



Minutes of the Technical Group Meeting

Regina, Saskatchewan, Canada

Tuesday, 16 June 2015

LIST OF ATTENDEES

Chair Trygve Riis (Norway)

Delegates

Australia: Clinton Foster (*Vice Chair*), Maxwell Watson
Canada: Stefan Bachu (*Vice Chair*), Eddy Chui, Geoff Murphy,
Kathryn Gagnon
China: Sizhen Peng, Xian Zhang
European Commission: Jeroen Schuppers, Stathis Peteves
France: Didier Bonijoly
Italy: Giuseppe Girardi, Sergio Persoglia
Japan: Ryoza Tanaka, Takashi Kawabata
Korea: Chang Keun Yi, Chong Kul Ryu
Mexico: Jazmin Mota
Netherlands: Paul Ramsak
Norway: Jostein Dahl Karlsen, Lars Ingolf Eide
Poland: Anna Madyniak
Saudi Arabia: Khalid Abuleif, Hamoud AlOtaibi, Fahad Almuhaish
South Africa: Landi Themba (*Acting Vice Chair*)
United Kingdom: Philip Sharman, Brian Allison
United States: Mark Ackiewicz, Stephanie Duran

Representatives of Allied Organizations

Global CCS Institute: Neil Wildgust
IEAGHG: Tim Dixon

CSLF Secretariat

Richard Lynch, Adam Wong

Invited Speakers

Michael Monea, President, Carbon Capture and Storage Initiatives, SaskPower
 John Schadan, President – Canada Operations, Westmoreland Coal Company
 Eddy Chui, Director, Clean Fossil Fuels, CanmetENERGY, Natural Resources Canada
 Mark Crombie, CCP3 Programme Manager, BP Group Technology
 David Bernier, Senior Principal Power Discipline Leader, Stantec
 Jinfeng Ma, Jingbian CCS Project Lead, Northwest University (China)
 Edward S. Rubin, Professor and Founding Member, Department of Engineering and Public Policy, Carnegie Mellon University
 Wayne Rowe, Senior Project Manager, Schlumberger
 Jonathan Carley, Vice President – Business Development, CO₂ Solutions, Inc.

Observers

Canada:	Chunjiang An, Scott Hendrigh, Brett Henkel, Matt Nasehi, Simon O'Brien, Scott Pittendrigh, Luc Rock, Floyd Wist, Kyle Worth, Zewei Yu
China:	Wei Wang
Korea:	Sung-ho Jo
Norway:	Britta Paasch, Åse Slagtern
United Kingdom:	Aatif Baskanderi, Bill Buschle
United States:	Richard Esposito, Robert Hilton, Scott McDonald, Ed Steadman

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 Regina. Mr. Riis mentioning that this is an important meeting because it prepares the Technical Group for the upcoming 6th CSLF Ministerial, in Saudi Arabia in November, and that some of the items on the agenda are directly relevant to the Ministerial.

Mr. Riis stated that two currently active task forces will be providing updates, as will the Projects Interaction and Review Team which has researched and developed a draft Interim Report on the CSLF Technology Roadmap. This Interim Report, once finalized, will be a Technical Group deliverable at the Ministerial. Another deliverable for the Ministerial will be a report on supporting development of 2nd and 3rd generation CO₂ capture technologies. This is one of the four main initiatives of the Policy Group's action plan and the report on this topic will be prepared jointly with the Policy Group.

In closing, Mr. Riis also mentioned that the current meeting is perhaps the most content-rich of any Technical Group meeting ever, with many presentations of interest to attendees. This includes a presentation about the Jingbian CCS Project, which has been nominated by China and Australia for CSLF recognition.

2. Meeting Host's Welcome

Michael Monea, President of SaskPower's Carbon Capture and Storage Initiative, provided a brief welcoming message for the CSLF meeting. CCS is now in a critical period, where the large-scale first-of-a-kind projects like SaskPower's Boundary Dam Project are showing that it is possible for coal-fueled power plants to have very low carbon emissions. Mr. Monea stated CSLF recognition for the Boundary Dam Project has provided it an additional level of positive attention, and he hoped the visit to the project later in the week would be enlightening.

3. Introduction of Delegates

Technical Group delegates present for the meeting introduced themselves. Sixteen of the twenty-three CSLF Members were present, including representatives from Australia, Canada, China, the European Commission, France, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Poland, Saudi Arabia, South Africa, the United Kingdom, and the United States. Observers representing Canada, China, Korea, Norway, the United Kingdom, and the United States were also present.

4. Adoption of Agenda

The Agenda was adopted with the small change of rearranging the order of two presentations in the morning session because of a schedule conflict for one of the invited speakers.

5. Approval of Minutes from Warsaw Meeting

The Minutes from the October 2014 Technical Group Meeting were approved with no changes.

6. Report from CSLF Secretariat

Richard Lynch provided a report from the Secretariat which covered the status of action items from the October 2014 meeting in Poland and some of the highlights from that meeting.

Mr. Lynch stated that there were six Action Items from the October 2014 meeting, five of which are now complete. There was one deferred Action Item, where Australia's delegation had been requested to prepare a background paper on how gas stream compositions could affect the performances of CO₂ capture solvents. Discussion of this topic may occur at a future Technical Group meeting. In addition to these Action Items, consensus was reached by the Technical Group on the following items:

- The Norcem CO₂ Capture Project is recommended by the Technical Group to the Policy Group for CSLF recognition. (*note: The project received CSLF recognition at the Policy Group's meeting two days later.*)
- The Review of CO₂ Storage Efficiency in Deep Saline Aquifers Task Force has concluded its work and will disband following publication of its journal paper.
- The Technical Group will not form a task force to address the Action Plan item on "CCS with the Industrial Emissions Sources".
- The Technical Group will not yet form a task force to address the Action Plan item on "Energy Penalty Reduction".
- The Technical Group will continue its collaboration with the Policy Group on "Supporting Development of 2nd and 3rd Generation CCS Technologies" with Norway the lead for all technical-related components. Other task force members will include Japan, Korea, the United Kingdom, the United States, and the IEAGHG.

Concerning the October 2014 meeting, Mr. Lynch mentioned that the overall meeting included a site visit to the lignite-fueled Bełchatów Power Plant in central Poland. Bełchatów is the largest thermal power plant in Europe and accounts for 20% of Poland's total electricity production. An 858-megawatt unit at the power plant has been made

CCS-ready but the project has not moved forward due to cost and public acceptance issues. The site visit included an extensive Q&A session with power plant management, which provided a much better understanding of why the project is on hold.

7. Coal's Perspective in a CCS Environment

John Schadan, President of Westmoreland Coal Company's Canada Operations, provided a short presentation on how the coal industry perceives CCS. Westmoreland is currently the 6th largest coal producer in North America and supplies fuel for more than coal-fired units, fifteen of which are in the western Canadian provinces of Alberta and Saskatchewan.

Mr. Schadan stated that with the global push toward a low-carbon future, coal producers have a stake in the success of CCS. In Canada, stringent federal emissions standards have made power companies look away from conventional coal-fueled power plants for new electricity sources, but commercialization of CCS would allow coal to remain a part of the fuel mix. This will be important in the next several decades, as existing coal-fueled units in Canada reach the end of their mandated 50-year lifetime. The long-term survival of the coal industry will depend on innovations like CCS to allow the continued use of coal, and the manner in which coal and power industries engage their stakeholders will play a large part on how broadly inclusive solutions are developed. Mr. Schadan closed his presentation by also mentioning that continued R&D is essential and that countries should continue to support development of the new generation of CCS technologies that will maintain coal's relevancy as a cost-effective fuel.

8. Overview of CCS Activities in Canada

Eddy Chui, Director of CanmetENERGY's Clean Fossil Fuels Program at Natural Resources Canada, gave a presentation that summarized Canada's extensive ongoing CCS program and related activities. Canada's overall strategy for advancing CCS includes implementing large-scale demonstration projects to prove technologies while learning-from-doing, sharing Canadian knowledge and expertise outside of Canada, improving the CCS business case through development of 2nd and 3rd generation CCS technologies, and promoting innovation in Canada's clean energy technology sector. Canada has been a leader in the CCS field with more than three decades of RD&D experience. Since 2008, the Canadian Government has invested more than C\$580 million in R&D and large-scale projects, with provincial governments contributing another C\$1.2 billion in funding. Additionally, the provincial utility SaskPower has invested more than C\$2 billion in CCS, which has resulted in its Boundary Dam Project.

Dr. Chui stated that there are currently four large-scale CCS projects in Canada that are in operation or under construction. Besides the Boundary Dam Project, which began operations in October 2014, the Weyburn-Midale Project has been in operation since the year 2000. The Quest Project is expected to begin operations before the end of 2015 and the Alberta Carbon Trunk Line Project is scheduled to be operational in 2017. In addition, the Aquistore Project, which commenced operations earlier in 2015, is a large-scale project which has created permanent storage for CO₂ from the Boundary Dam Project.

Dr. Chui also provided a sampling of the CCS projects and activities being supported by private sector companies in Canada. These include Saskatchewan-based HTC CO₂ Systems, which has a pilot project for testing an advanced post-combustion CO₂ capture process, Quebec-based CO₂ Solutions, which is developing an enzyme-enabled CO₂

capture technology, British Columbia-based Inventys Thermal Technologies, which is working toward pilot-scale demonstrations of a new post-combustion CO₂ capture technology, Nova Scotia-based CarbonCure Technologies, which has developed a technology for sequestering CO₂ in concrete, and SaskPower, which has built a new CO₂ capture test facility for evaluation of amine-based post-combustion technologies. In addition, the Government of Canada, through Natural Resources Canada, is also supporting a portfolio of CCS-related technologies under development, and these include pressurized oxyfuel combustion, supercritical CO₂ turbines, pressurized chemical looping combustion, and CO₂ utilization.

Dr. Chui closed his presentation by stating that Canada has parlayed its natural CCS advantage and strong R&D foundation into a position of global leadership, and is contributing to the global effort to advance CCS. Going forward, Canada's focus will be on strengthening the CCS business case through continued R&D, while collaborating with key international partners and participation in multilateral organizations such as the CSLF.

9. Update from the IEA Greenhouse Gas R&D Programme (IEAGHG)

Tim Dixon gave a presentation about the IEAGHG and its continuing collaboration with the CSLF's Technical Group. The IEAGHG was founded in 1991 with the mission to provide information about the role of technology in reducing greenhouse gas emissions from use of fossil fuels. The focus is on CCS, and the goal of the organization is to produce information that is objective, trustworthy, and independent, while also being policy relevant but not policy prescriptive. The "flagship" activities of the IEAGHG are the technical studies and reports it publishes on all aspects of CCS, the nine international research networks about various topics related to CCS, and the biennial GHGT conferences, the next one in November 2016 in Switzerland.

Mr. Dixon mentioned that since 2008 the IEAGHG and CSLF Technical Group have enjoyed a mutually beneficial relationship which allows each organization to cooperatively participate in the other's activities. This has included mutual representation of each at CSLF Technical Group and IEAGHG Executive Committee (ExCo) meetings, and also the opportunity for the Technical Group to propose studies to be undertaken by the IEAGHG. These, along with proposals from IEAGHG ExCo members, go through a selection process at semiannual ExCo meetings. So far there have been four IEAGHG studies that originated from the CSLF Technical Group: "Development of Storage Coefficients for CO₂ Storage in Deep Saline Formations" (March 2010), "Geological Storage of CO₂ in Basalts" (September 2011), "Potential Implications of Gas Production from Shales and Coal for CO₂ Geological Storage" (November 2013), and "Life Cycle Assessment of Carbon Capture, Utilization and Storage (CCUS) – Benchmarking". This benchmarking study will actually be a workshop with a resulting report, with the workshop taking place in the early part of 2016.

10. Update from the Global Carbon Capture and Storage Institute (GCCSI)

Neil Wildgust provided a concise update on GCCSI's technical focus for 2015 and beyond. The current emphasis is on the cost of CO₂ capture and how CO₂ storage projects can be facilitated and expedited. For CO₂ capture, while it is clear that 1st generation projects will deliver important lessons, it will require continued R&D to develop the 2nd and 3rd generation technologies that are crucial to achieving cost and performance goals for the 2020-2025 timeframe.

Mr. Wildgust stated that the GCCSI, as part of its report *The Global Status of CCS: 2015* has examined R&D projects globally to determine energy and capital cost impacts that would affect the development and deployment of the next generations of CO₂ capture technologies. These two factors, together, currently account for more than 50% of the increase in cost of electricity that would result from the implementation of CCS at a fossil fuel power plant. Concerning CO₂ storage, Mr. Wildgust stated that the international global warming scenario that would limit the increase to 2°C would require more than 2 gigatonnes storage of CO₂ annually by the year 2030 and more than 7 gigatonnes storage annually by the year 2050. One issue is that greenfield CO₂ storage sites can take up to ten years to assess and characterize, and a bigger issue is that industry currently has no incentive to undertake storage exploration. As part of its *The Global Status of CCS: 2015* report, the GCCSI has accomplished a global review of storage resource assessments and concluded that adequate resources exist to allow commercial deployment for CO₂ storage, but different regions of the world have differing emphases on the types of storage projects that would be achievable. Mr. Wildgust concluded his presentation by mentioning that knowledge sharing is imperative if CO₂ storage is to expeditiously move beyond the current first-of-a-kind generation of demonstration projects, and that the GCCSI has set up a series of knowledge-sharing networks for that purpose.

11. CSLF-recognized CO₂ Capture Project – Phase 3 Results

Mark Crombie, BP Group Technology's Programme Manager for the CO₂ Capture Project (CCP), gave a presentation which provided a detailed overview of the recently-concluded third phase of the project. Mr. Crombie stated that the CCP began in the year 2000 as a partnership of several energy companies, with the overall goal to demonstrate technologies which will reduce the cost and accelerate deployment of CCS. The third phase of the project (CCP3) had the specific objective of producing a fuller picture of the integrated costs for CCS and consisted of four work teams (supported by economic modeling):

- Capture, aimed at reducing the cost of CO₂ capture;
- Storage Monitoring and Verification (SMV), aimed at increasing understanding and developing methods for safely storing and monitoring CO₂ in the subsurface;
- Policy and Incentives, aimed at providing technical and economic insights needed by stakeholders and to keep track of ever-evolving legal and policy frameworks; and
- Communications, aimed at providing outreach of project outcomes to stakeholders and the general public.

Mr. Crombie stated that for CCP3, two CO₂ capture scenarios were developed and examined:

- Field demonstration of fluid catalytic cracking oxy-firing capture technology, with Petrobras in Brazil, which developed operability and scale-up data; and
- Field demonstration of oxy-fired – once-through steam generation, with Cenovus Energy and other partners in Canada, which confirmed the technical viability of the process.

Mr. Crombie mentioned that the SMV Program was comprised of several areas of investigation, including well integrity, subsurface processes, monitoring & verification, and field-trialing. The Policy and Incentives Program is contributing to the development of legal and regulatory frameworks via documentation of project experiences with

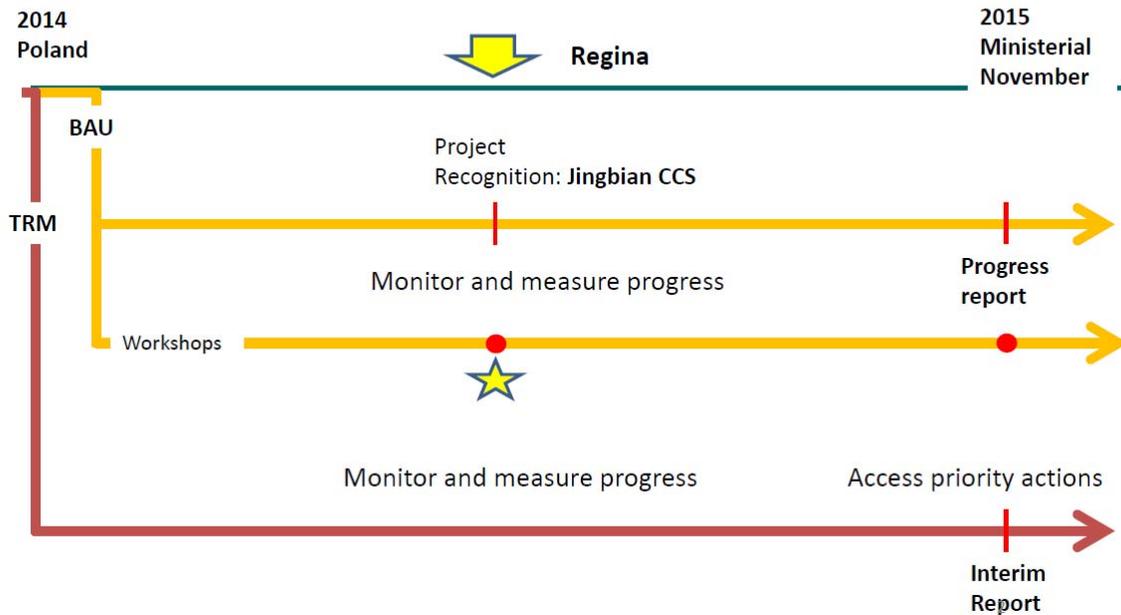
regulatory processes. The CCP3 Communications Program has promulgated project results via the project website and at conferences and meetings such as this CSLF event.

Concerning the 4th phase of the CCP, Mr. Crombie stated that the focus would be on assessing “breakthrough” technologies that could result in a substantial improvement in CO₂ capture costs. Many of these technologies would be suitable for non-utility use such as in refineries and natural gas operations. The storage part of CCP4 would have an emphasis on well integrity. Mr. Crombie ended his presentation by mentioning that CCP4 activities will build on its previous experience and expertise, and the project will welcome new partners and collaborate with others to ensure continued success.

12. Report from the CSLF Projects Interaction and Review Team (PIRT) and Update on the CSLF Technology Roadmap (TRM)

The PIRT Chair, Clinton Foster, gave a short presentation that summarized the previous day’s PIRT meeting. The PIRT currently has two main types of responsibilities. “Business As Usual” (BAU) activities include monitoring and measuring progress of the portfolio of CSLF-recognized projects, investigation of any new projects proposed for CSLF recognition, and organizing CSLF Technology Workshops. In parallel to this, the PIRT also has primary responsibility for updating the TRM.

PIRT Action Time Line - detail



Dr. Foster stated that during its previous day meeting, the PIRT had evaluated the Jingbian CCS Project as a first step in the CSLF recognition process and had reviewed the draft TRM Interim Report, whose finalized version will be a deliverable to the upcoming CSLF Ministerial Meeting. The TRM Interim Report is intended to report on ten technology needs areas that were identified by the 2013 edition of the TRM, specifically on the perceived amount of progress being made in each of these areas and on barriers which are inhibiting this progress.

Specific outcomes from the meeting were:

- The PIRT recommends approval by the Technical Group for the Jingbian CCS Project.
- The PIRT believes that the draft TRM Interim Report needs a substantial rewrite.

Concerning the second outcome, Dr. Foster stated that the draft report was deficient because perceived progress in any of the ten technology needs areas was being inexactly described due to adverse influences by economic and policy barriers. For instance, the draft TRM Interim Report, taking into account all kinds of barriers, indicates that 1st generation technologies to conduct large-scale CO₂ storage were perceived as showing only very slow to moderate progress for being developed and implemented. However, from a purely a technical viewpoint, actually there are no significant technology barriers in this area. Several delegates pointed out that this disconnect most likely occurred because the survey questionnaire asked for evidence-based opinions on “progress in both application and adaptation” of CCS technologies and not “technology readiness”. Another problem with the draft report is that 2nd and 3rd generation concepts, described in the report, do not apply to all ten technology needs areas.

There was extended discussion on what kinds of remedial actions were needed and in the end, the following plan was adopted:

- The TRM Interim Report will be rewritten, incorporating new information about the current status of technology for the ten technology needs areas.
- The PIRT working groups who wrote the ten sections describing progress for the technology needs areas will solicit opinions from world-class experts in these areas, from purely a technology viewpoint, on the degree of technical readiness.
- The Secretariat will collect these expert opinions and use them to produce new graphics for the report.
- The PIRT working groups which wrote the ten sections will also do the re-writes of these sections. The rewrites will de-emphasize 2nd and 3rd generation technologies (including removal of the graphics for 2nd and 3rd generation technologies) and eliminate any descriptions that are not applicable or relevant.
- The Secretariat will coordinate the overall rewrite process and do any rewrites to other parts of the report. The goal is for a new draft to be completed by about the end of August.

Technical Group delegates were also requested to provide the Secretariat their comments on the existing draft of the report by the end of August.

13. Full-Scale Design of a Post-Combustion CO₂ Capture Process for a Gas-Fired Plant

David Bernier, Senior Principal Power Discipline Leader for Stantec, gave a luncheon presentation that described concept study details for the planned CCS project at Statoil’s Mongstad facility in Norway. The gas-fueled power plant at Mongstad was to have been a combined heat and power (CHP) facility, producing 280 megawatts of electricity and 350 megawatts of thermal energy. Mr. Bernier stated that a comprehensive evaluation of the CCS project, including an engineering feasibility study, a technology qualification program, and an engineering concept (pre-FEED) study, was conducted over about a two year period before the project was terminated.

Concerning the pre-FEED study, Mr. Bernier stated that the engineering scope included many different modules: flue gas handling, the CO₂ removal and compression systems,

waste water treatment, the power distribution system, solvent storage, and the cooling water system. The technical approach focused on critical equipment, and utilized 3D modeling which resulted in a realistic design that would have facilitated construction of the project. The pre-FEED study also included numerous health and safety reviews, which were inputs to the site safety plan. Mr. Bernier illustrated his presentation with timeline depictions of the construction process, and concluded by stating that even though this project in the end did not go forward, it still resulted in useful information that could be beneficial in the design of future similar large-scale CCS projects.

14. Review and Approval of Project Proposed for CSLF-Recognition: Jingbian CCS Project

Jinfeng Ma, representing Northwest University of China, gave a presentation about the Jingbian project. This integrated large-scale pilot project, located at a coal-to-chemicals company in the Ordos Basin of China's Shaanxi Province, is capturing CO₂ from a coal gasification plant via a commercial chilled methanol process, transporting the CO₂ by tanker truck to a nearby oil field, and utilizing the CO₂ for EOR. The overall objective is to demonstrate the viability of a commercial EOR project in China. The project includes capture and injection of up to about 50,000 tonnes per year of CO₂. There will also be a comprehensive measurement, monitoring and verification (MMV) regime for both surface and subsurface monitoring of the injected CO₂. This project is intended to be a model for efficient exploitation of Shaanxi Province's coal and oil resources, as it is estimated that more than 60% of stationary source CO₂ emissions in the province could be utilized for EOR.

After a brief discussion, there was consensus to recommend to the Policy Group that the Jingbian Project receive CSLF recognition.

15. Final Report from Task Force on Review of CO₂ Storage Efficiency in Deep Saline Aquifers

Task Force Chair Stefan Bachu provided a brief update on the task force and its results. The task force was established at the November 2013 meeting in Washington, with the mandate to critically review, compile and report on relevant literature published since the 2007 final report by the CSLF Task Force for Review and Identification of Standards for CO₂ Storage Capacity Estimation. Storage capacity estimates can be "static" (i.e., based on pore volume) or "dynamic" (i.e., based on injectivity and pressure build-up). The mandate of the task force was to review, compile, and report on published literature since the 2007 final report of the previous task force, and also to review and evaluate the applicability of various published values for the storage efficiency coefficient 'E', which is the amount of CO₂ which can be stored in a unit of aquifer pore volume

Dr. Bachu stated that one of the main findings of the task force is that storage efficiency depends on many different elements. These include aquifer characteristics (many of them), operation characteristics (many of them), and regulatory constraints (e.g., "do not exceed" limitations). Another finding was that for atlas-type estimates of CO₂ storage resource at the aquifer/basin scale, storage efficiency coefficients of 2-3% should be used for P50 confidence. Further, for local-scale evaluations of CO₂ storage capacity, numerical (dynamic) estimates should be used, taking into account that storage capacity is pressure limited.

Dr. Bachu stated that a paper titled "Review of CO₂ Storage Efficiency in Deep Saline Aquifers", authored by himself, will be published in the September 2015 issue of *The*

International Journal of Greenhouse Gas Control, and this paper serves as the task force's final report. Dr. Bachu concluded his presentation by stating that the task force ended its activities in the 4th quarter of 2014 and has now disbanded.

16. Report from Task Force on Technical Barriers and R&D Opportunities for Offshore, Sub-Seabed Storage of CO₂

Task Force Chair Mark Ackiewicz gave a brief update on the task force and its activities. The task force was established at the March 2014 meeting with the mandate to identify technical barriers and R&D needs/opportunities for sub-seabed storage of CO₂. Mr. Ackiewicz stated that the task force developed a draft outline of its final report in June 2014 and provided a status report to the Technical Group at its October 2014 meeting. Since then, a first draft of the final report has been completed and is under review by task force members.

Mr. Ackiewicz provided information about the report's structure, which will include sections on all aspects of sub-seabed CO₂ storage such as resource assessments, CO₂ transport aspects, wellbore management, risk analysis, monitoring tools, and regulatory requirements. Also, there will be a set of recommendations concerning knowledge-sharing, storage capacity assessments, CO₂ transport infrastructure, offshore CO₂-EOR, understanding of CO₂ impacts on the subsea environment, and monitoring technology development. Mr. Ackiewicz concluded his presentation by mentioning that there have been a total of 28 members on this task force, representing six countries and four continents. The various task force members are affiliated with government agencies, universities, research laboratories, industry, and non-governmental organizations, making this both the largest and most diverse task force ever for the Technical Group.

17. Report on the ISO and its CCS-related Activities

Tim Dixon gave a short presentation about the International Organization for Standardization's Technical Committee on CO₂ Capture, Transportation and Geological Storage (ISO/TC 265). This committee was convened in 2011 with the mission of preparing standards for the design, construction, operation, environmental planning, risk management, MMV, and other activities related to CCS. Mr. Dixon stated that there are currently six working groups, each with its own set of activities. The standards development procedure works through consensus and is a multi-stage process. New work item proposals are first made into a working draft, and those that gain consensus from the working group are made into a committee draft. At that point a greater degree of working group consensus is required to move the proposal into the "draft international standard" phase, which then requires a comments period and consensus of the working group's panel of experts to become an ISO standard.

Mr. Dixon stated that the ISO/TC 265 currently includes nineteen participating countries, nine observer countries, and also seven liaison organizations (including the CSLF). The committee as a whole has met five previous times since its formation with the sixth meeting scheduled for September 2015 in Norway.

18. The Outlook for Improved Carbon Capture Technology

Edward S. Rubin, Professor and Founding Member of Carnegie Mellon University's Department of Engineering and Public Policy, gave a presentation that described the potential for future improvements for CO₂ capture and what it would take to achieve them. Prof. Rubin stated that there are two principal measures of progress in CO₂ capture

technology: improvements in performance (e.g., higher capture efficiencies, lower energy penalties, increased reliability, and reduced life cycle impacts) and reductions in cost (e.g., capital cost, cost of electricity, cost of CO₂ avoided, and cost of CO₂ captured). Most improvement goals now focus on cost reduction, and a recent cost update study has found there have actually been significant increases in CO₂ capture cost since the time of the IPCC's Special Report on CCS (2005), even after adjusting all costs to constant 2013 US\$.

Prof. Rubin stated that there are three main ingredients for technology innovations that would reduce CO₂ capture costs: sustained R&D, markets for the technology, and especially, learning from experience with full-scale projects. Experience has shown that dramatic improvements in other low-carbon technologies and for other technologies for power plant emissions reductions have occurred once wide deployment of these technologies has occurred. Currently, the key barriers to global CCS deployment are policy-related. Without a policy requirement or strong incentive to reduce CO₂ emissions significantly, there is no reason to deploy CCS widely. Prof. Rubin closed his presentation by offering that although sustained R&D is essential to achieve lower CO₂ capture costs, learning from experience is actually the critical step. And in the end, it will be strong policy drivers to create markets for CCS that will spur innovations for significantly reducing the cost of CO₂ capture.

19. Well Injectivity Lessons Learned at SaskPower's Aquistore Project

Wayne Rowe, Senior Project Manager for Schlumberger, provided a short technical status report on SaskPower's Aquistore Project, which focused on lessons learned and obstacles overcome while developing the CO₂ injection well. The project's injection well goes down to 4,300 meters in depth and passes through many different geologic layers to get to the four saline aquifer injection zones. The overall injection rate is determined by a series of injectivity tests which determine the maximum pressure at which the well can be operated during injection (typically 90% of the fracture pressure), and therefore the maximum CO₂ injection rate.

Mr. Rowe stated that during the initial injectivity test, in September 2012, a pressure spike occurred (the cause of which was not understood) that resulted in one of the four zones no longer being able to accept CO₂, and this greatly reduced the CO₂ injection rate. Three years later the test was repeated, with the result that whatever had happened to cause this problem had not gone away. However, a diversion treatment of the well using ping-pong balls was able to seal perforations into the zones where pressure spikes had occurred which resulted in a much greater injectivity into the favored injection zones. Mr. Rowe concluded by stating that the overriding lessons learned from this experience on how to overcome problems of this nature would benefit future injection projects.

20. Enzymatic Technology for Low-Cost Carbon Capture

Jonathan Carley, Vice President of Business Development for CO₂ Solutions, gave a presentation that described a novel method for CO₂ capture that utilizes a robust bio-engineered carbonic anhydrase enzyme as the capturing agent. This process improves on conventional liquid-phase CO₂ capture processes as it reduces the process energy requirement and does not create waste products. Mr. Carley stated that the process is now being demonstrated at pilot-scale (10 tonnes CO₂ capture per day) on the flue gas from a natural gas-fueled boiler (8.3% CO₂ content). Initial results have shown a 90% capture rate. The cost of capture (including compression to 2,250 psi) has been estimated at C\$39

per tonne, which would be a significant improvement over current commercial CO₂ capture processes.

Mr. Carley ended his presentation by summarizing some of the advantages of this new process: it utilizes an environmentally benign solvent, there is a smaller footprint for the capture unit than for conventional processes of the same scale, the solvent regeneration uses heat outside of the power plant steam cycle, and as a result there will be a lower total cost of CO₂ capture. Mr. Carley stated that the pilot plant, located near Montreal, is scheduled for 2,500 hours operation (which began in May 2015) and is open for visits by any interested parties.

21. Review of Technical Group Action Plan

Trygve Riis stated that the Secretariat had prepared a short update on the status of the Technical Group's Action Plan, and that after the end of 2015, if no new activities are initiated, the only ongoing task force would be the PIRT. In that regard, it would therefore be beneficial to expand the Technical Group's activities into some new areas. An extensive discussion ensued, with the outcome that a new working group was formed to develop additional Action Plan activities. Members of this working group are Australia (Maxwell Watson), Norway (Lars Ingolf Eide), Saudi Arabia (Ahmed Aleidan), the United Kingdom (Brian Allison and Philip Sharman), and the United States (Mark Ackiewicz). The CSLF Secretariat will assist in coordinating the working group's activities as needed. The working group was asked to complete its activities in time for the upcoming CSLF Ministerial.

22. Update from Joint Task Force on the Development of 2nd and 3rd Generation CCS Technologies

Lars Ingolf Eide provided a status update on the Joint Policy-Technical Task Force on "Supporting Development of 2nd and 3rd Generation CCS Technologies". This task force has been established with Norway as the lead for the Technical Group and Canada the lead for the Policy Group. The technical mandate of the task force includes:

- Mapping/identifying 2nd and 3rd generation technologies under consideration in CSLF member countries, especially those that may mature in the 2020-2030 timeframe;
- Identifying major challenges facing development of these next generation technologies; and
- Using existing networks such as the International CCS Test Centre Network to map potential for testing these next generation technologies at existing test facilities.

Mr. Eide stated that a report is being prepared which will summarize existing information in the area of 2nd and 3rd generation CO₂ capture technologies, and that the report is being organized to provide descriptions of the technologies and their development pathways as well as information on existing CCS test centers where some of these technologies could be scaled-up. Due to resource and time limitations, the report groups technologies into four categories: post-combustion, pre-combustion, oxy-combustion, and other emerging technologies. Individual technology summaries provide a description of the technology, an assessment of its maturity, a description of challenges it faces, a list of the companies and organizations that are involved in development, a description of the kinds of R&D still needed for maturity, any environmental impacts of the technology, and the types of industries where the technology could see use. Mr. Eide stated that the report does not

address the economics for use of these technologies but does show technology readiness levels. Completion of the report is expected in time for the Ministerial meeting. At the conclusion of Mr. Eide's presentation, there was agreement that Secretariat will circulate a copy of the report-in-progress to all Technical Group delegates, and that the delegates will provide any comments, additions and corrections to Mr. Eide by the end of August.

Following Mr. Eide's update, Geoff Murphy gave a short presentation that described a proposed new section of the CSLF website that would track the development of 2nd and 3rd generation CO₂ capture technologies. This new section, to be created and maintained by the CSLF Secretariat, would highlight technology approaches and existing test facilities. Mr. Murphy provided that the new section would also include the task force's definitions of what constitutes a 2nd generation and a 3rd generation technology.

It was also proposed that this new section also include information on technology providers, but several delegates were skeptical about how well such a section on technology providers could be developed and maintained, in terms of both completeness and accuracy. Philip Sharman pointed out that the proposed country-by-country approach is not always adequate as some technology providers are multinational. In the end there was agreement that the Secretariat should, for now, create new website sections for technology approaches and test facilities, with the allowance that it would be a continuing work in progress and information would be added as it becomes available.

Kathryn Gagnon then gave a short presentation that highlighted the policy context for advancement of 2nd and 3rd generation technologies. As a background, Canada's delegation had brought in a consultant who interviewed 35 individuals representing eight countries and a variety of organizations to provide insight on what policy barriers existed for inhibiting progress on these technologies, what success factors were in place for advancing the technologies, and what mechanisms would be useful for accelerating development of the technologies. Ms. Gagnon stated that results from this process showed that there were already some mechanisms, such as carbon pricing and loan guarantees, which were helping the first generation of technologies make it to the demonstration phase but there were currently no real market drivers for CCS. The existence of test centers was considered critical to the development of newer and more advanced technologies as these reduce the costs for testing these technologies at larger scales. Even more critical, the existence of country initiatives such as Norway's CLIMIT Program are providing a pathway for technology developers for development and scale-up, including funding opportunities. Ms. Gagnon closed her presentation by stating that she would expand on these themes at the upcoming Policy Group meeting.

23. Technical Group Deliverables for 6th CSLF Ministerial Conference

Richard Lynch provided a short summary on Technical Group deliverables to the upcoming Ministerial Conference. Four documents are anticipated: the TRM Interim Report, the report on "Supporting Development of 2nd and 3rd Generation CO₂ Capture Technologies" (though an executive summary may be the specific deliverable to the Ministers), a paper describing outcomes from the upcoming "Lessons Learned from Large-Scale CCS" Technology Workshop (*note: successfully held on June 17th*), and a "Messages and Recommendations from the CSLF Technical Group" document which would bring together results and outcomes from various other Technical Group task forces and events. Mr. Lynch also stated that unlike what happened at the previous Ministerial Meeting in 2013, this time the Technical Group will have a much greater

presence at the Ministerial Conference including a seat at the table and an item on the agenda.

24. Update on International CO₂ Capture Test Centre Network

Lars Ingolf Eide gave a short presentation on the status of the International CO₂ Capture Test Centre Network, which was officially launched in 2013 to accelerate CCS technology development. Mr. Eide stated that the network's main function is to facilitate knowledge sharing of operational experience and non-confidential information, and that analysis and problem solving (and *not* data collection) is the network's focus. Criteria for a test facility's membership in the network is that the facility must be operating on real flue gas (i.e., be connected to a power plant or industrial plant), it must have the intent of being neutral in any technology decisions, it must be willing to share information and receive visitors, and it must be willing to pay a membership fee. Some of the fee money is being used to support workshops.

Mr. Eide stated that there have been three previous workshops, in Mongstad, Norway in May 2014 (which was focused on amine-based post-combustion capture), in Austin, Texas, U.S.A., in October 2014 (which was an exchange of experiences on how best to measure and model amine emissions), and in Wilhelmshaven, Germany in April 2015 (which was focused on aerosols and mist formations). The next workshop will be in Regina in September 2015 as part of the IEAGHG Post-Combustion Capture Conference. Future knowledge-sharing topics may include health, safety and the environment (HSE), instrumentation and monitoring, waste management, comparing baselines, and promoting technology certification and standardization. Mr. Eide concluded his presentation by mentioning that the network is actively pursuing new members and seeks to establish liaisons with other CCS-related networks.

25. Update on Future CSLF Meetings

Richard Lynch provided a short summary of upcoming CSLF events, beginning with the next day's "Lessons Learned from Large-Scale CCS" technology workshop. Mr. Lynch stated that the workshop will have two sessions, on siting / construction and operation, with eight large-scale projects represented. Concerning the 6th CSLF Ministerial Meeting, being hosted by the Kingdom of Saudi Arabia's Ministry of Petroleum and Mineral Resources in Riyadh, Mr. Lynch stated that the event would be a five day meeting, organized as follows:

- Sunday, November 1: task force meetings
- Monday, November 2: Technical Group meeting
- Tuesday, November 3: Policy Group meeting
- Wednesday, November 4: Ministerial Conference
- Thursday, November 5: site visit (*intended for Ministers and heads of delegation*)

Mr. Lynch stated that further details concerning the Ministerial would be forthcoming soon. Hamoud AlOtaibi expanded on this outline by mentioning that the Ministerial Conference will include a public-private roundtable and that the site visit on November 5th would be to Saudi Aramco facilities in Dhahran. Mr. AlOtaibi also mentioned that there would be an exhibition area, where companies and CSLF member countries can showcase their CCS-related technologies and projects.

For the 2016 CSLF meetings, Mr. Lynch stated that there was nothing yet to report concerning the mid-year meeting but Japan may be willing to host the year-end annual

meeting. Takashi Kawabata was called on for additional comments and welcomed the opportunity to bring the CSLF to Japan. Mr. Kawabata stated that a budgetary request for the meeting has been made, so Japan’s hosting of the 2016 CSLF Annual Meeting should be considered tentative at this point with a final decision expected by the end of the year.

26. Farewell to Two Friends

Earlier in the meeting there was a short appreciation of two retiring CSLF delegates. This was the last meeting for two of the Technical Group’s Vice Chairs, Stefan Bachu and Clinton Foster. Richard Lynch expressed gratitude from the Secretariat for the tremendous amount of proactiveness and leadership they have provided the CSLF and said that it had been a privilege to have worked with them. Trygve Riis presented Dr. Bachu and Dr. Foster each with a gift to recognize and honor their years of service to the CSLF. The meeting attendees bid farewell to Dr. Bachu and Dr. Foster with a round of applause.

27. Review of Consensuses Reached and Action Items

Consensus was reached on the following items:

- The Jingbian CCS Project is recommended by the Technical Group to the Policy Group for CSLF recognition.
- The Technical Group will form a working group to develop additional Action Plan activities. Members of the working group are Australia, Norway, Saudi Arabia, the United Kingdom, and the United States.
- The Technical Group will revise the TRM Interim Report, incorporating new information about the current status of technology for the identified ten technology needs areas.

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 Jingbian Project be recognized by the CSLF. <i>(Note: this was done at the June 18th Policy Group meeting.)</i>
2	The ten PIRT working groups	Obtain expert opinions on technology readiness for the technology needs areas identified in the TRM. Once new graphics are available, do rewrites of the ten technology sections of the TRM Interim Report, de-emphasizing 2 nd and 3 rd generation technologies (including removal of the graphics for 2 nd and 3 rd generation technologies) and eliminating any descriptions that are not applicable or relevant.
3	Secretariat	Coordinate the rewrite of the TRM Interim Report, including developing new graphics based on expert opinions about technology readiness and doing any re-writes that are needed for other parts of the report.

Item	Lead	Action
4	Secretariat	Send a copy of the draft Joint Policy-Technical Task Force report on “Supporting Development of 2 nd and 3 rd Generation CCS Technologies” to Technical Group delegates for their comments.
5	Technical Group delegates	Provide any comments, additions, and corrections on the draft Joint Policy-Technical Task Force report on “Supporting Development of 2 nd and 3 rd Generation CCS Technologies” to the task force co-chair.
6	Action Plan Working Group	Develop ideas for additional Action Plan activities in time for the 6 th CSLF Ministerial.
7	Secretariat	Create new section on CSLF website for tracking progress on 2 nd and 3 rd generation CO ₂ capture technologies.

28. Closing Remarks / Adjourn

In adjourning the meeting, Trygve Riis expressed his appreciation to the meeting host SaskPower, the CSLF Secretariat, the meeting sponsors, and all the meeting attendees. Richard Lynch recognized SaskPower’s Sandra Beingessner as having provided a tremendous amount of effort in making the meeting happen.

Mr. Riis mentioned that the meeting was very interactive and participatory, and that much had been accomplished in this the beginning of the run-up to the upcoming Ministerial meeting. Mr. Riis then reminded attendees of the next day’s technology workshop and adjourned the meeting.