

# CSLF Gaps Analysis Summary

## Prepared by CSLF Secretariat

At the March 2010 Technical Group meeting, a comprehensive plan was developed for analyzing carbon capture and storage (CCS) projects in relation to technology gaps, both for projects that have already been recognized by the CSLF and for projects that could be proposed for recognition. To that end, a preliminary version of a gaps analysis matrix “report card” on the thirty CSLF-recognized projects was prepared by the PIRT to help identify which technology gaps these projects address. This matrix could also be used to help identify new projects that would address any remaining gaps.

In order to provide an opportunity for project managers to verify the accuracy of the matrix, the CSLF Secretariat prepared and sent out an individual gap analysis worksheet based on the matrix to each of the 27 active or completed CSLF-recognized projects. Responses were received from 15 projects, and corrections provided in these responses were incorporated into the matrix.

The updated gaps analysis matrix identifies the following six gaps as not currently addressed:

### **CAPTURE**

#### **Post-Combustion Capture**

- Identify advantages and limitations of precipitating systems (e.g., carbonates)

### **STORAGE**

#### **Storage Options**

- Ultra-low permeability rocks (e.g., organic rich shales, non-conventional reservoirs)
  - proof of concept
- A world-wide digital CO<sub>2</sub> storage atlas

#### **Unmineable Coal Seams**

- Worldwide storage capacity in unmineable coal seams

#### **Mineral Carbonation**

- Techno-economic viability of mineral storage of CO<sub>2</sub>

#### **Software**

- Integration in single software system of geological, reservoir engineering and hydrodynamic aspects

In addition, there are many other gaps that are addressed by only a single CSLF-recognized project.

The following pages present the updated technology gaps analysis matrix

Responses were received from the following CSLF-recognized Projects:

Project #	Project Name
1	Alberta Enhanced Coal-Bed Methane Recovery Project <i>(project completed)</i>
2	CANMET Energy Technology Center R&D Oxyfuel Combustion for CO <sub>2</sub> Capture
3	CASTOR <i>(project completed)</i>
4	CCS Northern Netherlands
5	CCS Rotterdam
6	China Coalbed Methane Technology / CO <sub>2</sub> Sequestration Project <i>(project completed)</i>
8	CO2CRC Otway Project
9	CO <sub>2</sub> GeoNet
11	CO <sub>2</sub> SINK <i>(project completed)</i>
15	Dynamis <i>(project completed)</i>
19	Fort Nelson Carbon Capture and Storage Project
22	Heartland Area Redwater Project
26	Regional Carbon Sequestration Partnerships
29	Zama Acid Gas EOR, CO <sub>2</sub> Sequestration, and Management Project
30	ZeroGen Project

Gaps information was developed by the PIRT for the following CSLF-recognized projects:

Project #	Project Name
7	CO <sub>2</sub> Capture Project (Phase 2) <i>(project completed)</i>
10	CO <sub>2</sub> Separation from Pressurized Gas Stream
13	CO <sub>2</sub> STORE <i>(project completed)</i>
14	Demonstration of an Oxyfuel Combustion System
16	ENCAP <i>(project completed)</i>
17	European CO <sub>2</sub> Technology Center Mongstad
20	Frio Project <i>(project completed)</i>
21	Geologic CO <sub>2</sub> Storage Assurance at In Salah, Algeria
23	IEA GHG Weyburn-Midale CO <sub>2</sub> Monitoring and Storage Project
24	ITC CO <sub>2</sub> Capture with Chemical Solvents
25	Lacq CO <sub>2</sub> Capture and Storage Project
27	Regional Opportunities for CO <sub>2</sub> Capture and Storage in China <i>(project completed)</i>

The following CSLF-recognized projects are inactive and were not included in the gaps analysis matrix:

Project #	Project Name
12	CO <sub>2</sub> Storage in Limburg Coal and Sandstone Layers
18	Feasibility Study of Geologic Sequestration of CO <sub>2</sub> in Basalt Formations of (Deccan Trap) in India
28	TX Energy Carbon Management and Gasification Project

# CSLF Gaps Analysis Checklist

## CAPTURE TECHNOLOGIES

<b>Post-Combustion Capture</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Optimise capture systems	2, 3, 5, 15, 24	5
Improved solvent systems	3, 5, 24	3
Power plant concepts to integrate CO <sub>2</sub> capture	3, 4, 5, 15, 7, 24	6
CO <sub>2</sub> capture pilot plant	3, 4, 5, 15, 26, 24	6
Fully integrated demonstration plant	5, 15, 24	3
Develop better solvents	3, 5, 24	3
Optimise capture process systems to reduce power stations energy loss and environmental impact	2, 3, 5, 15, 24	5
Advance organic / inorganic non-precipitation absorption systems	2	1
Identify advantages and limitations of precipitating systems (e.g., carbonates)	Not Addressed	0
Develop better understanding of the assessment of environmental impacts of capture technologies	2	1
<b>Pre-Combustion Capture</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Hydrogen-rich turbines	5, 15, 30, 16	4
Improved air separation processes	2, 15, 16	3
Improved water-gas shift	15, 30, 7	3
Improved H <sub>2</sub> /CO <sub>2</sub> separation	2, 5, 15, 30, 7	5
Power plant concepts to integrate CO <sub>2</sub> capture	5, 15, 30, 7, 16	5
Polygeneration optimization	5, 15	2
Advance integration and optimization of components for power station applications	15, 30	2
Coal and liquid petroleum gasification, natural gas reformer, syngas cooler	5, 15, 30	3
Improve CO <sub>2</sub> separation and capture technologies	2, 5, 15, 30, 7	5
Develop high efficiency and low emission H <sub>2</sub> gas turbines	15, 30, 16	3
Fully integrated demonstration plant	5, 15, 30	3
<b>Oxyfuel Combustion</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Boiler design	2, 7, 14, 16	4
Improved air separation processes	2, 16	2
Oxy-fuel gas turbines	2, 14, 16	3
Combustion science	2, 14, 16	3

# CSLF Gaps Analysis Checklist

## CAPTURE TECHNOLOGIES

Power plant concepts to integrate CO <sub>2</sub> capture	2, 14, 16, 25	4
CO <sub>2</sub> capture pilot plant	2, 14, 16, 25	4
Fully integrated demonstration plant	2, 16, 25	3
High temperature turbines	2, 16	2
CO <sub>2</sub> /N <sub>2</sub> separation technology for industrial processes	7	1
Research into material selections	2, 7	2
Cryogenic air separation	2	1
<b>Industrial Applications</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Capture from non-power industrial processes	3, 5, 19, 26, 7, 21	6
<b>Emerging and new concepts for CO<sub>2</sub> capture</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Research into Post-combustion carbonate looping cycles	7	1
Research into Gas separation membranes and adsorption processes for CO <sub>2</sub>	2, 3, 5, 15, 7, 10, 24	7
Research into Ion-transport membranes for O <sub>2</sub> separation	15, 7	2
Research into Chemical looping	2, 7, 16	3
<b>Generation Efficiency</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Support initiatives to improve efficiency of electricity generation plant	2, 15, 30, 7, 14, 16, 25	7
Develop high efficiency gas turbines and support new cycle concepts	2, 30, 7	3
Develop alternative power generation processes that have the potential to produce improved economics when paired with absorption capture	2, 15, 30, 14	4

# CSLF Gaps Analysis Checklist

## STORAGE TECHNOLOGIES

Injection	Project #s	Total # of Projects
Optimum well spacings and patterns	2, 5, 19, 26, 30, 7, 21, 23	8
Optimum injection parameters	5, 8, 11, 19, 22, 26, 30, 7, 21, 23, 25	11
Definition of variable rock facies or rock property types for injectivity.	3, 5, 8, 9, 19, 22, 26, 30, 7, 21, 23, 25	12
Sustainability of high injection rates	1, 5, 19, 30, 7, 21, 23	7
Formation water compression / displacement in closed or open system	5, 19, 22, 26, 30, 7, 21, 23	9
Reservoir engineering aspects	5, 8, 11, 19, 22, 26, 30, 21, 23	9
Address costs associated with storage, especially drilling and establishing wells	5, 22, 26, 30, 7, 21	6
Storage Options	Project #s	Total # of Projects
Saline Aquifers – fluids/rock relationships and interactions	3, 5, 8, 9, 11, 15, 19, 22, 26, 30, 13, 20, 21	13
Coal – rock properties	9, 26	2
EOR – lessons to be applied to other storage reservoirs	5, 9, 15, 26, 29, 23	6
Depleted oil and gas fields – viability	3, 4, 5, 8, 15, 26, 21	7
Basalts – proof of concept	26	1
Ultra-low permeability rocks (e.g., organic rich shales, non-conventional reservoirs) – proof of concept	Not Addressed	0
A world-wide digital CO <sub>2</sub> storage atlas	Not Addressed	0
Deep Saline Formations	Project #s	Total # of Projects
Consistent methodology for storage capacity estimation	5, 15, 19, 26, 30	5
Record and define existing aquifer capacity data from world-wide projects	15	1
Provide a robust storage capacity classification system and informs the legal end of storage licensing procedures	19, 26, 30, 7	4

# CSLF Gaps Analysis Checklist

## STORAGE TECHNOLOGIES

Reservoir and cap rock characteristics – storage injectivity, capacity and integrity	3, 5, 8, 9, 11, 19, 22, 26, 29, 30, 20, 21, 23, 25	14
Predicting spatial reservoir and cap rock characteristics with uncertainties	5, 8, 9, 15, 26, 30, 21	7
<b>Depleted Oil and Gas Fields</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Depleted oil and gas fields – existing wells and remediation	3, 5, 19, 26	4
Inventory of oil and gas fields with large storage capacity	5, 26	2
<b>Unmineable Coal Seams</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Worldwide storage capacity in unmineable coal seams	Not Addressed	0
CO <sub>2</sub> -coal interactions – methane displacement and permeability decreases	1, 9, 26	3
<b>Mineral Carbonation</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Enhancing mineral trapping in specific types of settings (basalt, saline aquifers, etc.)	8, 19, 26	3
Impact on fluid flow, injectivity, and geomechanics	3, 8, 19, 26, 21	5
Thermodynamics and kinetics of chemical and microbiological reactions	3, 8, 11	3
Techno-economic viability of mineral storage of CO <sub>2</sub>	Not Addressed	0
<b>Gaps in Uses of CO<sub>2</sub> (EOR and EGR)</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Validate enhanced recovery of gas (EGR) (including ECBM)	3, 5, 9, 26	4
<b>Trapping</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Understanding physical or chemical trapping mechanisms	8, 9, 19, 22, 26, 29, 13, 21, 23	9
Migration rate	8, 9, 11, 19, 22, 26, 30, 21, 23	9
<b>Hydrodynamics</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Petroleum field development impact on hydrodynamic regime	22, 30, 23	3
Research the impact of the quality of CO <sub>2</sub> (purity of CO <sub>2</sub> ) on interactions with the formation, brine, and storage behavior	5, 8, 9, 19, 22, 26, 29, 30, 13, 20, 21	11

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## STORAGE TECHNOLOGIES

<b>CO<sub>2</sub> Properties</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Behaviour of CO <sub>2</sub> under different regimes of pressure, temperature and fluid mixtures	2, 5, 8, 11, 15, 19, 26, 29, 30, 20, 23	11
<b>Assessments</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Storage Capacity assessment methodologies or standards	5, 8, 9, 11, 15, 26, 30, 13, 20, 23, 25, 27	12
Country wide or regional assessments of storage potential	5, 15, 26, 13, 23, 27	6
Innovative methods for assessments of geological storage potential	8, 22, 26, 30, 23, 25, 27	7
Geological site characterisation, methodologies, techniques and standards	5, 8, 9, 11, 19, 22, 26, 30, 20, 23, 25	11
Protocols for evaluation of potential sterilisation of existing resources	30, 23	2
Develop appropriate models to predict the fate and effects of the injected CO <sub>2</sub> (multi-phase fluid flow, thermo-mechanical-chemical effects and feedback), including leakage	5, 8, 9, 11, 19, 22, 26, 30, 13, 20, 21	11
<b>Leakage</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Flux rates of modern and ancient systems	8, 9, 23	3
Quantification and modeling of potential subsurface leakage impacts	5, 8, 22, 26, 30, 13	6
Existing facilities and materials	5, 9, 11, 26	4
<b>Economics</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Costs of storage	4, 5, 19, 26, 30, 27	6
<b>Software</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Parameters for modeling fluid and rock interactions	5, 8, 9, 26, 30, 20	6
Improvements in software for basin wide geological, reservoir engineering and hydrodynamic model	8, 9, 20	3
Integration in single software system of geological, reservoir engineering and hydrodynamic aspects	Not Addressed	0

## CSLF Gaps Analysis Checklist

### STORAGE TECHNOLOGIES

Risk	Project #s	Total # of Projects
Risk assessment models	5, 8, 9, 15, 19, 22, 26, 30, 23	9
Public Outreach	Project #s	Total # of Projects
Procedures and approaches for communicating the impacts of geological storage to the general public	4, 5, 8, 9, 11, 15, 19, 22, 26, 29, 30, 20, 25	13

Obsolete



# CSLF Gaps Analysis Checklist

## MONITORING

General	Project #s	Total # of Projects
Assess long-term site security post-injection including verified mathematical models of storage	5, 9, 11, 15, 26, 30, 13, 20, 21	9
Define methods for the production and disposal of brine from saline formations as a result of CO <sub>2</sub> injection	26, 30	2
Wellbore Integrity	Project #s	Total # of Projects
Functionality and resolution of available logging tools	5, 8, 19, 26, 30, 20, 21, 23, 25	9
Improved interpretation of cased hole logs	5, 26, 30, 23	4
Improved wellbore monitoring techniques	5, 8, 9, 11, 19, 26, 29, 30, 20, 21, 23, 25	12
Physical or chemical changes to cement	5, 9, 29, 30, 21, 23	6
Identification of Faults and Fractures	Project #s	Total # of Projects
Use of seismic techniques	5, 8, 9, 11, 19, 26, 30, 13, 21, 23, 25	11
Use of non-seismic geophysical techniques	5, 8, 9, 11, 19, 26, 30, 21	8
Improved recognition and interpretation of the nature of faults and fractures	5, 8, 9, 19, 26, 30, 21, 23	8
Subsurface Leaks	Project #s	Total # of Projects
Seismic, resolution	5, 8, 9, 11, 26, 30, 20, 21, 25	9
Seismic, cost reduction	5, 8, 9, 30, 20, 21	6
Evaluation of permanent or semi-permanent sampling points in an observation well	8, 19, 26, 30, 20, 21	6
Surface and Near-Surface Leaks	Project #s	Total # of Projects
Detecting CO <sub>2</sub> seeps into subaqueous settings	8, 9, 30, 13, 21, 23	6
Remote sensing of CO <sub>2</sub> flux	8, 9, 26, 30, 21, 25	6
Use of vegetational changes by hyperspectral surveys changes to identify gas levels in the vadose zone	8, 9, 22, 26, 21	5

# CSLF Gaps Analysis Checklist

## MONITORING

Improved remote sensing to identify sources of CO <sub>2</sub>	9, 20, 21	3
Compile baseline surveys for measurement, monitoring and verification (MMV) activities including site-specific information on CO <sub>2</sub> background concentration and seismic activity	5, 8, 9, 11, 19, 22, 26, 30, 20, 21, 23, 25	12
Develop instruments capable of measuring CO <sub>2</sub> levels close to background and to distinguish between CO <sub>2</sub> from natural processes and that from storage	5, 8, 11, 22, 26, 23, 25	7
Monitor impacts (if any) on the environment	5, 9, 19, 22, 30, 20, 21	7
<b>Guideline Development</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Determination of effective pre-injection surveys	5, 30, 21	3
Improved integration of monitoring techniques	5, 9, 19, 22, 26, 30, 21	7
Identify thresholds of leakage that can be measured	5, 26, 30, 21	4
Develop best practice guidelines selection, operation and closure, including risk assessment and response and remediation plans in case of leakage	3, 5, 19, 26, 29, 30, 7	7
<b>Gaps in Security of Geologic Storage</b>	<b>Project #s</b>	<b>Total # of Projects</b>
Model the fate and effects of injected or leaked CO <sub>2</sub>	5, 8, 9, 11, 19, 22, 26, 29, 30, 13, 20, 21, 23	13
Develop best practice guidelines on how to characterize and monitor a site prior to, during, and after storage	3, 5, 19, 26, 29, 30, 7, 23	8
Build tools that can be used to characterise a potential storage site	5, 26, 30, 20, 21	5
Develop low cost and sensitive CO <sub>2</sub> monitoring technologies	5, 8, 9, 26, 30, 20, 21, 23	8
Construct maximum impact procedures and guidelines for dealing with CO <sub>2</sub> leaks	7	1
Create risk assessment tools to identify the likelihood and consequence of CO <sub>2</sub> leaks and inform effective decision making	5, 8, 9, 19, 26, 30, 7, 21	8

# CSLF Gaps Analysis Checklist

## TRANSPORT

General	Project #s	Total # of Projects
Cost benefit analysis and modeling of CO <sub>2</sub> pipeline and transport systems	5, 15, 13, 25	4
Tanker transport of liquid CO <sub>2</sub>	5, 15	2
Specifications for impurities from various processes	2, 5, 15	3
Dispersion modeling and safety analysis for incidental release of large quantities of CO <sub>2</sub>	5	1
Safety and mitigation of pipelines through urban areas	5, 15, 26	3
Safety protocols to protect CO <sub>2</sub> pipelines, including response and remediation	5	1
Identify regulations and standards for CO <sub>2</sub> transport	5, 15	2
Integration	Project #s	Total # of Projects
Identify reliable sources of information and data related to the design, cost, and space requirements, operation, and integration of CCS with energy facilities	2, 5, 15	3
Conduct periodic technical reviews of all aspects of recognized large-scale CCS demonstration projects and report on the “lessons learned”	5	1
On a periodic basis, update the Technology Roadmap to include technology gaps identified during the technical assessment of demonstration projects	2, 5	2
Integrate with existing infrastructure	5, 15, 7	3
Cross-Cutting Issues	Project #s	Total # of Projects
Energy price issues would encourage the take-up of CCS	5, 15, 7, 21	4