028 when it is assumed to drop to 8%.
  - n the storage sector the cost of capital is assumed to steadily decline from 15% to 14% to 12% in 2013, 2020 and 2028 respectively.

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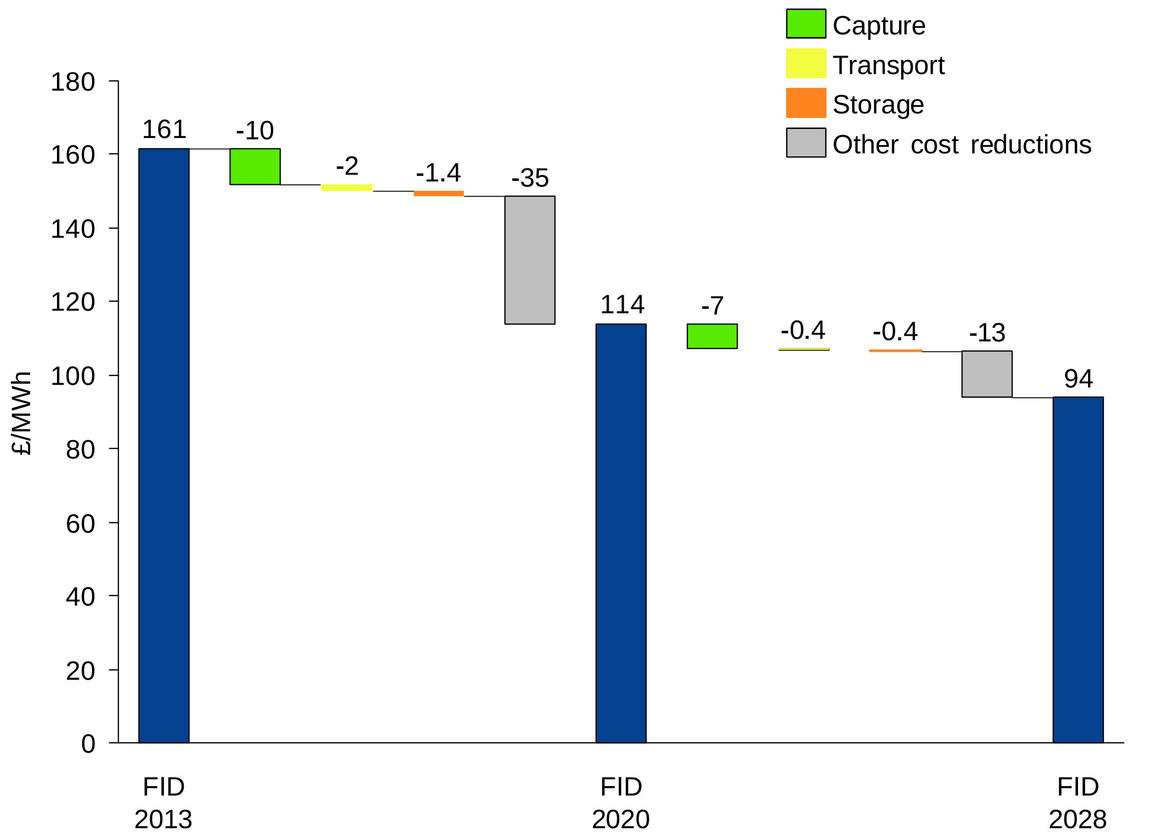
11 "ClimateWise (2012): Managing Carbon Capture and Storage Liabilities in Europe" http://www.climatewise.org.uk/

12 It is noted that the 'correct' cost of capital figure is uncertain even for established industries and differing assumptions can drive very different results for LCOE calculations. The numbers stated have taken the Mott Macdonald report as a starting point and are regarded by the Task Force as broadly appropriate for this kind of analysis. However, it should be recognised that individual Task Force members choose to use (sometime very) different numbers in their own internal analysis.

Figure 3 shows cost reduction mechanisms from accessing affordable finance for the CCs chain. The 'Other reductions' category includes the cost reduction measures achievable by the other cost reduction pathways in this report. These are discussed in Chapters 3 and 4 above.

Figure 3 – Potential cost reduction mechanisms relating to improved financeability (real 2012 £/MWh)



Modelling results indicate that the capture section of the chain has the most to gain from mechanisms that improve financeability; this is to be expected because it retains the largest cost elements.

The cost reduction shown here is actually relatively small for the Transport and Storage sectors. This is because this shows only financial and commercial impacts in isolation. The greatest savings in these sectors are harnessed from the economies of scale discussed in Section 3. In reality the de-risking of the sector as discussed in Section 5.1, will be essential to the financing and building of large scale infrastructure. As such the combined impact of **not** undertaking the cost saving routes discussed in this Chapter would be much greater than Figure 3 indicates due to their necessity for other aspects of cost saving.

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6. LEVERAGING THE BENEFITS OF CCS

Developing a CCS industry in the UK has the potential to create significant value not only through low cost power production but also within the Oil and Gas sector and by stimulating other areas of the economy. Many of these benefits are cross-workstream so we discuss them separately here.

6.1 Encouraging EOR

CO_2 injection into oil fields is one method of recovering otherwise unrecoverable oil from mature oil fields, creating additional income to offset CCS costs, and deferring oil and gasfield decommissioning costs. The Central North Sea (CNS) oil province is mature with many fields set to close in the next decade and therefore suitable for EOR developments. However, developing CO_2 led EOR will also require capital investment in new equipment at each field of the order of £1bn.

CCS and CO_2-based EOR could fit together extremely well; use of CO_2 for EOR provides a way of monetising a waste product, and permanently disposing of the CO_2 at the same time. This is a key reason for the financial success of many CCS projects in the USA and Canada.

A word of caution is needed, as not all CNS fields are suitable for CO_2 EOR campaigns, and there is no direct experience of offshore CO_2 EOR in the CNS or elsewhere. However, several oil companies are actively exploring the option of pursuing CO_2-based EOR on a number of fields in the CNS.

Recent work on the overall value of EOR opportunities such as the Scottish Enterprise Study on the 'Economic Impacts of CO_2-enhanced oil recovery for Scotland' and the University of Aberdeen's Occasional Paper on the 'Economics of CO_2-EOR in the UK Central North Sea' add testimony to this view.

However neither of the above papers takes the step of looking at the potential impact for LCOE of CCS power projects. Only a rough estimate can be made currently of the value that CO_2 may attract if it were delivered at pressure to CNS oil field operators. There is uncertainty in both the overall EOR value and the likely split of value between government, CO_2 provider and EOR developer. Indeed, these values are likely to vary significantly according to the features of each field/project. However, based on US experience the value could well cover the cost of conventional CO_2 storage, and perhaps some of the transport costs as well. As a result this might decrease electricity costs by £5-12/MWh for gas CCS and £10-26/MWh for coal CCS.

It is the view of informed Task Force members, and others who have been consulted, that EOR investments will be actively pursued, and probably sanctioned on some fields, as soon as there is confidence that CO_2 is being delivered to the CNS; and that this will reduce the cost of electricity from some of the power project investments which are expected to be built in the early 2020s. This can act as a stimulus to:

- maintain or extend existing and future offshore infrastructure;
- provide high-quality employment as well as protecting the existing offshore service industry; and
- provide oil and gas tax revenues.

Candidate Action: Stakeholders to work together to consider what measures could encourage CO_2 EOR in the UK.

6.2 Industrial CCS

Only around 40% of UK GHG emissions originate from the energy supply sector. If CCS is developed for the power sector, there is potential significant further opportunity to leverage the benefits of symbiosis between CO_2 capture from power stations with CO_2 capture from industrial sources.

In the absence of an existing CO_2 transport and storage network the low volumes of CO_2 generated at individual sites are unlikely to make underground storage of CO_2 a viable option for non-power industrial CO_2 sources. The large economies of scale associated with CO_2 storage and transport simply make it uneconomic.

However, the industrial processes are such that often CO_2 can be captured at a reasonably high purity for relatively low unit cost. If this CO_2 can be fed into already existing transport and storage networks then the incremental cost of the additional CO_2 saving would be very low.

Whilst the decarbonisation benefits may be attractive from a UK perspective industrial CCS is not necessarily economic to industrial emitters. As the CO_2 price faced by industrial emitters under the European Union Emission Trading Scheme (EU ETS) is so low – averaging around €8/tCO_2 in 2012 to date – abatement from these sources is not currently economic even though it may be significantly less costly than power sector decarbonisation.

This situation is expected to change as the EU ETS price increases during Phase III and Phase IV but the timing and extent of this rise is currently unclear. If industrial sectors faced higher costs of emissions earlier (as is the case for the power sector with a Carbon Price Floor) we would expect to see industrial CCS becoming more attractive.

The Task Force believe that encouraging industrial CCS would further reduce UK GHG emissions but also help to safeguard the competitiveness of UK industries as the costs of emitting CO_2 under schemes such as the EU ETS increases over time.

Candidate Action: Investigate options to incentive the development of industrial CCS projects.

6.3 Additional hydrogen value

IGCCs involve a process that produces decarbonised hydrogen in bulk that is then transported and combusted to produce low-CO_2 power. There is scope for the hydrogen to be fed into higher value uses and harder to access carbon abatement areas and not only in direct large-scale power generation facilities. This includes:

- providing feedstock for industry (as is currently the case on Teesside, Merseyside and elsewhere);
- smaller CHP installations;
- in the longer term, the opportunity to provide low carbon transport; and
- remote decarbonisation of CCGT power plant through a wider hydrogen network.

Banking of gasifiers would provide economies of scale benefits and produce sufficient volumes of hydrogen to feed into multiple processes. Whilst appropriate technology for such a system is under development, it would require a high level of integration of the source and use of hydrogen to achieve a viable financial proposition.

6.4 Wider Energy System Benefits

Energy system modelling by the Energy Technologies Institute suggests that successful deployment of CCS would be a major prize for the UK economy, cutting the annual costs of meeting carbon targets by up to 1% of GDP (or around £42 billion per year) by 2050.

Section 1.1 describes the important role that CCS is envisaged to play in a decarbonised UK electricity mix. There are significant network management benefits to introducing alternative, potentially flexible, sources of low-carbon electricity especially when it is installed alongside intermittent generation.

DECC's Technology Innovation Need Assessment released in August 2012 highlights the potential role of CCS in the UK's energy system:

- Having CCS available (compared to an energy system without CCS) is estimated to save the UK hundreds of billions of GBP in cumulative value between 2010 and 2050. Nevertheless, considerable work remains to demonstrate CCS at large scale and across the entire chain.
- CCS offers many benefits to a low-carbon energy and economic system as it allows the flexibility and energy security benefits of fossil fuel combustion with near-zero GHG emissions.

Therefore not only will CCS provide low carbon generation to the grid, alongside other low carbon options such as renewables and nuclear, it can also provide two additional services:

- Provision of secure power – unlike intermittent forms of generation, CCS can be scheduled so that it has a very high level of availability at times of peak demand on the grid; and
- Provision of flexibility – the electricity system must be balanced instantaneously by the System Operator to maintain the necessary level of electricity supply stability. CCS has the capability to both increase and decrease generation levels relatively quickly (compared to many other forms of low carbon generation).

We have loosely grouped these as the additional 'energy system' value of CCS. As the proportion of intermittent generation on the grid increases it is likely that the value of these services will increase.

It is not currently clear how these benefits will be rewarded for CCS plants under current market arrangements.

Candidate Action: Develop work to examine how CCS can operate to deliver flexible rather than base-load electricity generation.

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7. CONCLUSIONS

The Cost Reduction Task Force's objective was to examine the long-term outlook for generation costs from power stations that capture and store their carbon dioxide emissions. Many scenarios suggest that CCS power stations are likely to be a major component of the British decarbonisation targets for 2050. Indeed the flexibility of operation that gas- and coal-fired CCS power stations can offer may be essential in complementing the intermittent output of the wind generation fleet.

At this early stage of deployment, with even the few reference points of the costs of operation being largely based on technical studies rather than operation, this exercise has required members of the Task Force to use their experience to forecast the costs as the industry reaches maturity. Such an exercise has required:

- combining expertise from a technical point of view for the generation and capture part;
- understanding of the impact of developing a major infrastructure for the transport and storage part; as well as; and
- projecting the complex way in which commercial and financial arrangements grow from those appropriate to early projects those expected of a well-established industry.

With the collected experience of 30 members and contributors directly involved in all aspects of CCS project development, this Task Force is well-qualified to address the above issues.

Having the right landscape…

It is clear from the previous sections of this Report that significant cost reductions are to be expected provided the right landscape engenders them.

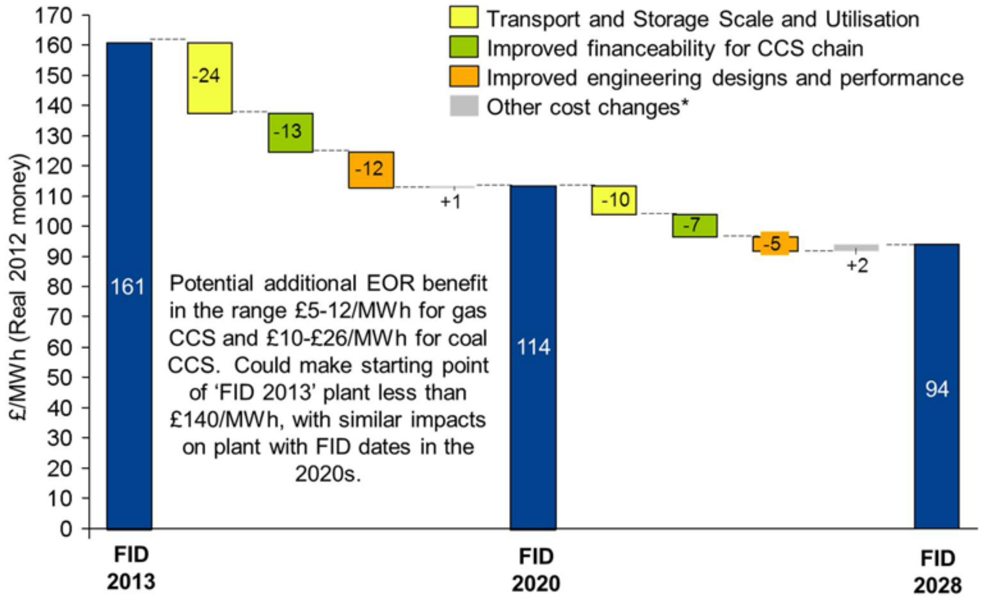
Key components of the right landscape are as follows:

- Credible and long-term UK commitment to CCS by government and industry which includes a recognition of the role of CCS in the future generation mix, as well as a coordinated plan for transport and storage and an appropriate underpinning regulatory landscape;
- Multiple operating full-chain CCS plants that build on the current commercialisation programme; and
- Continued engagement with the financial sector, so that the industry and government jointly create access to low cost finance for CCS.

…delivering the cost reductions

With this landscape in place, the overall cost reduction path for baseload CCS generation is shown in Figure 4, which translates the cost savings identified in Chapters 3, 4 and 5 – expressing them in terms of LCOE. For simplicity the diagram averages costs from the different technical approaches to capture, and takes as its starting point the baseline of a hypothetical full scale CCS-equipped power station reaching FID in 2013.

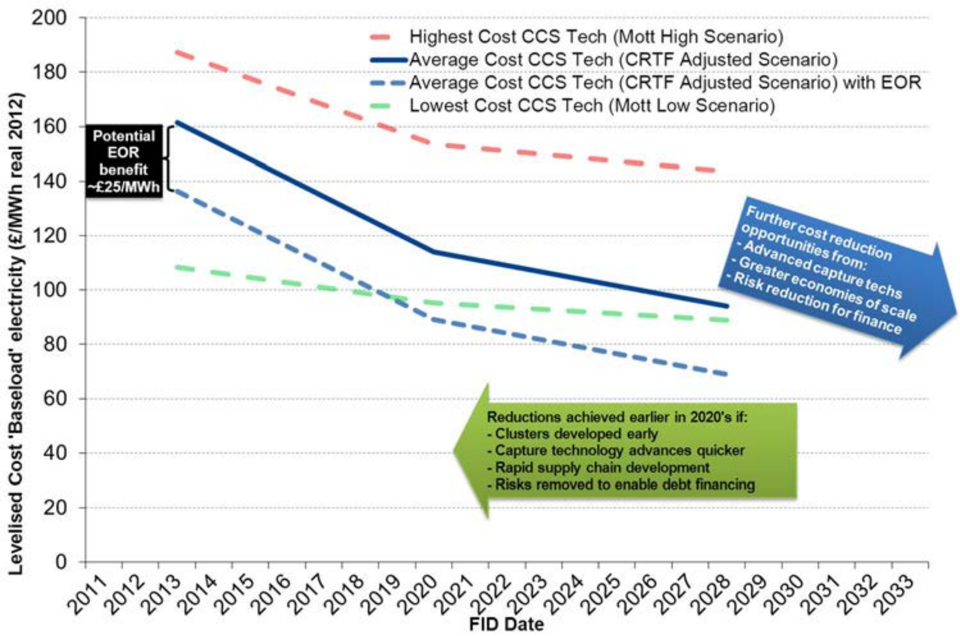
Figure 4 – Potential cost reduction mechanisms for CCS between plants reaching FID in 2013, 2020 and 2028 (technology average, 2012 £/MWh)



Note: Shows average costs across technologies. *E.G. Increasing CO_2 price, falling storage abandonment costs

If we take into account realistic ranges in both the overall costs of different technical approaches, and also in the range of cost reductions, we see a very significant downward trend. Figure 5 illustrates the trend for a baseload electricity station. The material potential for further reducing costs by incorporating EOR projects is also shown in this diagram.

Figure 5 – Range of cost reduction opportunities for CCS



…generating at costs comparable to other low carbon technologies

Several recent reports have suggested that offshore wind generation has the potential to reach LCOE of the order of £100/MWh, and this seems to be gradually being adopted as a benchmark for all low-carbon technologies.

It is clear that Carbon Capture and Storage will be a direct economic competitor with more traditional ‘renewables’ – and even more so when its ability to back-up wind intermittency is taken into account.

Still significant challenges ahead

It is by no means a given that these low cost levels will be reached: both Government and Industry will need to play their part, and while there are some clear policy gaps in the current CCS policy framework, industry has a significant contribution to make.

The Task Force is confident that this future is possible.

Note

As an interim report, the above conclusions may be modified somewhat as final packages of analysis are completed.

Additional programme of work to be included in the final report

In the six months since the Task Force was convened a great deal of very intensive work has been undertaken to prepare this interim report. The purpose of preparing an interim report was to take stock of the accumulated knowledge and understanding of this highly complex subject. The report will inform the Minister on the thinking of the Task Force to date at an important time of energy policy development and will establish a baseline on which the Task Force can base its on-going programme of work.

Throughout the report there are recommended candidate actions that may place an onus on the various different stakeholders to put in place measures that will ultimately lead to CCS cost reductions. It should be recognised that many of these actions are already in progress such as for example various policy matters already under developments as well as on-going technical R&D being undertaken by all stakeholders.

The next meeting of the Task Force to be convened soon after the publication will have its objective to examine the conclusions of the report and its candidate actions, to isolate and prioritise those actions that would otherwise not happen and to recommend or to allocate actions to ensure fulfilment of the cost reduction objective.

It is intended that a final report will be delivered to the Minister in Spring 2013.

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ANNEX A – BASIS OF MODELLING ASSUMPTIONS

The baseline agreed for this work is a derivative of estimated costs outlined in the DECC report by Mott Macdonald 2012. These costs were modelled in detail using the supporting information provided by Mott MacDonald.

Examining the "Mott High" and "Mott Low" scenarios, the opinions of the Task Force (on the sub-set of information contained in that model) were used to form a new baseline. This Baseline is titled the "Cost Reduction Task Force Adjusted Path" and is referenced when discussing cost reduction opportunities, and their impacts, within this report.

A.1 Summary of cost outputs for CRTF adjusted path

In general the cost assumptions made in the Mott Low Cost pathway were supported by the Task Force as achievable given the actions and recommendations in this report. The high cost pathway was regarded as representative of a world where the cost reduction opportunities presented here were not exploited (and was therefore not appropriate from the perspective of cost reduction opportunities).

The following is a brief description of the plant types and CCS industry position from which the adjusted cost path was derived. Where aspects are highlighted in red they have been adjusted compared to the Mott Macdonald Low Cost Pathway. Fuel prices have been kept equal to those contained in the Mott Macdonald report (based on 2011 DECC central case) to ensure results are comparable. As with the Mott Macdonald work, the cost estimates include costs for a base (or host) plant and as such are focused on newly constructed CCS projects rather than the retrofit of CCS to existing power stations.

It should be recognised that the levelised cost of electricity from CCS will be partially driven by aspects unrelated to the cost reductions in this report. In particular these aspects include intentionally-driven commodity prices and, in some circumstances, the eventual load factor of the plants.

A.1.1 2013

- FID in 2013
- ~300MW net electrical output for both coal and gas plants, single projects
  - t a specific design but using BAT technology
- Assumptions on all capex & opex from the Mott 2013 Low scenario
  - st gas plant 54% HHV & £550/kW; Host post-comb coal plant 43% HHV & £1400/kW; Host oxy-comb coal plant 43% HHV & £1500/kW; IGCC 43% HHV & £2200/kW.
  - rgy penalty 25% for PC Coal & Oxy Coal, 17% for IGCC and 19% for PC Gas
- Plants capture 85% of the CO_2 produced and run at 80% load factor
- CO_2 transported 30km onshore and then 300km offshore in appropriate scale pipes (10'' for gas [1mtpa], 15'' for coal [2mtpa]) in dense phase and then stored in a DOGF
- We assume a 15 year economic lifetime for all components (inc. base plant, capture, transport and storage) with no terminal value
  - ter than standard due to the current lack of maturity of technology, assumed to increase to 25 years in the 2020s

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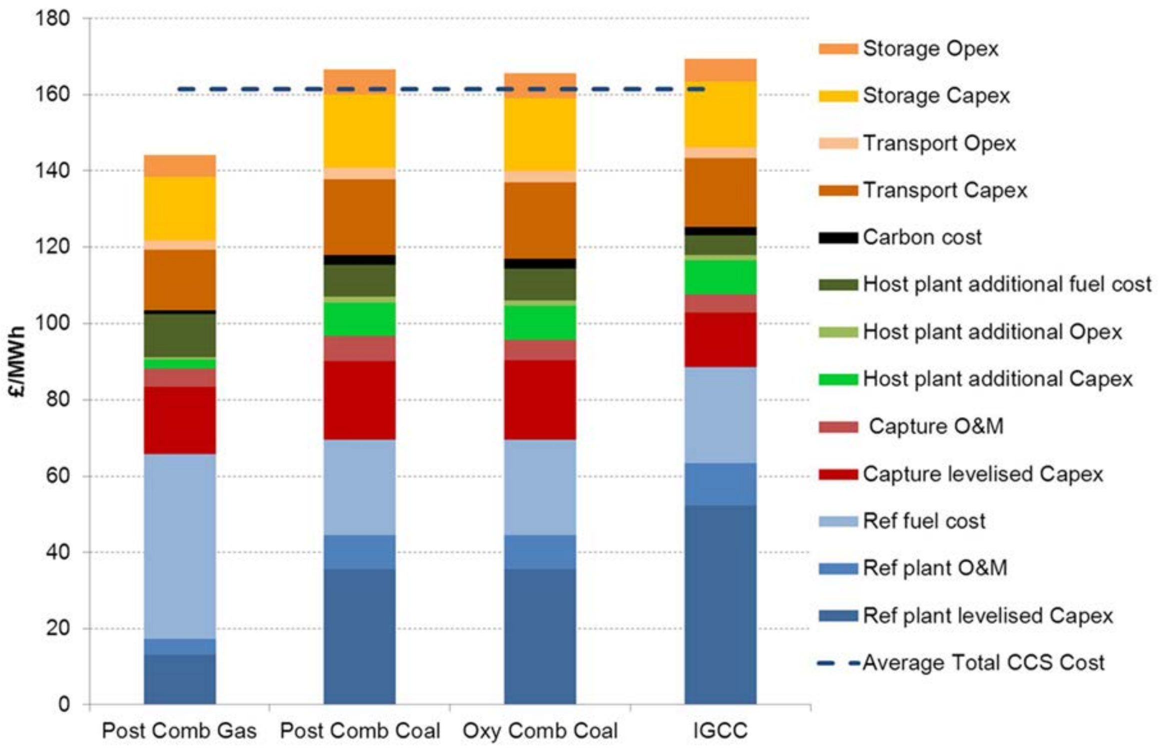
- Pre-tax real Weighted Average Cost of Capital (WACC) assumption is 10% on the generation and capture, 10% on the transport pipeline infrastructure and 15% on the Storage
- Developer contingency included as a 10% uplift on all capital costs (supplier contingency is assumed to be contained in the capital cost estimates)

Figure 6 – LCOE of FID 2013 CCS technologies (£/MWh 2012 money)

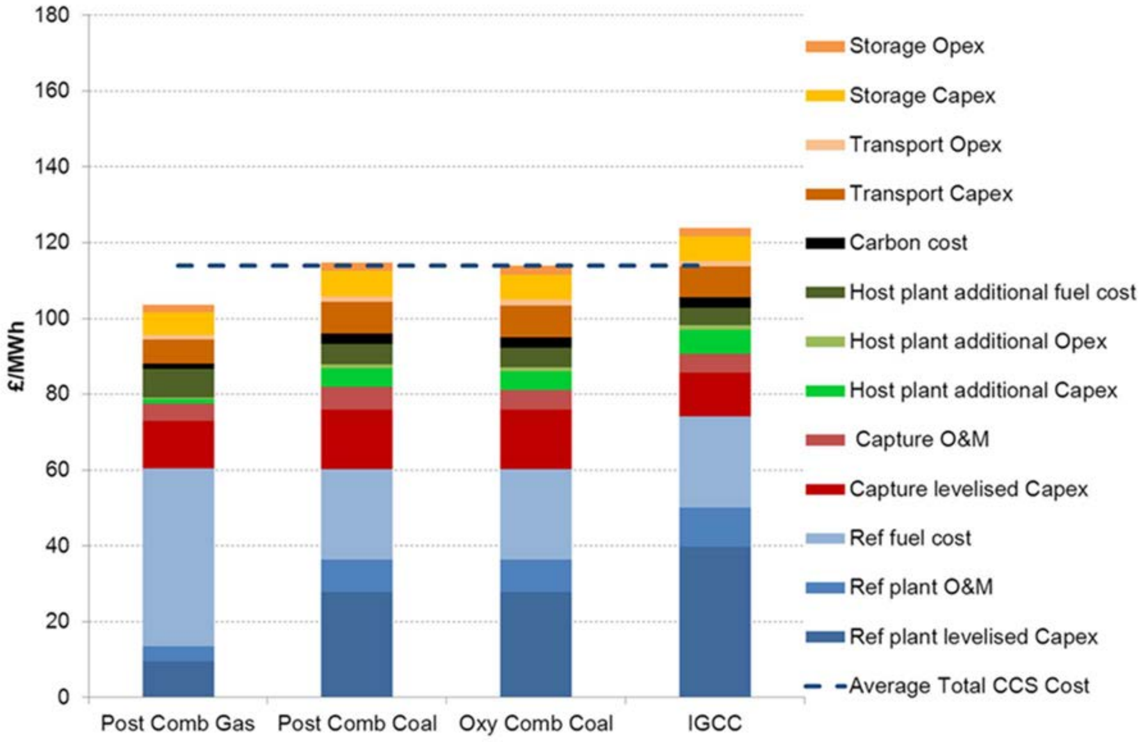


£/MWh	Post Comb Gas	Post Comb Coal	Oxy Comb Coal	IGCC
Ref plant levelised Capex	13.1	35.6	35.6	52.2
Ref plant O&M	4.2	8.9	8.9	11.1
Ref fuel cost	48.7	25.1	25.1	25.1
Capture levelised Capex	17.3	20.5	20.6	14.2
Host plant additional Capex	2.5	8.9	8.9	8.9
Host plant additional Opex	0.4	1.5	1.5	1.5
Capture O&M	4.9	6.4	5.4	4.9
Host plant additional fuel cost	11.4	8.4	8.4	5.1
Carbon cost	1.1	2.5	2.5	2.3
Transport Capex	15.8	20.0	20.0	18.1
Transport Opex	2.4	3.0	3.0	2.7
Storage Capex	16.8	19.2	19.2	17.3
Storage Opex	5.7	6.5	6.5	5.9
Total	144.1	166.5	165.6	169.3
Average Total CCS Cost	**161.4**	**161.4**	**161.4**	**161.4**

A.1.2 2020

- FID in 2020
- ~800MW net electrical output for coal, ~600MW for gas, single projects
- Full commercial scale brings significant economies of scale benefits in capture, transport and storage
- Projects benefit from partial economies of scale in transport & storage but not yet part of large, well utilised clusters
- Not a specific design but using BAT technology
- Assumptions on all capex and opex from Mott 2020 Low (recognising potential range)
- Host gas plant 56% HHV & £500/kW; post-combustion coal plant 45% HHV & £1400/kW; oxyfuel coal plant 45% HHV & £1400/kW ; IGCC 45% HHV & £2000/kW
- Energy penalty 18% for PC Coal & Oxy Coal, 16% for IGCC and 14% for PC Gas
- Plants capture 90% of the CO_2 produced and run at 80% load factor
- CO_2 transported 40km onshore and then 300km offshore in appropriately scaled pipes (15'' for gas [2mtpa], 18'' for coal [4mtpa]) in dense phase and then stored in a DOGF
- We assume a 25 year economic lifetime for all components (inc. base plant, capture, transport and storage) with no terminal value
- Pre-tax real WACC assumption is 10% on the generation and capture, 10% on the transport pipeline infrastructure and 14% on the Storage
  — % lower than 2013 as risk perception lowered on storage component (still 4% higher than Mott Low Cost path assumption)
- Developer contingency included as a 10% uplift on all capital costs (supplier contingency is assumed to be contained in the capital cost estimates).

Figure 7 – LCOE of FID 2020 CCS technologies (£/MWh 2012 money)



£/MWh	Post Comb Gas	Post Comb Coal	Oxy Comb Coal	IGCC
Ref plant levelised Capex	9.5	27.8	27.8	39.8
Ref plant O&M	4.0	8.5	8.5	10.3
Ref fuel cost	46.9	24.0	24.0	24.0
Capture levelised Capex	12.5	15.5	15.6	11.7
Host plant additional Capex	1.3	5.0	5.0	6.4
Host plant additional Opex	0.3	1.0	1.0	1.3
Capture O&M	4.6	6.1	5.1	4.8
Host plant additional fuel cost	7.6	5.3	5.3	4.6
Carbon cost	1.3	2.8	2.8	2.7
Transport Capex	6.4	8.3	8.3	8.1
Transport Opex	1.2	1.5	1.5	1.5
Storage Capex	6.0	6.7	6.7	6.5
Storage Opex	2.1	2.3	2.3	2.2
Total	103.7	114.7	113.9	123.8
Average Total CCS Cost	**114.0**	**114.0**	**114.0**	**114.0**

A.1.3 2028

- FID in 2028
- ~800MW+ net electrical output for coal, ~600MW+ for gas
  - lusters allow for higher CO_2 flow than from the single station – 15mpta through the network
- Not a specific design but using BAT technology
- Assumptions on all capex and opex from Mott 2028 Low figures
- Host gas plant 56% HHV & £500/kW; post-combustion coal plant 45% HHV & £1400/kW; oxyfuel coal plant 45% HHV & £1400/kW ; IGCC 45% HHV & £1900/kW
- Energy penalty 15% for PC Coal & Oxy Coal, 12% for IGCC and 11% for PC Gas
- Plants capture 90% of the CO_2 produced and run at 80% load factor
- CO_2 transported 40 km onshore and then 300km offshore in appropriate scale pipes (36'' for both gas and coal - 15mtpa) in dense phase and then stored in a DOGF
- We assume a 25 year economic lifetime for all components (inc. base plant, capture, transport and storage) with no terminal value
- Pre-tax real WACC assumption is 8% on the generation and capture, 8% on the transport pipeline infrastructure and 12% on the Storage
  - ll of 2-3% from 2013 as some risk has been removed from due to 'landscape' actions and project finance is now available for at least certain aspects. Storage WACC still 2% higher than Mott assumption.
- Developer contingency included as a 10% uplift on all capital costs (supplier contingency is assumed to be contained in the capital cost estimates).

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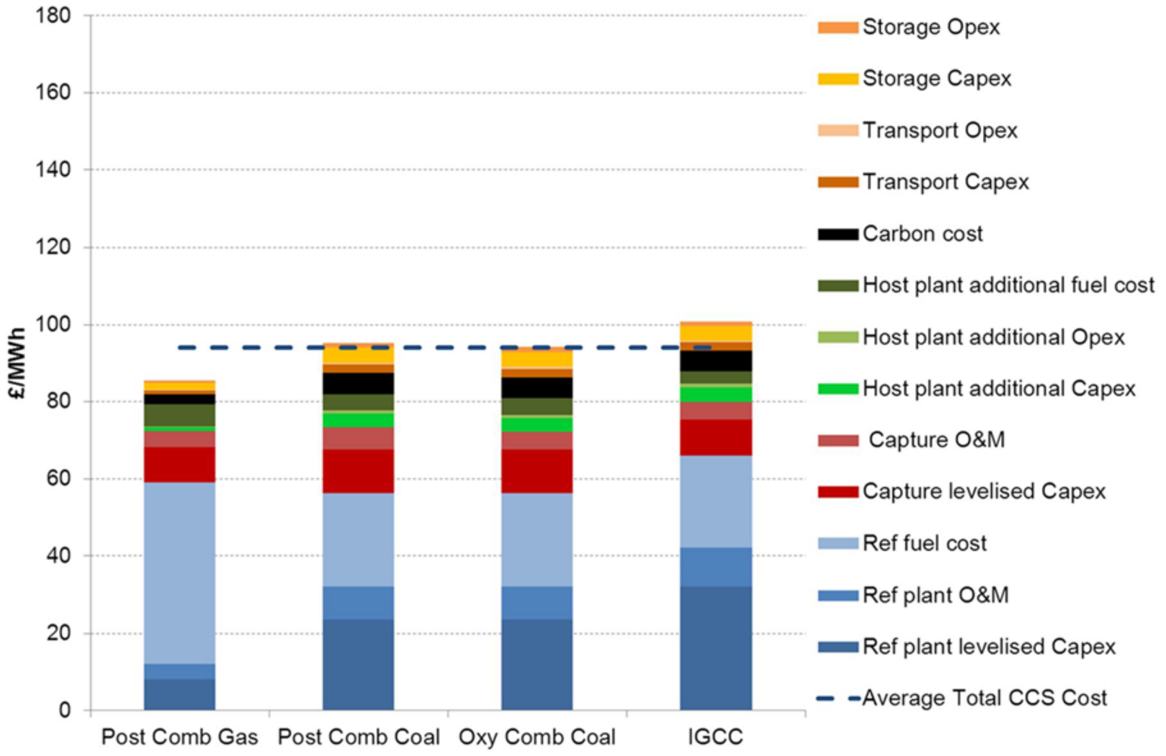
Figure 8 – LCOE of FID 2028 CCS technologies (£/MWh 2012 money)



£/MWh	Post Comb Gas	Post Comb Coal	Oxy Comb Coal	IGCC
Ref plant levelised Capex	8.1	23.7	23.7	32.1
Ref plant O&M	4.0	8.5	8.5	10.0
Ref fuel cost	46.9	24.0	24.0	24.0
Capture levelised Capex	9.2	11.5	11.4	9.2
Host plant additional Capex	0.9	3.6	3.6	3.9
Host plant additional Opex	0.2	0.8	0.8	0.9
Capture O&M	4.2	5.7	4.7	4.6
Host plant additional fuel cost	5.8	4.2	4.2	3.3
Carbon cost	2.5	5.5	5.5	5.3
Transport Capex	1.0	2.2	2.2	2.1
Transport Opex	0.2	0.5	0.5	0.4
Storage Capex	1.9	3.9	3.9	3.7
Storage Opex	0.6	1.4	1.4	1.3
Total	85.6	95.3	94.2	100.8
Average Total CCS Cost	**94.0**	**94.0**	**94.0**	**94.0**

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A.2 Generation and capture assumptions

A.2.1 Post-combustion coal

Post Combustion Coal			Low cost path				High cost path				Adjusted path		
			2013	2020	2028	2040	2013	2020	2028	2040	2013	2020	2028
Capture	ACF	%	80%	80%	80%	80%	60%	60%	60%	60%	80%	80%	80%
Capture	WACC	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Capture	Plant life	Years	15	30	30	30	15	20	25	30	15	25	25
Capture	Energy penalty	%	25%	23%	18%	13%	26%	24%	22%	18%	25%	18%	15%
Both	Energy cost	£/GJ	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Capture	Tech. component: Dev.etc	£/kW	67	63	60	57	77	77	74	71	67	63	60
Capture	Tech. component: Absorbers	£/kW	350	304	256	226	403	398	375	353	350	304	256
Capture	Tech. component: Regen.	£/kW	125	113	97	88	144	141	133	127	125	113	97
Capture	Tech. component: Compres.	£/kW	216	203	180	158	248	239	229	220	216	203	180
Capture	Tech. component: Host plant	£/kW	375	322	252	182	442	384	352	288	375	322	252
Capture	Tech. component: BoP	£/kW	108	98	87	77	124	123	118	111	108	98	87
Capture	VOM (CCS)	% capex	3.00	3.00	3.00	3.00	4.00	4.00	4.00	4.00	3.00	3.00	3.00
Ref	Specific Capex (Ref Plant)	£/kW	1500	1400	1400	1400	1700	1600	1600	1600	1500	1400	1400
Ref	ACF (Ref Plant)	%	80%	80%	80%	80%	60%	60%	60%	60%	80%	80%	80%
Ref	WACC (Ref Plant)	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Ref	Plant life (Ref Plant)	Years	30	30	30	30	25	25	25	30	15	25	25
Ref	VOM (Ref Plant)	% capex	3.0	3.0	3.0	3.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0
Both	Carbon cost	£/tCO2	16	30	62	110	16	30	62	110	16	30	62
Both	% Carbon stored	%	85%	85%	85%	85%	85%	85%	85%	85%	85%	90%	90%
Both	Implied IDC %	%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Both	CO2 content of fuel	tCO2/tFuel	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341
Capture	Efficiency of plant (CCS)	%	30%	31%	33%	35%	30%	30%	31%	33%	32%	37%	38%
Ref	Efficiency of plant (Ref)	%	40%	40%	40%	40%	40%	40%	40%	40%	43%	45%	45%
Both	FOM %	%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
All (inc. T&S)	Developer contingency	%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%

A.2.2 Post-combustion gas

Post Combustion Gas			Low cost path				High cost path				Adjusted path		
			2013	2020	2028	2040	2013	2020	2028	2040	2013	2020	2028
Capture	ACF	%	80%	80%	80%	80%	60%	60%	60%	60%	80%	80%	80%
Capture	WACC	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Capture	Plant life	Years	15	30	30	30	15	20	25	30	15	25	25
Capture	Energy penalty	%	15%	14%	11%	7%	16%	15%	13%	10%	19%	14%	11%
Both	Energy cost	£/GJ	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30	7.30
Capture	Tech. component: Dev.etc	£/kW	55	52	50	47	66	66	64	61	55	52	50
Capture	Tech. component: Absorbers	£/kW	310	269	226	200	372	368	347	326	310	269	226
Capture	Tech. component: Regen.	£/kW	120	108	93	84	144	141	133	128	120	108	93
Capture	Tech. component: Compres.	£/kW	150	141	125	110	180	173	166	160	150	141	125
Capture	Tech. component: Host plant	£/kW	83	70	55	35	88	83	72	55	83	70	55
Capture	Tech. component: BoP	£/kW	95	86	77	67	114	113	108	102	95	86	77
Capture	VOM (CCS)	% capex	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00
Ref	Specific Capex (Ref Plant)	£/kW	550	500	500	500	550	550	550	550	550	500	500
Ref	ACF (Ref Plant)	%	80%	80%	80%	80%	60%	60%	60%	60%	80%	80%	80%
Ref	WACC (Ref Plant)	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Ref	Plant life (Ref Plant)	Years	25	30	30	30	20	20	25	30	15	25	25
Ref	VOM (Ref Plant)	% capex	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0
Both	Carbon cost	£/tCO2	16	30	62	110	16	30	62	110	16	30	62
Both	% Carbon stored	%	85%	85%	85%	85%	85%	85%	85%	85%	85%	90%	90%
Both	Implied IDC %	%	10%	10%	10%	10%	10%	10%	10%	10%	15%	10%	10%
Both	CO2 content of fuel	tCO2/tFuel	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202	0.202
Capture	Efficiency of plant (CCS)	%	46%	46%	48%	50%	45%	45%	46%	48%	44%	48%	50%
Ref	Efficiency of plant (Ref)	%	54%	54%	54%	54%	53%	53%	53%	53%	54%	56%	56%
Both	FOM %	%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
All (inc. T&S)	Developer contingency	%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%

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A.2.3 Oxyfuel combustion coal

			Low cost path				High cost path				Adjusted path		
Oxy-Combustion Coal			2013	2020	2028	2040	2013	2020	2028	2040	2013	2020	2028
Capture	ACF	%	80%	80%	80%	80%	60%	60%	60%	60%	80%	80%	80%
Capture	WACC	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Capture	Plant life	Years	15	30	30	30	15	20	25	30	15	25	25
Capture	Energy penalty	%	25%	22%	16%	11%	26%	24%	21%	17%	25%	18%	15%
Both	Energy cost	£/GJ	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Capture	Tech. component: Dev.etc	£/kW	67	63	60	57	80	80	78	74	67	63	60
Capture	Tech. component: Air Sep.	£/kW	280	243	200	177	336	329	301	283	280	243	200
Capture	Tech. component: Conditioning	£/kW	200	181	152	136	240	233	213	204	200	181	152
Capture	Tech. component: Compres.	£/kW	216	203	176	155	259	246	237	227	216	203	176
Capture	Tech. component: Host plant	£/kW	375	308	224	154	442	384	336	272	375	308	224
Capture	Tech. component: BoP	£/kW	107	97	87	76	128	127	122	115	107	97	87
Capture	VOM (CCS)	% capex	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00
Ref	Specific Capex (Ref Plant)	£/kW	1500	1400	1400	1400	1700	1600	1600	1600	1500	1400	1400
Ref	ACF (Ref Plant)	%	80%	80%	80%	80%	60%	60%	60%	60%	80%	80%	80%
Ref	WACC (Ref Plant)	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Ref	Plant life (Ref Plant)	Years	30	30	30	30	25	25	25	30	15	25	25
Ref	VOM (Ref Plant)	% capex	3.0	3.0	3.0	3.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0
Both	Carbon cost	£/tCO2	16	30	62	110	16	30	62	110	16	30	62
Both	% Carbon stored	%	85%	85%	85%	85%	85%	85%	85%	85%	85%	90%	90%
Both	Implied IDC %	%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Both	CO2 content of fuel	tCO2/tFuel	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341
Capture	Efficiency of plant (CCS)	%	30%	31%	34%	36%	30%	30%	32%	33%	32%	37%	38%
Ref	Efficiency of plant (Ref)	%	40%	40%	40%	40%	40%	40%	40%	40%	43%	45%	45%
Both	FOM %	%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
All (inc. T&S)	Developer contingency	%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%

A.2.4 IGCC

			Low cost path				High cost path				Adjusted path		
IGCC			2013	2020	2028	2040	2013	2020	2028	2040	2013	2020	2028
Capture	ACF	%	80%	75%	70%	65%	60%	55%	50%	45%	80%	80%	80%
Capture	WACC	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Capture	Plant life	Years	15	30	30	30	15	20	25	30	15	25	25
Capture	Energy penalty	%	17%	16%	12%	10%	20%	19%	17%	15%	17%	16%	12%
Both	Energy cost	£/GJ	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Capture	Tech. component: Dev.etc	£/kW	60	59	58	56	72	72	71	71	60	59	58
Capture	Tech. component: Water shift	£/kW	200	198	183	165	240	242	242	238	200	198	183
Capture	Tech. component: Conditioning	£/kW	160	155	140	131	192	192	192	188	160	155	140
Capture	Tech. component: Compres.	£/kW	80	78	72	65	96	94	94	94	80	78	72
Capture	Tech. component: Host plant	£/kW	374	320	228	180	500	456	391	330	374	320	228
Capture	Tech. component: BoP	£/kW	100	96	90	83	120	121	119	119	100	96	90
Capture	VOM (CCS)	% capex	2.50	2.50	2.50	2.50	3.00	3.00	3.00	3.00	2.50	2.50	2.50
Ref	Specific Capex (Ref Plant)	£/kW	2200	2000	1900	1800	2500	2400	2300	2200	2200	2000	1900
Ref	ACF (Ref Plant)	%	80%	80%	80%	80%	60%	60%	60%	60%	80%	80%	80%
Ref	WACC (Ref Plant)	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	8%
Ref	Plant life (Ref Plant)	Years	30	30	30	30	20	20	25	30	15	25	25
Ref	VOM (Ref Plant)	% capex	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
Both	Carbon cost	£/tCO2	16	30	62	110	16	30	62	110	16	30	62
Both	% Carbon stored	%	85%	85%	85%	85%	85%	85%	85%	85%	85%	90%	90%
Both	Implied IDC %	%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Both	CO2 content of fuel	tCO2/tFuel	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341	0.341
Capture	Efficiency of plant (CCS)	%	33%	34%	35%	36%	32%	32%	33%	34%	36%	38%	40%
Ref	Efficiency of plant (Ref)	%	40%	40%	40%	40%	40%	40%	40%	40%	43%	45%	45%
Both	FOM %	%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
All (inc. T&S)	Developer contingency	%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%

A.3 Transport Assumptions

Transport capital and operational cost assumptions have been taken from the Mott Macdonald report. Only minor adjustments have been made for the CRTF adjusted scenario at this point, largely regarding the assumed throughput of CO_2 and pipeline diameters in FID 2013 and 2020 gas projects. The amortisation rate and period applied to the capital expenditure has also been adjusted to better reflect Task Force estimates. It should be recognised that the simplified approach taken in these kinds of LCOE calculations can only partially reflect real-world financial arrangements.

Common assumptions			**2013**	**2020**	**2028**	**2040**
Subsea	Subsea Capex 10"	£/km	0.77	0.69	0.66	0.63
Subsea	Subsea Capex 15"	£/km	0.85	0.77	0.73	0.69
Subsea	Subsea Capex 18"	£/km	1.00	0.90	0.86	0.81
Subsea	Subsea Capex 36"	£/km	1.25	1.13	1.07	1.02
Subsea	Subsea Opex %	%	2.0%	2.0%	2.0%	2.0%
Subsea & onshore	Throughput 10"	mtpa	1	1	1	1
Subsea & onshore	Throughput 15"	mtpa	2	2	2	3
Subsea & onshore	Throughput 18"	mtpa	2	4	4	5
Subsea & onshore	Throughput 36"	mtpa	2	10	15	18
Onshore	Onshore Capex 10"	£/km	0.39	0.35	0.33	0.31
Onshore	Onshore Capex 15"	£/km	0.43	0.38	0.36	0.35
Onshore	Onshore Capex 18"	£/km	0.50	0.45	0.43	0.41
Onshore	Onshore Capex 36"	£/km	0.63	0.56	0.53	0.51
Onshore	Onshore opex %	%	1.5%	1.5%	1.5%	1.5%
Pipe diameters			**2013**	**2020**	**2028**	**2040**
Subsea	Low gas subsea pipe diameter	"	15	18	36	36
Subsea	High gas subsea pipe diameter	"	10	15	15	15
Subsea	Adjusted gas subsea pipe diameter	"	10	15	36	
Subsea	Low coal subsea pipe diameter	"	15	18	36	36
Subsea	High coal subsea pipe diameter	"	10	15	15	15
Subsea	Adjusted coal subsea pipe diameter	"	15	18	36	
Onshore	Low gas onshore pipe diameter	"	15	18	36	36
Onshore	High gas onshore pipe diameter	"	10	15	15	15
Onshore	Adjusted gas onshore pipe diameter	"	10	15	36	
Onshore	Low coal onshore pipe diameter	"	15	18	36	36
Onshore	High coal onshore pipe diameter	"	10	15	15	15
Onshore	Adjusted coal onshore pipe diameter	"	15	18	36	
Amortisation life			**2013**	**2020**	**2028**	**2040**
Subsea & onshore	Low gas amortisation life (onshore & offshore)	years	25	30	35	40
Subsea & onshore	High gas amortisation life (onshore & offshore)	years	25	30	35	40
Subsea & onshore	Adjusted gas amortisation life (onshore & offshore)	years	15	25	25	
Subsea & onshore	Low coal amortisation life (onshore & offshore)	years	25	30	35	40
Subsea & onshore	High coal amortisation life (onshore & offshore)	years	25	30	35	40
Subsea & onshore	Adjusted coal amortisation life (onshore & offshore)	years	15	25	25	
PMT rate			**2013**	**2020**	**2028**	**2040**
Subsea & onshore	Low gas PMT rate (onshore & offshore)	%	10%	10%	10%	10%
Subsea & onshore	High gas PMT rate (onshore & offshore)	%	10%	10%	10%	10%
Subsea & onshore	Adjusted gas PMT rate (onshore & offshore)	%	10%	10%	8%	
Subsea & onshore	Low coal PMT rate (onshore & offshore)	%	10%	10%	10%	10%
Subsea & onshore	High coal PMT rate (onshore & offshore)	%	10%	10%	10%	10%
Subsea & onshore	Adjusted coal PMT rate (onshore & offshore)	%	10%	10%	8%	
Average pipe lengths						
Onshore	Low gas onshore pipe length	km	30	50	80	80
Onshore	High gas onshore pipe length	km	30	30	30	30
Onshore	Adjusted gas onshore pipe length	km	30	40	40	
Onshore	Low coal onshore pipe length	km	30	50	80	80
Onshore	High coal onshore pipe length	km	30	30	30	30
Onshore	Adjusted coal onshore pipe length	km	30	40	40	
Subsea	Subsea pipe length	km	300	300	300	300

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A.4 Storage assumptions

Storage capital and operational cost assumptions have been taken from Mott Macdonald report. Only minor adjustments have been made for the CRTF adjusted scenario at this point, largely regarding the assumed throughput of CO_2 in FID 2013 and 2020 projects and the amortisation rate and period applied to the capital expenditure (labelled as PMT rate below).

DOGF: Low path coal		2013	2020	2028	2040
Pre-FID	£m	19.20	19.20	19.20	19.20
Pipelines	£m	6.00	5.36	4.54	3.86
Platforms	£m	124.00	110.84	93.86	79.70
Wells	£m	41.00	36.65	31.03	25.56
MMV	£m	0.00	0.00	0.00	0.00
Abandonment	£m	75.00	58.93	46.30	37.25
Throughput CO2	mtpa	2	4	5	5
Amortisation period	years	20	25	30	35
Annual OPEX%	%	6.0%	5.0%	4.5%	4.0%
PMT rate	%	10%	10%	10%	10%
IDC %	%	15%	15%	15%	15%

DOGF: Low path gas	2013	2020	2028	2040
Pre-FID	19.20	19.20	19.20	19.20
Pipelines	6.00	5.36	4.54	3.86
Platforms	124.00	110.84	93.86	79.70
Wells	41.00	36.65	31.03	25.56
MMV	0.00	0.00	0.00	0.00
Abandonment	75.00	58.93	46.30	37.25
Throughput CO2	2	4	5	5
Amortisation period	20	25	30	35
Annual OPEX%	6.0%	5.0%	4.5%	4.0%
PMT rate	10%	10%	10%	10%
IDC %	15%	15%	15%	15%

DOGF: High path coal		2013	2020	2028	2040
Pre-FID	£m	22.08	22.08	22.08	22.08
Pipelines	£m	6.90	6.70	6.36	5.99
Platforms	£m	142.60	138.36	131.54	123.81
Wells	£m	47.15	45.75	43.49	40.53
MMV	£m	0.00	0.00	0.00	0.00
Abandonment	£m	86.25	77.06	65.23	54.66
Throughput CO2	mtpa	2.00	3.00	4.00	4.00
Amortisation period	years	15	25	39	40
Annual OPEX%	%	6.0%	5.0%	4.5%	4.5%
PMT rate	%	10%	10%	10%	10%
IDC %	%	15%	15%	15%	15%

DOGF: High path gas	2013	2020	2028	2040
Pre-FID	22.08	22.08	22.08	22.08
Pipelines	6.90	6.70	6.36	5.99
Platforms	142.60	138.36	131.54	123.81
Wells	47.15	45.75	43.49	40.53
MMV	0.00	0.00	0.00	0.00
Abandonment	86.25	77.06	65.23	54.66
Throughput CO2	2.00	3.00	4.00	4.00
Amortisation period	15	25	39	40
Annual OPEX%	6.0%	5.0%	4.5%	4.5%
PMT rate	10%	10%	10%	10%
IDC %	15%	15%	15%	15%

DOGF: Adjusted coal		2013	2020	2028	2040
Pre-FID	£m	19.20	19.20	19.20	
Pipelines	£m	6.00	5.36	4.54	
Platforms	£m	124.00	110.84	93.86	
Wells	£m	41.00	36.65	31.03	
MMV	£m	0.00	0.00	0.00	
Abandonment	£m	75.00	58.93	46.30	
Throughput CO2	mtpa	2	4	5	
Amortisation period	years	15	25	25	
Annual OPEX%	%	6.0%	5.0%	4.5%	
PMT rate	%	15%	14%	12%	
IDC %	%	15%	15%	15%	

DOGF: Adjusted gas	2013	2020	2028	2040
Pre-FID	19.20	19.20	19.20	
Pipelines	6.00	5.36	4.54	
Platforms	124.00	110.84	93.86	
Wells	41.00	36.65	31.03	
MMV	0.00	0.00	0.00	
Abandonment	75.00	58.93	46.30	
Throughput CO2	1	2	5	
Amortisation period	15	25	25	
Annual OPEX%	6.0%	5.0%	4.5%	
PMT rate	15%	14%	13%	
IDC %	15%	15%	15%	

ANNEX B – CONSOLIDATED LIST OF CANDIDATE ACTIONS

B.1 Section 2.1: Landscape

- Development of CCS could benefit from a planning framework that has an assumption that CCS will be needed, rather than that CCS might be needed.
- Consider work on an optimal strategy for locating CCS, to optimise fuel transport, electricity transport and CO_2 transport across the UK.

B.2 Section 3.1: Optimal scale in transport and storage

- Consider how to ensure that the configuration of the transport system for early projects takes into account likely future developments of the CO_2 pipeline network, in order to minimise long-run average costs.
- Future projects need to build on opportunities created by early projects to achieve cost savings through storage hubs.
- Consider how to ensure contracts and licences can be structured flexibly enough to allow CO_2 to be injected into alternative stores by agreement between storage owners.

B.3 Section 3.2: Characterisation of storage

- Consider further work to be undertaken to examine the options for a more or less coordinated approach to developing transport and storage of CO_2 in the Central and Southern North Sea, and to recommend a way forward.

B.4 Section 3.3: Regulatory framework

- Assess what future development of the regulatory regime is required to deliver CCS projects, including guidance on whether access by third parties to storage is required.

B.5 Section 4.1: Optimal scale of generation and capture unit size

- Projects developed in the UK following those arising from the Commercialisation Programme should be of a size much closer to the full size unabated plants available, in order to capture the economies of scale that should then be available.

B.6 Section 4.2: Optimisation of early designs and reducing engineering redundancies

- Ensure that any constraints (e.g. CO_2 specifications), design requirements (e.g. capture percentage limits) or performance objectives (e.g. minimisation of cost of electricity generation) are set with the intended and unintended consequences of these limits clearly understood and agreed.
- A proper dialogue needs to occur between the project developer, plant designer and supplier of critical equipment to ensure that the optimal balance between scale risk, equipment redundancy, design margins and required availability is achieved.
- The benefits and downsides of integration should be examined from the experience of all early projects, worldwide, in order to incorporate this experience into future designs.

B.7 Section 4.5: Next generation capture technologies

- R&D funding for future technologies should continue from all sides to create cost reductions beyond the incremental reductions available from existing technology.

B.8 Section 5.1: De-risking the CCS chain

- Consider how the business model for CCS in the UK should migrate away from early end-to-end full chain projects to projects more suited to cluster development.

B.9 Section 5.2: Ensuring funding mechanisms are fit for purpose

- Continue work to develop the CfD structure, and other relevant EMR instruments, with a view to their widespread use in CCS projects.

B.10 Section 5.3: Continued involvement from financial and insurance sectors

- Keep a variety of financial institutions, analysts and insurance companies engaged in CCS such that they:
  - nderstand and gain comfort with the full chain of CCS, its technical characteristics and the financing mechanisms in place;
  - n correctly analyse risks and risk mitigation options; and
  - n work with the industry to provide the financial structuring expertise required to fund the anticipated growth of the industry in an efficient manner.

B.11 Section 6.1: Encouraging EOR

- Stakeholders to work together to consider what measures could encourage CO_2 EOR in the UK.

B.12 Section 6.2: Industrial CCS

- Investigate options to incentive the development of industrial CCS projects.

B.13 Section 6.4: Wider Energy System Benefits

- Develop work to examine how CCS can operate to deliver flexible rather than base-load electricity generation.

ANNEX C – COST REDUCTION TASK FORCE

C.1 Task Force Membership

- Alstom
- Air Liquide
- AMEC
- CCSA
- CCS TLM
- CO_2DeepStore
- Costain
- E.On
- Ecofin
- ETI
- Gassnova
- National Grid Carbon
- Norton Rose
- Progressive Energy
- SSE
- Scottish Government
- Scottish Enterprise/IPA
- SCCS
- Shell
- Societe Generale
- Statoil
- TCM
- The Crown Estate

Additional Task Force Contributions

- Zurich
- Element Energy
- BGS
- 2CO
- BNP Paribas
- RBS
- Doosan Babcock

Report Sponsors

- The Crown Estate
- CCSA
- DECC

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C.2 Task Force Terms of Reference

The Carbon Capture and Storage (CCS) Cost Reduction Task Force is an industry-led joint task force established by Government to assist with the challenge of making CCS commercially available for operation by the early 2020s.

The Government is reforming the electricity market with the aim of providing a framework that will facilitate low carbon investment, including in CCS. The Government's objective is to have competition between low carbon generation technologies in the 2020s with the market deciding which of the competing technologies delivers the most cost-effective mix of supply and ensures a balanced electricity system. If CCS-equipped power stations are to play a significant role in the electricity market they will need to be cost-competitive with these other technologies.

In the industrial sector CCS provides one of the main opportunities for significant emissions reduction to mitigate the increasing cost of carbon. Cost reduction is essential to ensure that the UK industrial sector can be decarbonised at least cost and remains competitive.

The Government has launched a CCS Commercialisation Programme with £1bn in capital funding which aims to support practical experience in the design, construction and operation of commercial scale CCS. To avoid any conflicts of interest the Task Force will not advise the Government on development of that programme.

Objective

The objective of the Task Force is to publish a report to advise Government and industry on reducing the cost of CCS so that projects are financeable and competitive with other low carbon technologies in the early 2020s.

Key Activities

The Task Force will:

A. identify and quantify the key cost components of CCS and the key cost reduction opportunities;

B. describe routes to realising these cost reductions and the actions required from industry and Government;

C. seek commitment from industry on initiatives to reduce cost and the steps Government could take to establish the right market framework and incentives to encourage industry to invest; and

D. Present to DECC Ministers:

   i. Interim findings, by Autumn 2012, setting out the opportunity and the planned programme of work; and

   ii. A final report, in early 2013, setting out findings and recommendations for action by Government and industry.

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CSLF Technical Group Action Plan, 2011-2016

Action Plan 1: Technology Gaps Closure

Action: The Technical Group will identify and monitor key CCS technology gaps and related issues and recommend any R&D and demonstration activities that address these gaps and issues.

Outcome: Identification of all key technology gaps/issues and determination of the effectiveness of ongoing CCS RD&D for addressing these gaps/issues.

Status: Task Force formed.

Action Plan 2: Best-Practice Knowledge Sharing

Action: The Technical Group will facilitate the sharing of knowledge, information, and lessons learned from CSLF-recognized projects and other CCS RD&D.

Outcome: Development of interactive references for assisting next-generation commercial CCS projects, which will include links with other CCS entities.

Status: Deferred due to GCCSI activity in this area.

Action Plan 3: Energy Penalty Reduction

Action: The Technical Group will identify technological progress and any new research needs for reducing the energy penalty for CCS, both for traditional CO_2 capture processes and new breakthrough technologies.

Outcome: Identification of opportunities for process improvements and increased efficiency from experiences of "early mover" projects.

Status: Deferred pending review of United Kingdom DECC report in this area.

Action Plan 4: CCS with Industrial Emissions Sources

Action: The Technical Group will document the progress and application of CCS for industrial emissions sources and will identify demonstration opportunities for CSLF Members.

Outcome: Identification of opportunities for CCS with industrial sources. Identification and attempted resolution of technology-related issues (including integration) unique to this type of application.

Status: Deferred pending completion of Clean Energy Ministerial report in this area.

Action Plan 5: CO_2 Compression and Transport

Action: The Technical Group will review technologies and assess pipeline standards for CO_2 transport, in particular in relation to impurities in the CO_2 stream. Issues such as thermodynamics, fluid dynamics, and materials of construction, will be considered. Alternatives to pipelines, such as ship transport, will also be assessed.

Outcome: Identification of optimum technical CO_2 transport strategies, both for pipeline and non-pipeline alternatives. Assessment of purity issues as they apply to CO_2 transport. Identification of optimal compression options and alternatives.

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Action Plan 6: Reviewing Best Practices and Standards for Geologic Storage and Monitoring of CO_2

Action: The Technical Group will identify and review standards for CO_2 storage and monitoring.

Outcome: Identification of standards for storage and monitoring of injected CO_2. The application of such standards should inform CO_2 crediting mechanisms.

Status: Task Force formed. Report for Year 2012 issued.

Action Plan 7: Technical Challenges for Conversion of CO_2-EOR to CCS

Action: The Technical Group will determine technical and economic aspects that can affect moving from enhanced oil recovery (EOR) to carbon storage.

Outcome: Identification of permitting, monitoring, and reporting requirements for CO_2 EOR applications that apply for CO_2 credits.

Status: Task Force formed.

Action Plan 8: Competition of CCS with Other Resources

Action: The Technical Group will examine criteria for assessing competing development priorities between CCS (particularly CO_2 storage) and other economic resources.

Outcome: Identification of criteria for determining relative economic viability of CO_2 storage sites.

Status: Deferred pending review of IEA GHG report in this area.

Action Plan 9: Life Cycle Assessment and Environmental Footprint of CCS

Action: The Technical Group will identify and review methodologies for Life Cycle Assessment (LCA) for CCS, including life cycle inventory analysis, life cycle impact assessment, and interpretation of results.

Outcome: Identification of criteria for determining the full range of environmental effects for CCS technologies.

Action Plan 10: Risk and Liability

Action: The Technical Group will identify and assess links between technology-related risks and liability.

Outcome: Identification of guidelines for addressing long-term technology-related risks with respect to potential liabilities.

Status: Canceled. Policy Group task force has been formed to investigate this area.

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Action Plan 11: Carbon-neutral and Carbon-negative CCS

Action: The Technical Group will investigate technical challenges in use of CCS with power plants that utilize biomass (either pure or co-fired), to determine a pathway toward carbon-neutral or carbon-negative functionality.

Outcomes: Identification of issues and challenges for use of CCS with biomass-fueled power plants.

Action Plan 12: CO_2 Utilization Options

Action: The Technical Group will investigate CO_2 utilization options.

Outcome: Identification of most economically attractive CO_2 utilization options.

Status: Task Force formed. Phase 1 report issued.

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Carbon Sequestration Leadership Forum

www.cslforum.org

CHARTER FOR THE CARBON SEQUESTRATION LEADERSHIP FORUM (CSLF) A CARBON CAPTURE AND STORAGE TECHNOLOGY INITIATIVE

The undersigned national governmental entities (collectively the "Members") set forth the following revised Terms of Reference for the Carbon Sequestration Leadership Forum (CSLF), a framework for international cooperation in research, development demonstration and commercialization for the separation, capture, transportation, utilization and storage of carbon dioxide. The CSLF seeks to realize the promise of carbon capture utilization and storage (CCUS) over the coming decades, ensuring it to be commercially competitive and environmentally safe.

1. Purpose of the CSLF

To accelerate the research, development, demonstration, and commercial deployment of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage or utilization; to make these technologies broadly available internationally; and to identify and address wider issues relating to CCUS. This could include promoting the appropriate technical, political, economic and regulatory environments for the research, development, demonstration, and commercial deployment of such technology.

2. Function of the CSLF

The CSLF seeks to:

2.1 Identify key obstacles to achieving improved technological capacity;

2.2 Identify potential areas of multilateral collaborations on carbon separation, capture, utilization, transport and storage technologies;

2.3 Foster collaborative research, development, and demonstration (RD&D) projects reflecting Members' priorities;

2.4 Identify potential issues relating to the treatment of intellectual property;

2.5 Establish guidelines for the collaborations and reporting of their results;

2.6 Assess regularly the progress of collaborative RD&D projects and make recommendations on the direction of such projects;

2.7 Establish and regularly assess an inventory of the potential RD&D needs and gaps;

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2.8 Organize collaboration with the international stakeholder community, including industry, academia, financial institutions, government and non-government organizations; the CSLF is also intended to complement ongoing international cooperation;

2.9 Disseminate information and foster knowledge-sharing, in particular among members' demonstration projects;

2.10 Build the capacity of Members;

2.11 Conduct such other activities to advance achievement of the CSLF's purpose as the Members may determine;

2.12 Consult with and consider the views and needs of stakeholders in the activities of the CSLF;

2.13 Initiate and support international efforts to explain the value of CCUS, and address issues of public acceptance, legal and market frameworks and promote broad-based adoption of CCUS; and

2.14 Support international efforts to promote RD&D and capacity building projects in developing countries.

3. Organization of the CSLF

3.1 A Policy Group and a Technical Group oversee the management of the CSLF. Unless otherwise determined by consensus of the Members, each Member will make up to two appointments to the Policy Group and up to two appointments to the Technical Group.

3.2 The CSLF operates in a transparent manner. CSLF meetings are open to stakeholders who register for the meeting.

3.3 The Policy Group governs the overall framework and policies of the CSLF, periodically reviews the program of collaborative projects, and provides direction to the Secretariat. The Group should meet at least once a year, at times and places to be determined by its appointed representatives. All decisions of the Group will be made by consensus of the Members.

3.4 The Technical Group reports to the Policy Group. The Technical Group meets as often as necessary to review the progress of collaborative projects, identify promising directions for the research, and make recommendations to the Policy Group on needed actions.

3.5 The CSLF meets at such times and places as determined by the Policy Group. The Technical Group and Task Forces will meet at times that they decide in coordination with the Secretariat.

3.6 The principal coordinator of the CSLF's communications and activities is the CSLF Secretariat. The Secretariat: (1) organizes the meetings of the CSLF and its sub-groups, (2) arranges special activities such as teleconferences and workshops, (3) receives and forwards new membership requests to the Policy Group, (4)

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coordinates communications with regard to CSLF activities and their status, (5) acts as a clearing house of information for the CSLF, (6) maintains procedures for key functions that are approved by the Policy Group, and (7) performs such other tasks as the Policy Group directs. The focus of the Secretariat is administrative. The Secretariat does not act on matters of substance except as specifically instructed by the Policy Group.

3.7 The Secretariat may, as required, use the services of personnel employed by the Members and made available to the Secretariat. Unless otherwise provided in writing, such personnel are remunerated by their respective employers and will remain subject to their employers' conditions of employment.

3.8 The U.S. Department of Energy acts as the CSLF Secretariat unless otherwise decided by consensus of the Members.

3.9 Each Member individually determines the nature of its participation in the CSLF activities.

4 Membership

4.1 This Charter, which is administrative in nature, does not create any legally binding obligations between or among its Members. Each Member should conduct the activities contemplated by this Charter in accordance with the laws under which it operates and the international instruments to which its government is a party.

4.2 The CSLF is open to other national governmental entities and its membership will be decided by the Policy Group.

4.3 Technical and other experts from within and without CSLF Member organizations may participate in RD&D projects conducted under the auspices of the CSLF. These projects may be initiated either by the Policy Group or the Technical Group.

5 Funding

Unless otherwise determined by the Members, any costs arising from the activities contemplated by this Charter are to be borne by the Member that incurs them. Each Member's participation in CSLF activities is subject to the availability of funds, personnel and other resources.

6 Open Research and Intellectual Property

6.1 To the extent practicable, the RD&D fostered by the CSLF should be open and nonproprietary.

6.2 The protection and allocation of intellectual property, and the treatment of proprietary information, generated in RD&D collaborations under CSLF auspices should be defined by written implementing arrangements between the participants therein.

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7. Commencement, Modification, Withdrawal, and Discontinuation

7.1 Commencement and Modification

7.1.1 Activities under this Charter may commence on June 25, 2003. The Members may, by unanimous consent, discontinue activities under this Charter by written arrangement at any time.

7.1.2 This Charter may be modified in writing at any time by unanimous consent of all Members.

7.2 Withdrawal and Discontinuation

A Member may withdraw from membership in the CSLF by giving 90 days advance written notice to the Secretariat.

8. Counterparts

This Charter may be signed in counterpart.

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CARBON SEQUESTRATION LEADERSHIP FORUM
TERMS OF REFERENCE AND PROCEDURES

These Terms of Reference and Procedures provide the overall framework to implement the Charter of the Carbon Sequestration Leadership Forum (CSLF). They define the organization of the CSLF and provide the rules under which the CSLF will operate.

1. Organizational Responsibilities

1.1. Policy Group. The Policy Group will govern the overall framework and policies of the CSLF in line with Article 3.2 of the CSLF Charter. The Policy Group is responsible for carrying out the following functions of the CSLF as delineated in Article 2 of the CSLF Charter:

- Identify key legal, regulatory, financial, public perception, institutional-related or other issues associated with the achievement of improved technological capacity.
- Identify potential issues relating to the treatment of intellectual property.
- Establish guidelines for the collaborations and reporting of results.
- Assess regularly the progress of collaborative projects and following reports from the Technical Group make recommendations on the direction of such projects.
- Ensure that CSLF activities complement ongoing international cooperation in this area.
- Consider approaches to address issues associated with the above functions.

In order to implement Article 3.2 of the CSLF Charter, the Policy Group will:

- Review all projects for consistency with the CSLF Charter.
- Consider recommendations of the Technical Group for appropriate action.
- Annually review the overall program of the Policy and Technical Groups and each of their activities.
- Periodically review the Terms of Reference and Procedures.

The Chair of the Policy Group will provide information and guidance to the Technical Group on required tasks and initiatives to be undertaken based upon decisions of the Policy Group. The Chair of the Policy Group will also arrange for appropriate exchange of information between both the Policy Group and the Technical Group.

1.2. Technical Group. The Technical Group will report to the Policy Group and make recommendations to the Policy Group on needed actions in line with Article 3.3 of the CSLF Charter. The Technical Group is responsible for carrying out the following functions of the CSLF as delineated in Article 2 of the CSLF Charter:

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- Identify key technical, economic, environmental and other issues related to the achievement of improved technological capacity.
- Identify potential areas of multilateral collaboration on carbon capture, transport and storage technologies.
- Foster collaborative research, development, and demonstration (RD&D) projects reflecting Members' priorities.
- Assess regularly the progress of collaborative projects and make recommendations to the Policy Group on the direction of such projects.
- Establish and regularly assess an inventory of the potential areas of needed research.
- Facilitate technical collaboration with all sectors of the international research community, academia, industry, government and non-governmental organizations.
- Consider approaches to address issues associated with the above functions.

In order to implement Article 3.2 of the CSLF Charter, the Technical Group will:

- Recommend collaborative projects to the Policy Group.
- Set up and keep procedures to review the progress of collaborative projects.
- Follow the instructions and guidance of the Policy Group on required tasks and initiatives to be undertaken.

1.3. Secretariat. The Secretariat will carry out those activities enumerated in Section 3.5 of the CSLF Charter. The role of the Secretariat is administrative and the Secretariat acts on matters of substance as specifically instructed by the Policy Group. The Secretariat will review all Members material submitted for the CSLF web site and suggest modification where warranted. The Secretariat will also clearly identify the status and ownership of the materials.

2. Additions to Membership

2.1. Application.

Pursuant to Article 4 of the CSLF Charter, national governmental entities may apply for membership to the CSLF by writing to the Secretariat. A letter of application should be signed by the responsible Minister from the applicant country. In their application letter, prospective Members should:

1) demonstrate they are a significant producer or user of fossil fuels that have the potential for carbon capture;
2) describe their existing national vision and/or plan regarding carbon capture and storage (CCS) technologies;
3) describe an existing national commitment to invest resources on research, development and demonstration activities in CCS technologies;
4) describe their commitment to engage the private sector in the development and deployment of CCS technologies; and
5) describe specific projects or activities proposed for being undertaken within the frame of the CSLF.

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The Policy Group will address new member applications at the Policy Group Meetings.

2.2. Offer. If the Policy Group approves the application, membership will then be offered to the national governmental entity that submitted the application.

2.3. Acceptance. The applicant national governmental entity may accept the offer of membership by signing the Charter in Counterpart and delivering such signature to the embassy of the Secretariat. A notarized “true copy” of the signed document is acceptable in lieu of the original. The nominated national governmental entity to which an offer has been extended becomes a Member upon receipt by the Secretariat of the signed Charter.

3. CSLF Governance

3.1. Appointment of Members’ Representatives. Members may make appointments and/or replacements to the Policy Group and Technical Group at any time pursuant to Article 3.1 of the CSLF Charter by notifying the Secretariat. The Secretariat will acknowledge such appointment to the Member and keep an up-to-date list of all Policy Group and Technical Group representatives on the CSLF web site.

3.2. Meetings.

(a) The Policy Group should meet at least once each year at a venue and date selected by a decision of the Members.

(b) Ministerial meetings will normally be held approximately every other year. Ministerial meetings will review the overall progress of CSLF collaboration, findings, and accomplishments on major carbon capture and storage issues and provide overall direction on priorities for future work.

(c) The Technical Group will meet as often as necessary and at least once each year at a considered time interval prior to the meeting of the Policy Group.

(d) Meetings of the Policy Group or Technical Group may be called by the respective Chairs of those Groups after consultation with the members.

(e) The Policy and Technical Groups may designate observers and resource persons to attend their respective meetings. CSLF Members may bring other individuals, as indicated in Article 3.1 of the CSLF Charter, to the Policy and Technical Group meetings with prior notice to the Secretariat. The Chair of the Technical Group and whomever else the Technical Group designates may be observers at the Policy Group meeting.

(f) The Secretariat will produce minutes for each of the meetings of the Policy Group and the Technical Group and provide such minutes to all the Members’ representatives to the appropriate Group within thirty (30) days of the meeting. Any materials to be considered by Members of the Policy or Technical Groups will be made available to the Secretariat for distribution thirty (30) days prior to meetings.

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3.3. Organization of the Policy and Technical Groups

(a) The Policy Group and the Technical Group will each have a Chair and up to three Vice Chairs. The Chairs of the Policy and Technical Groups will be elected every three years.

1) At least 3 months before a CSLF decision is required on the election of a Chair or Vice Chair a note should be sent from the Secretariat to CSLF Members asking for nominations. The note should contain the following:

   Nominations should be made by the heads of delegations. Nominations should be sent to the Secretariat. The closing date for nominations should be six weeks prior to the CSLF decision date.

2) Within one week after the closing date for nominations, the Secretariat should post on the CSLF website and email to Policy and Technical Group delegates as appropriate the names of Members nominated and identify the Members that nominated them.
3) As specified by Article 3.2 of the CSLF Charter, the election of Chair and Vice- Chairs will be made by consensus of the Members.
4) When possible, regional balance and emerging economy representation among the Chairs and Vice Chairs should be taken into consideration by Members.

(b) Task Forces of the Policy Group and Technical Group consisting of Members' representatives and/or other individuals may be organized to perform specific tasks as agreed by a decision of the representatives at a meeting of that Group. Meetings of Task Forces of the Policy or Technical Group will be set by those Task Forces.

(c) The Chairs of the Policy Group and the Technical Group will have the option of presiding over the Groups' meetings. Task force leaders will be appointed by a consensus of the Policy and Technical Groups on the basis of recommendations by individual Members. Overall direction of the Secretariat is the responsibility of the Chair of the Policy Group. The Chair of the Technical Group may give such direction to the Secretariat as is relevant to the operations of the Technical Group.

3.4. Decision Making. As specified by Article 3.2 of the CSLF Charter, all decisions will be made by consensus of the Members.

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4. CSLF Projects

4.1. Types of Collaborative Projects. Collaborative projects of any type consistent with Article 1 of the CSLF Charter may be recognized by the CSLF as described below. This specifically includes projects that are indicative of the following:

- Information exchange and networking,
- Planning and road-mapping,
- Facilitation of collaboration,
- Research and development,
- Demonstrations, or
- Other issues as indicated in Article 1 of the CSLF Charter.

4.2. Project Recognition. All projects proposed for recognition by the CSLF shall be evaluated via a CSLF Project Submission Form. The CSLF Project Submission Form shall request from project sponsors the type and quantity of information that will allow the project to be adequately evaluated by the CSLF.

A proposal for project recognition can be submitted by any CSLF delegate to the Technical Group and must contain a completed CSLF Project Submission Form. In order to formalize and document the relationship with the CSLF, the representatives of the project sponsors and the delegates of Members nominating a project must sign the CSLF Project Submission Form specifying that relationship before the project can be considered.

The Technical Group shall evaluate all projects proposed for recognition. Projects that meet all evaluation criteria shall be recommended to the Policy Group. A project becomes recognized by the CSLF following approval by the Policy Group.

4.3. Information Availability from Recognized Projects. Non-proprietary information from CSLF-recognized projects, including key project contacts, shall be made available to the CSLF by project sponsors. The Secretariat shall have the responsibility of maintaining this information on the CSLF website.

5. Interaction with Stakeholders

It is recognized that stakeholders, those organizations that are affected by and can affect the goals of the CSLF, form an essential component of CSLF activities. Accordingly, the CSLF will engage stakeholders paying due attention to equitable access, effectiveness and efficiency and will be open, visible, flexible and transparent. In addition, CSLF members will continue to build and communicate with their respective stakeholder networks.

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Active and Completed CSLF Recognized Projects

(as of February 2013)

1. **Air Products CO_2 Capture from Hydrogen Facility Project**
   Nominators: United States (lead), Netherlands, and United Kingdom
   This is a large-scale commercial project, located in eastern Texas in the United States, which will demonstrate a state-of-the-art system to concentrate CO_2 from two steam methane reformer (SMR) hydrogen production plants, and purify the CO_2 to make it suitable for sequestration by injection into an oil reservoir as part of an ongoing CO_2 Enhanced Oil Recovery (EOR) project. The commercial goal of the project is to recover and purify approximately 1 million tonnes per year of CO_2 for pipeline transport to Texas oilfields for use in EOR. The technical goal is to capture at least 75% of the CO_2 from a treated industrial gas stream that would otherwise be emitted to the atmosphere. A financial goal is to demonstrate real-world CO_2 capture economics.
   Recognized by the CSLF at its Perth meeting, October 2012

2. **Alberta Enhanced Coal-Bed Methane Recovery Project** ***(Completed)***
   Nominators: Canada (lead), United States, and United Kingdom
   This pilot-scale project, located in Alberta, Canada, aimed at demonstrating, from both economic and environmental criteria, the overall feasibility of coal bed methane (CBM) production and simultaneous CO_2 storage in deep unmineable coal seams. Specific objectives of the project were to determine baseline production of CBM from coals; determine the effect of CO_2 injection and storage on CBM production; assess economics; and monitor and trace the path of CO_2 movement by geochemical and geophysical methods. All testing undertaken was successful, with one important conclusion being that flue gas injection appears to enhance methane production to a greater degree possible than with CO_2 while still sequestering CO_2, albeit in smaller quantities.
   Recognized by the CSLF at its Melbourne meeting, September 2004

3. **CANMET Energy Technology Centre (CETC) R&D Oxyfuel Combustion for CO_2 Capture**
   Nominators: Canada (lead) and United States
   This is a pilot-scale project, located in Ontario, Canada, that will demonstrate oxy-fuel combustion technology with CO_2 capture. The goal of the project is to develop energy-efficient integrated multi-pollutant control, waste management and CO_2 capture technologies for combustion-based applications and to provide information for the scale-up, design and operation of large-scale industrial and utility plants based on the oxy-fuel concept.
   Recognized by the CSLF at its Melbourne meeting, September 2004

4. **CarbonNet Project**
   Nominators: Australia (lead) and United States
   This is a large-scale project that will implement a large-scale multi-user CO_2 capture, transport, and storage network in southeastern Australia in the Latrobe Valley. Multiple

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industrial and utility point sources of CO_2 will be connected via a pipeline to a site where the CO_2 can be stored in depleted oil and gas fields in the offshore Gippsland Basin. The project initially plans to sequester approximately 1 to 5 million tonnes of CO_2 per year, with the potential to increase capacity significantly over time. The project will also include reservoir characterization and, once storage is underway, measurement, monitoring and verification (MMV) technologies.
Recognized by the CSLF at its Perth meeting, October 2012

5. **CASTOR** ***(Completed)***
Nominators: European Commission (lead), France, and Norway
This was a multifaceted project that had activities at various sites in Europe, in three main areas: strategy for CO_2 reduction, post-combustion capture, and CO_2 storage performance and risk assessment studies. The goal was to reduce the cost of post-combustion CO_2 capture and to develop and validate, in both public and private partnerships, all the innovative technologies needed to capture and store CO_2 in a reliable and safe way. The tests showed the reliability and efficiency of the post-combustion capture process.
Recognized by the CSLF at its Melbourne meeting, September 2004

6. **CCS Bełchatów Project**
Nominators: Poland (lead), European Commission, and United States
This is a large-scale project, located in central Poland, which will demonstrate commercial-scale CO_2 capture, transport and storage at a new lignite-fired power plant unit. The project will demonstrate the full CCS value chain, including capture, transport, and safe geological storage of up to 1.8 million tonnes of CO_2 per year. Project components include identification of potential issues related to intellectual property, storage site selection, permitting, facilities and pipeline construction, and public engagement activities. Success of this project will expedite commercialization of CCS for large-scale fossil fuel power generation.
Recognized by the CSLF at its Warsaw meeting, October 2010

7. **CCS Rotterdam Project**
Nominators: Netherlands (lead) and Germany
This project will implement a large-scale “CO_2 Hub” for capture, transport, utilization, and storage of CO_2 in the Rotterdam metropolitan area. The project is part of the Rotterdam Climate Initiative (RCI), which has a goal of reducing Rotterdam’s CO_2 emissions by 50% by 2025 (as compared to 1990 levels). A “CO_2 cluster approach” will be utilized, with various point sources (e.g., CO_2 captured from power plants) connected via a hub / manifold arrangement to multiple storage sites such as depleted gas fields under the North Sea. This will reduce the costs for capture, transport and storage compared to individual CCS chains. The project will also work toward developing a policy and enabling framework for CCS in the region.
Recognized by the CSLF at its London meeting, October 2009

8. **CGS Europe Project**
Nominators: Netherlands (lead) and Germany
This is a collaborative venture, involving 35 partners from participant countries in Europe, with extensive structured networking, knowledge transfer, and information exchange. A goal of the project is to create a durable network of experts in CO_2 geological storage and a centralized knowledge base which will provide an independent source of information for European and international stakeholders. The CGS Europe Project is intended to provide an information pathway toward large-scale implementation of CO_2 geological

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storage throughout Europe. This is intended to be a three-year project, starting in November 2011, and has received financial support from the European Commission's 7th Framework Programme (FP7).
Recognized by the CSLF at its Beijing meeting, September 2011

9. China Coalbed Methane Technology/CO_2 Sequestration Project ***(Completed)***
Nominators: Canada (lead), United States, and China
This pilot-scale project successfully demonstrated that coal seams in the anthracitic coals of Shanxi Province of China are permeable and stable enough to absorb CO_2 and enhance methane production, leading to a clean energy source for China. The project evaluated reservoir properties of selected coal seams of the Qinshui Basin of eastern China and carried out field testing at relatively low CO_2 injection rates. The project recommendation was to proceed to full scale pilot test at south Qinshui, as the prospect in other coal basins in China is good.
Recognized by the CSLF at its Berlin meeting, September 2005

10. CO_2 Capture Project – Phase 2 ***(Completed)***
Nominators: United Kingdom (lead), Italy, Norway, and United States
This pilot-scale project continued the development of new technologies to reduce the cost of CO_2 separation, capture, and geologic storage from combustion sources such as turbines, heaters and boilers. These technologies will be applicable to a large fraction of CO_2 sources around the world, including power plants and other industrial processes. The ultimate goal of the entire project is to reduce the cost of CO_2 capture from large fixed combustion sources by 20-30%, while also addressing critical issues such as storage site/project certification, well integrity and monitoring.
Recognized by the CSLF at its Melbourne meeting, September 2004

11. CO_2 Capture Project – Phase 3
Nominators: United Kingdom (lead) and United States
This is a collaborative venture of seven partner companies (international oil and gas producers) plus the Electric Power Research Institute. The overall goals of the project are to increase technical and cost knowledge associated with CO_2 capture technologies, to reduce CO_2 capture costs by 20-30%, to quantify remaining assurance issues surrounding geological storage of CO_2, and to validate cost-effectiveness of monitoring technologies. The project is comprised of four areas: CO_2 Capture; Storage Monitoring & Verification; Policy & Incentives; and Communications. A fifth activity, in support of these four teams, is Economic Modeling. This third phase of the project will include at least two field demonstrations of CO_2 capture technologies and a series of monitoring field trials in order to obtain a clearer understanding of how to monitor CO_2 in the subsurface. Third phase activities began in 2009 and are expected to continue into 2013. Financial support is being provided by project consortium members.
Recognized by the CSLF at its Beijing meeting, September 2011

12. CO2CRC Otway Project
Nominators: Australia (lead) and United States
This is a pilot-scale project, located in southwestern Victoria, Australia, that involves transport and injection of approximately 100,000 tons of CO_2 over a two year period into a depleted natural gas well. Besides the operational aspects of processing, transport and injection of a CO_2-containing gas stream, the project also includes development and testing of new and enhanced monitoring, and verification of storage (MMV) technologies, modeling of post-injection CO_2 behavior, and implementation of an outreach program for

stakeholders and nearby communities. Data from the project will be used in developing a future regulatory regime for CO_2 capture and storage (CCS) in Australia.
Recognized by the CSLF at its Paris meeting, March 2007

13. CO_2 Field Lab Project
Nominators: Norway (lead), France, and United Kingdom
This is a pilot-scale project, located at Svelvik, Norway, which will investigate CO_2 leakage characteristics in a well-controlled and well-characterized permeable geological formation. Relatively small amounts of CO_2 will be injected to obtain underground distribution data that resemble leakage at different depths. The resulting underground CO_2 distribution will resemble leakages and will be monitored with an extensive set of methods deployed by the project partners. The main objective is to assure and increase CO_2 storage safety by obtaining valuable knowledge about monitoring CO_2 migration and leakage. The outcomes from this project will help facilitate commercial deployment of CO_2 storage by providing the protocols for ensuring compliance with regulations, and will help assure the public about the safety of CO_2 storage by demonstrating the performance of monitoring systems.
Recognized by the CSLF at its Warsaw meeting, October 2010

14. CO_2 GeoNet
Nominators: European Commission (lead) and United Kingdom
This multifaceted project is focused on geologic storage options for CO_2 as a greenhouse gas mitigation option, and on assembling an authoritative body for Europe on geologic sequestration. Major objectives include formation of a partnership consisting, at first, of 13 key European research centers and other expert collaborators in the area of geological storage of CO_2, identification of knowledge gaps in the long-term geologic storage of CO_2, and formulation of new research projects and tools to eliminate these gaps. This project will result in re-alignment of European national research programs and prevention of site selection, injection operations, monitoring, verification, safety, environmental protection, and training standards.
Recognized by the CSLF at its Berlin meeting, September 2005

15. CO_2 Separation from Pressurized Gas Stream
Nominators: Japan (lead) and United States
This is a small-scale project that will evaluate processes and economics for CO_2 separation from pressurized gas streams. The project will evaluate primary promising new gas separation membranes, initially at atmospheric pressure. A subsequent stage of the project will improve the performance of the membranes for CO_2 removal from the fuel gas product of coal gasification and other gas streams under high pressure.
Recognized by the CSLF at its Melbourne meeting, September 2004

16. CO_2 STORE ***(Completed)***
Nominators: Norway (lead) and European Commission
This project, a follow-on to the Sleipner project, involved the monitoring of CO_2 migration (involving a seismic survey) in a saline formation beneath the North Sea and additional studies to gain further knowledge of geochemistry and dissolution processes. There were also several preliminary feasibility studies for additional geologic settings of future candidate project sites in Denmark, Germany, Norway, and the UK. The project was successful in developing sound scientific methodologies for the assessment, planning, and long-term monitoring of underground CO_2 storage, both onshore and offshore.
Recognized by the CSLF at its Melbourne meeting, September 2004

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17. CO_2 Technology Centre Mongstad Project (formerly European CO_2 Technology Centre Mongstad Project)

Nominators: Norway (lead) and Netherlands

This is a large-scale project (100,000 tonnes per year CO_2 capacity) that will establish a facility for parallel testing of amine-based and chilled ammonia CO_2 capture technologies from two flue gas sources with different CO_2 contents. The goal of the project is to reduce cost and technical, environmental, and financial risks related to large scale CO_2 capture, while allowing evaluation of equipment, materials, process configurations, different capture solvents, and different operating conditions. The project will result in validation of process and engineering design for full-scale application and will provide insight into other aspects such as thermodynamics, kinetics, engineering, materials of construction, and health / safety / environmental (HSE).

Recognized by the CSLF at its London meeting, October 2009

18. Demonstration of an Oxyfuel Combustion System ***(Completed)***

Nominators: United Kingdom (lead) and France

This project, located at Renfrew, Scotland, UK, demonstrated oxyfuel technology on a full-scale 40-megawatt burner. The goal of the project was to gather sufficient data to establish the operational envelope of a full-scale oxyfuel burner and to determine the performance characteristics of the oxyfuel combustion process at such a scale and across a range of operating conditions. Data from the project is being used to develop advanced computer models of the oxyfuel combustion process, which will be utilized in the design of large oxyfuel boilers.

Recognized by the CSLF at its London meeting, October 2009

19. Dynamis ***(Completed)***

Nominators: European Commission (lead), and Norway

This was the first phase of the multifaceted European Hypogen program, which will result in the construction and operation of an advanced commercial-scale power plant with hydrogen production and CO_2 management. The overall aim is for operation and validation of the power plant during the 2012-2015 timeframe. The Dynamis project assessed the various options for large-scale hydrogen production while focusing on the technological, economic, and societal issues.

Recognized by the CSLF at its Cape Town meeting, April 2008

20. ENCAP ***(Completed)***

Nominators: European Commission (lead), France, and Germany

This multifaceted research project consisted of six sub-projects: Process and Power Systems, Pre-Combustion Decarbonization Technologies, O_2/ CO_2 Combustion (Oxy-fuel) Boiler Technologies, Chemical Looping Combustion (CLC), High-Temperature Oxygen Generation for Power Cycles, and Novel Pre-Combustion Capture Concepts. The goals were to develop promising pre-combustion CO_2 capture technologies (including O_2/ CO_2 combustion technologies) and propose the most competitive demonstration power plant technology, design, process scheme, and component choices. All sub-projects were successfully completed by March 2009.

Recognized by the CSLF at its Berlin meeting, September 2005

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21. Fort Nelson Carbon Capture and Storage Project

Nominators: Canada (lead) and United States

This is a large-scale project in northeastern British Columbia, Canada, which will permanently sequester approximately two million tonnes per year CO_2 emissions from a large natural gas-processing plant into deep saline formations of the Western Canadian Sedimentary Basin (WCSB). Goals of the project are to verify and validate the technical and economic feasibility of using brine-saturated carbonate formations for large-scale CO_2 injection and demonstrate that robust monitoring, verification, and accounting (MVA) of a brine-saturated CO_2 sequestration project can be conducted cost-effectively. The project will also develop appropriate tenure, regulations, and MVA technologies to support the implementation of future large-scale sour CO_2 injection into saline-filled deep carbonate reservoirs in the northeast British Columbia area of the WCSB.

Recognized by the CSLF at its London meeting, October 2009

22. Frio Project ***(Completed)***

Nominators: United States (lead) and Australia

This pilot-scale project demonstrated the process of CO_2 sequestration in an on-shore underground saline formation in Eastern Texas, USA. This location was ideal, as very large scale sequestration may be needed in the area to significantly offset anthropogenic CO_2 releases. The project involved injecting relatively small quantities of CO_2 into the formation and monitoring its movement for several years thereafter. The goals were to verify conceptual models of CO_2 sequestration in such geologic structures; demonstrate that no adverse health, safety or environmental effects will occur from this kind of sequestration; demonstrate field-test monitoring methods; and develop experience necessary for larger scale CO_2 injection experiments.

Recognized by the CSLF at its Melbourne meeting, September 2004

23. Geologic CO_2 Storage Assurance at In Salah, Algeria

Nominators: United Kingdom (lead) and Norway

This multifaceted project will develop the tools, technologies, techniques and management systems required to cost-effectively demonstrate, safe, secure, and verifiable CO_2 storage in conjunction with commercial natural gas production. The goals of the project are to develop a detailed dataset on the performance of CO_2 storage; provide a field-scale example on the verification and regulation of geologic storage systems; test technology options for the early detection of low-level seepage of CO_2 out of primary containment; evaluate monitoring options and develop guidelines for an appropriate and cost-effective, long-term monitoring methodology; and quantify the interaction of CO_2 re-injection and hydrocarbon production for long-term storage in oil and gas fields.

Recognized by the CSLF at its Berlin meeting, September 2005

24. Gorgon CO_2 Injection Project

Nominators: Australia (lead), Canada, and United States

This is a large-scale project that will store approximately 120 million tonnes of CO_2 in a water-bearing sandstone formation two kilometers below Barrow Island, off the northwest coast of Australia. The CO_2 stored by the project will be extracted from natural gas being produced from the nearby Gorgon Field and injected at approximately 3.5 to 4 million tonnes per year. There is an extensive integrated monitoring plan, and the objective of the project is to demonstrate the safe commercial-scale application of greenhouse gas storage technologies at a scale not previously attempted. The project has already progressed through its early development stages including site selection and

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appraisal, and is fully funded. Injection operations are expected to commence by the end of 2014.
Recognized by the CSLF at its Warsaw meeting, October 2010

25. IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project ***(Completed)***
Nominators: Canada and United States (leads) and Japan
This is a large-scale project that will utilize CO_2 for enhanced oil recovery (EOR) at a Canadian oil field. The goal of the project is to determine the performance and undertake a thorough risk assessment of CO_2 storage in conjunction with its use in enhanced oil recovery. The work program will encompass four major technical themes of the project: geological integrity; wellbore injection and integrity; storage monitoring methods; and risk assessment and storage mechanisms. Results from these technical themes, when integrated with policy research, will result in a Best Practices Manual for future CO_2 Enhanced Oil Recovery projects.
Recognized by the CSLF at its Melbourne meeting, September 2004

26. Illinois Basin – Decatur Project
Nominators: United States (lead) and United Kingdom
This is a large-scale research project that will geologically store up to 1 million metric tons of CO_2 over a 3-year period. The CO_2 is being captured from the fermentation process used to produce ethanol at an industrial corn processing complex in Decatur, Illinois, in the United States. After three years, the injection well will be sealed and the reservoir monitored using geophysical techniques. Monitoring, verification, and accounting (MVA) efforts include tracking the CO_2 in the subsurface, monitoring the performance of the reservoir seal, and continuous checking of soil, air, and groundwater both during and after injection. The project focus is on demonstration of CCS project development, operation, and implementation while demonstrating CCS technology and reservoir quality.
Recognized by the CSLF at its Perth meeting, October 2012

27. Illinois Industrial Carbon Capture and Storage Project
Nominators: United States (lead) and France
This is a large-scale commercial project that will collect up to 3,000 tonnes per day of CO_2 for deep geologic storage. The CO_2 is being captured from the fermentation process used to produce ethanol at an industrial corn processing complex in Decatur, Illinois, in the United States. The goals of the project are to design, construct, and operate a new CO_2 collection, compression, and dehydration facility capable of delivering up to 2,000 tonnes of CO_2 per day to the injection site; to integrate the new facility with an existing 1,000 tonnes of CO_2 per day compression and dehydration facility to achieve a total CO_2 injection capacity of 3,000 tonnes per day (or one million tonnes annually); to implement deep subsurface and near-surface MVA of the stored CO_2; and to develop and conduct an integrated community outreach, training, and education initiative.
Recognized by the CSLF at its Perth meeting, October 2012

28. ITC CO_2 Capture with Chemical Solvents Project
Nominators: Canada (lead) and United States
This is a pilot-scale project that will demonstrate CO_2 capture using chemical solvents. Supporting activities include bench and lab-scale units that will be used to optimize the entire process using improved solvents and contactors, develop fundamental knowledge of solvent stability, and minimize energy usage requirements. The goal of the project is to

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develop improved cost-effective technologies for separation and capture of CO_2 from flue gas.
Recognized by the CSLF at its Melbourne meeting, September 2004

29. Ketzin Test Site Project (formerly CO_2 SINK) ***(Completed)***
Nominators: European Commission (lead) and Germany
This is a pilot-scale project that tested and evaluated CO_2 capture and storage at an existing natural gas storage facility and in a deeper land-based saline formation. A key part of the project was monitoring the migration characteristics of the stored CO_2. The project was successful in advancing the understanding of the science and practical processes involved in underground storage of CO_2 and provided real case experience for use in development of future regulatory frameworks for geological storage of CO_2.
Recognized by the CSLF at its Melbourne meeting, September 2004

30. Lacq Integrated CCS Project
Nominators: France (lead) and Canada
This is an intermediate-scale project that will test and demonstrate an entire integrated CCS process, from emissions source to underground storage in a depleted gas field. The project will capture and store 60,000 tonnes per year of CO_2 for two years from an oxyfuel industrial boiler in the Lacq industrial complex in southwestern France. The goal is demonstrate the technical feasibility and reliability of the integrated process, including the oxyfuel boiler, at an intermediate scale before proceeding to a large-scale demonstration. The project will also include geological storage qualification methodologies, as well as monitoring and verification techniques, to prepare future larger-scale long term CO_2 storage projects.
Recognized by the CSLF at its London meeting, October 2009

31. Quest CCS Project
Nominators: Canada (lead), United Kingdom, and United States
This is a large-scale project, located at Fort Saskatchewan, Alberta, Canada, with integrated capture, transportation, storage, and monitoring, which will capture and store up to 1.2 million tonnes per year of CO_2 from an oil sands upgrading unit. The CO_2 will be transported via pipeline and stored in a deep saline aquifer in the Western Sedimentary Basin in Alberta, Canada. This is a fully integrated project, intended to significantly reduce the carbon footprint of the commercial oil sands upgrading facility while developing detailed cost data for projects of this nature. This will also be a large-scale deployment of CCS technologies and methodologies, including a comprehensive measurement, monitoring and verification (MMV) program.
Recognized by the CSLF at its Warsaw meeting, October 2010

32. Regional Carbon Sequestration Partnerships
Nominators: United States (lead) and Canada
This multifaceted project will identify and test the most promising opportunities to implement sequestration technologies in the United States and Canada. There are seven different regional partnerships, each with their own specific program plans, which will conduct field validation tests of specific sequestration technologies and infrastructure concepts; refine and implement (via field tests) appropriate measurement, monitoring and verification (MMV) protocols for sequestration projects; characterize the regions to determine the technical and economic storage capacities; implement and continue to research the regulatory compliance requirements for each type of sequestration

technology; and identify commercially available sequestration technologies ready for large scale deployment.
Recognized by the CSLF at its Berlin meeting, September 2005

33. Regional Opportunities for CO_2 Capture and Storage in China ***(Completed)***
Nominators: United States (lead) and China
This project characterized the technical and economic potential of CO_2 capture and storage technologies in China. The goals were to compile key characteristics of large anthropogenic CO_2 sources (including power generation, iron and steel plants, cement kilns, petroleum and chemical refineries, etc.) as well as candidate geologic storage formations, and to develop estimates of geologic CO_2 storage capacities in China. The project found 2,300 gigatons of potential CO_2 storage capacity in onshore Chinese basins, significantly more than previous estimates. Another important finding is that the heavily developed coastal areas of the East and South Central regions appear to have less access to large quantities of onshore storage capacity than many of the inland regions. These findings present the possibility for China's continued economic growth with coal while safely and securely reducing CO_2 emissions to the atmosphere.
Recognized by the CSLF at its Berlin meeting, September 2005

34. Rotterdam Opslag en Afvang Demonstratieproject (ROAD)
Nominators: Netherlands (lead) and the European Commission
This is a large-scale integrated project, located near the city of Rotterdam, Netherlands, which includes CO_2 capture from a coal-fueled power plant, pipeline transportation of the CO_2, and offshore storage of the CO_2 in a depleted natural gas reservoir beneath the seabed of the North Sea (approximately 20 kilometers from the power plant). The goal of the project is to demonstrate the feasibility of a large-scale, integrated CCS project while addressing the various technical, legal, economic, organizational, and societal aspects of the project. ROAD will result in the capture and storage of approximately 1.1 million tonnes of CO_2 annually over a five year span starting in 2015. Subsequent commercial operation is anticipated, and there will be continuous knowledge sharing. This project has received financial support from the European Energy Programme for Recovery (EEPR), the Dutch Government, and the Global CCS Institute, and is a component of the Rotterdam Climate Initiative CO_2 Transportation Network.
Recognized by the CSLF at its Beijing meeting, September 2011

35. SaskPower Integrated CCS Demonstration Project at Boundary Dam Unit 3
Nominators: Canada (lead) and the United States
This is a large-scale project, located in the southeastern corner of Saskatchewan Province in Canada, which will be the first application of full stream CO_2 recovery from flue gas of a 139 megawatt coal-fueled power plant unit. A major goal is to demonstrate that a post-combustion CO_2 capture retrofit on a commercial power plant can achieve optimal integration with the thermodynamic power cycle and with power production at full commercial scale. The project will result in capture of approximately one million tonnes of CO_2 per year, which will be sold to oil producers for enhanced oil recovery (EOR) and injected into a deep saline aquifer. Commissioning of the reconfigured power plant unit is expected by early 2014. The project has received financial support from the Government of Canada and the Saskatchewan Provincial Government, and SaskPower is investing additional funds for refurbishment of the power plant unit and installation of the CO_2 capture system.
Recognized by the CSLF at its Beijing meeting, September 2011

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36. SECARB Early Test at Cranfield Project

Nominators: United States (lead) and Canada

This is a large-scale project, located near Natchez, Mississippi, USA, which involves transport, injection, and monitoring of approximately one million tonnes of CO_2 per year into a deep saline reservoir associated with a commercial enhanced oil recovery operation, but the focus of this project will be on the CO_2 storage and monitoring aspects. The project will promote the building of experience necessary for the validation and deployment of carbon sequestration technologies in the United States, and will increase technical competence and public confidence that large volumes of CO_2 can be safely injected and stored. Components of the project also include public outreach and education, site permitting, and implementation of an extensive data collection, modeling, and monitoring plan. This "early" test will set the stage for a subsequent large-scale integrated project that will involve post-combustion CO_2 capture, transportation via pipeline, and injection into a deep saline formation.

Recognized by the CSLF at its Warsaw meeting, October 2010

37. South West Hub Geosequestration Project

Nominators: Australia (lead), United States, and Canada

This is a large-scale project that will implement a large-scale "CO_2 Hub" for multi-user capture, transport, utilization, and storage of CO_2 in southwestern Australia near the city of Perth. Several industrial and utility point sources of CO_2 will be connected via a pipeline to a site for safe geologic storage deep underground in the Triassic Lesueur Sandstone Formation. The project initially plans to sequester 2.4 million tonnes of CO_2 per year and has the potential for capturing approximately 6.5 million tonnes of CO_2 per year. The project will also include reservoir characterization and, once storage is underway, MMV technologies.

Recognized by the CSLF at its Perth meeting, October 2012

38. Zama Acid Gas EOR, CO_2 Sequestration, and Monitoring Project

Nominators: Canada (lead) and United States

This is a pilot-scale project that involves utilization of acid gas (approximately 70% CO_2 and 30% hydrogen sulfide) derived from natural gas extraction for enhanced oil recovery. Project objectives are to predict, monitor, and evaluate the fate of the injected acid gas; to determine the effect of hydrogen sulfide on CO_2 sequestration; and to develop a "best practices manual" for measurement, monitoring, and verification of storage (MMV) of the acid gas. Acid gas injection was initiated in December 2006 and will result in sequestration of about 25,000 tons (or 375 million cubic feet) of CO_2 per year.

Recognized by the CSLF at its Paris meeting, March 2007

39. Zero Emission Porto Tolle Project (ZEPT)

Nominators: Italy (lead) and European Commission

This is a large-scale project, located in northeastern Italy, which will demonstrate post-combustion CCS on 40% of the flue gas from one of the three 660 megawatt units of the existing Porto Tolle Power Plant (which is being converted from heavy oil fuel to coal). The goal of the project is to demonstrate industrial application of CO_2 capture and geological storage for the power sector at full commercial scale. The demonstration plant will be operated for an extended period (approx. 10 years) in order to fully demonstrate the technology on an industrial scale, clarify the real costs of CCS, and prove the retrofit option for high-efficiency coal fired units which will be built (or replaced) in the coming 10-15 years. Storage of approx. 1 million tonnes per year of CO_2 will take place in a deep

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saline aquifer beneath the seabed of the Adriatic Sea approx. 100 kilometers from the project site.
Recognized by the CSLF at its Beijing meeting, September 2011

Note: “Lead Nominator” in this usage indicates the CSLF Member which proposed the project.

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Meeting Registration (as of April 11, 2013)			
#	**Name**	**Organization**	**Country / Entity**
1	Christopher Consoli	Geoscience Australia	Australia
2	Andrew Feitz	Geoscience Australia	Australia
3	Stefan Bachu	Alberta Innovates – Technology Futures	Canada
4	Eddy Chui	CANMET Energy, Natural Resources Canada	Canada
5	Sean McFadden	Shell Canada	Canada
6	Risheng Gao	The Administrative Centre for China's Agenda 21, MOST	China
7	Cailing Hu	EACEE	China
8	Qi Li	Chinese Academy of Sciences	China
9	Ruina Xu	Tsinghua University	China
10	Jiutian Zhang	The Administrative Centre for China's Agenda 21, MOST	China
11	Xian Zhang	The Administrative Centre for China's Agenda 21, MOST	China
12	Chi-Wen Liao	Industrial Technology Research Institute (ITRI)	Chinese Taipei
13	Cheng-Hsien Shen	Industrial Technology Research Institute (ITRI)	Chinese Taipei
14	Richard Lynch	CSLF Secretariat	CSLF Secretariat
15	John Panek	CSLF Secretariat	CSLF Secretariat
16	Stathis Peteves	European Commission	European Commission
17	Jeroen Schuppers	European Commission	European Commission
18	Didier Bonijoly	BRGM	France
19	François Kalaydijan	IFPEN	France
20	Jürgen-Friedrich Hake	Forschungszentrum Juelich GmbH, IEK-STE	Germany
21	Martin Streibel	GFZ Potsdam	Germany
22	Angeline Kneppers	GCCSI	Global CCS Institute
23	Tim Dixon	IEA GHG	IEA GHG
24	Amir Mohammad Eslami	Rahbord Energy Alborz Ltd.	Iran
25	Claudia Bassano	ENEA	Italy

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Meeting Registration (as of April 11, 2013)			
#	Name	Organization	Country / Entity
26	Andrea Corleto	ENEA	Italy
27	Gabriele Calì	Sotacarbo S.p.A.	Italy
28	Francesca Cappelletti	Ministry of Economic Development	Italy
29	Marcello Capra	Ministry of Economic Development	Italy
30	Loredana De Mondi	ENEA	Italy
31	Berardina De Silvestris	ENEA	Italy
32	Paolo Deiana	ENEA	Italy
33	Stefano Giammartini	ENEA	Italy
34	Giuseppe Girardi	ENEA	Italy
35	Silvana Iacobellis	Enel I&R	Italy
36	Salvatore Lombardi	University of Rome	Italy
37	Enrico Maggio	Sotacarbo S.p.A.	Italy
38	Sergio Persoglia	OGS	Italy
39	Alberto Pettinau	Sotacarbo S.p.A.	Italy
40	Stefano Stendardo	ENEA	Italy
41	Ryozo Tanaka	RITE	Japan
42	Chong Kul Ryu	KEPCO RI	Korea
43	Chang Keun Yi	Korea Institute of Energy Research (KIER)	Korea
44	Paul Ramsak	NL Agency	Netherlands
45	Ton Wildenborg	TNO	Netherlands
46	Maria Barrio	SINTEF	Norway
47	Alvar Braathen	University Centre in Svalbard (UNIS)	Norway
48	Lars Ingolf Eide	Research Council of Norway	Norway
49	Olav Hansen	Statoil	Norway
50	Jostein Dahl Karlsen	Ministry of Petroleum and Energy	Norway

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#	Name	Organization	Country / Entity
51	Kei Ogata	University Centre in Svalbard (UNIS)	Norway
52	Etor Querendez	SINTEF Petroleum Research	Norway
53	Trygve Riis	Research Council of Norway	Norway
54	Muhammad Kashif	Nouveau Energy Management (Pvt) Ltd.	Pakistan
55	Georgy Ryabov	All-Russia Thermal Engineering Institute	Russia
56	Khalid Abuleif	Ministry of Petroleum and Mineral Resources	Saudi Arabia
57	Ahmed Aleidan	Saudi Aramco	Saudi Arabia
58	Ali Al-Meshari	Ministry of Petroleum and Mineral Resources	Saudi Arabia
59	Hamoud R. Al-Otaibi	Ministry of Petroleum and Mineral Resources	Saudi Arabia
60	Tony Surridge	SANEDI	South Africa
61	Suk Yee Lam	Department of Energy and Climate Change	United Kingdom
62	Philip Sharman	Alstom Power	United Kingdom
63	Mark Ackiewicz	U.S. Department of Energy	United States
64	Robert Finley	Illinois State Geological Survey	United States
65	Sallie Greenberg	Illinois State Geological Survey	United States
66	George Guthrie	U.S. Department of Energy – NETL	United States
67	John Harju	Energy & Environmental Research Center	United States
68	Susan Hovorka	Bureau of Economic Geology, University of Texas	United States
69	Lee Spangler	Montana State University	United States
70	Edward Steadman	Energy & Environmental Research Center	United States