Summary and Key Messages from the CSLF "Lessons Learned from Large-Scale CCS" Workshop

Session 1: Siting and Construction

This session was co-chaired by Lars Ingolf Eide (Norway) and Philip Sharman (United Kingdom). Presenters were:

1. Hans Schoenmakers of the Maasvlatke CCS Project (MCP), representing the Rotterdam Opslag en Afvand Demonstratieproject (ROAD)
2. Scott McDonald of Archer Daniels Midland (ADM), representing the Illinois Industrial CCS Project
3. Richard Esposito of the Southern Company, representing the Kemper County Energy Facility
4. Luc Rock of Shell Canada, representing the Quest Project

Main takeaways from the session were:

A. Site Selection and Overall Project Viability

- Economic drivers that affect CCS project siting include the availability of nearby indigenous fuels, opportunities for polygeneration of potentially saleable byproducts, and proximity of existing pipeline infrastructure. It has been shown to be possible to structure a project such that sales of byproducts are the major source of revenue. However, any project that includes sales of CO_2 for EOR must be sited in relatively close proximity to an existing CO_2 pipeline due to the high cost of pipeline construction.
- For non-EOR projects, understanding the regional geology will greatly aid CO_2 storage site selection and characterization. Comprehensive modeling and injectivity test programs should not be considered a luxury.
- Stakeholder engagement is crucial for success, as storage sites and pipelines may be near populated areas. Spending the time and resources to develop an effective outreach plan, making use of credible consultants, will pay dividends in the long run. A good public outreach program focuses on education, and openness is essential. A badly-handled public outreach program can doom a project.

B. Project Design

- CO_2 capture rate will impact overall project economics. This may result in a need for compromise on what is possible vs. what is do-able.
- First-of-a-kind (FOAK) projects are not designed for financial efficiency, they are designed to demonstrate the integration of CCS technology components at large scale. To reduce the risk of integration in FOAK projects, there are typically large safety factors in design and a significant on-site presence by technology providers, both of which drive up project costs. A major objective of FOAK projects is for the learnings to enable a significant reduction in the risk of integration so that future large-scale projects can be designed more efficiently and less expensively.
- For CCS at power projects, it is essential that the CO_2 capture plant be designed to maximize its flexibility in terms of capture rate, as the power plant may not be operated in baseload mode.
- Focus on overall integration and interfaces between components. There will usually be opportunities for incremental cost savings, such as utilizing waste heat for drying the power plant fuel supply.

C. Permitting

- The permitting process for CO_2 storage will almost always take longer than planned. This is a relatively new regulatory area, and the relevant authorities are often on a steep learning curve.
- The overall storage plan will need to include an extensive and adaptive Measuring, Monitoring and Verification (MMV) program. Do not even begin the permitting process until the MMV plan is fully developed.
- There will be a continuing need for data, and having an environmental baseline will be very helpful toward the overall permitting process.

D. Construction

- A larger footprint for the plant will make construction easier and faster, which may result lower construction costs. But this will also result in greater materials costs.
- Expect the unexpected. Do not underestimate the complexity and the infrastructure requirements of the project.
- There will always be unanticipated FOAK plant issues. Be ready to adapt and learn.

Session 2: Operations

This session was co-chaired by Clinton Foster (Australia) and Philip Sharman (United Kingdom). Presenters were:

1. Edward Steadman of the University of North Dakota's Energy and Environmental Research Center (EERC), presenting experience from EOR operations for the PCOR Bell Creek Project
2. Michael Monea of SaskPower, presenting experience from utility sector operations for the SaskPower Boundary Dam Project
3. Kyle Worth of the Petroleum Technology Research Center (PTRC), presenting experience from CO_2 storage operations for the Aquistore Project
4. Britta Paasch of Statoil, presenting experience from natural gas operations for Statoil's operations offshore Norway
5. Mike Holmes of EERC, presenting experience from industry operations for Dakota Gasification Company's CO_2 capture and transport operations

Main takeaways from the session were:

A. Clarity of Mission

- Have agreed aims and objectives, and regularly review progress against these goals.
- Focus on long-term sustainable commercial operations and improving the business case for the project. This will make future projects of this kind easier to do.
- Avoid getting too obsessed with technology. The project will enhance the overall knowledge base without needing to "push the envelope" on the limits of the technology components.

B. Transitioning into the Operational Phase

- Use of retrofitted new technology in an older plant will inevitably be challenging. There will be a need for experienced process engineers.
- Uncertainty can be a good thing. Recognizing and understanding real-world deviations from CO_2 storage models will in the end improve those models.
- Stuff happens. Expect the unexpected, and always have a "Plan B".
- Above all, have realistic expectations from FOAK projects. The next-generation projects are the ones that will change the world.

C. <u>MMV and Data Management</u>

- The more comprehensive the MMV, the better. A good MMV program is key for completing technical risk assessments and developing mitigation strategies.
- A comprehensive MMV program will generate large amounts of data. Working with these quantities of data requires appropriate management systems.
- Exercise caution regarding interpretation and release of data. Peer reviews should first be considered.
- Large-scale CCS projects are intended to enhance the overall knowledge base, but not at the expense of protection of intellectual property (IP). A proper balance between knowledge sharing and IP management requires procedures which allow sharing of information and experiences without revealing proprietary information.

D. <u>Communications</u>

- The project won't be a success unless people believe it is a success. Therefore, continuing external communications with stakeholders should be a key part of the project plan.
- Social acceptance is a goal for any CCS project. To be successful in that regard, people need to understand how the project works so there will be a need for experienced public outreach professionals.
- Good relations with abutting landowners and nearby population centers will pay dividends. Once in a while there may be an unexpected event of some kind and it is highly desirable that these people be supportive of the project.
- The single greatest benefit from FOAK large-scale CCS projects is the knowledge gained (in all aspects of the project) that will allow future projects to be less costly and problematic to implement. Sharing lessons learned in international conferences and forums should therefore be a priority.